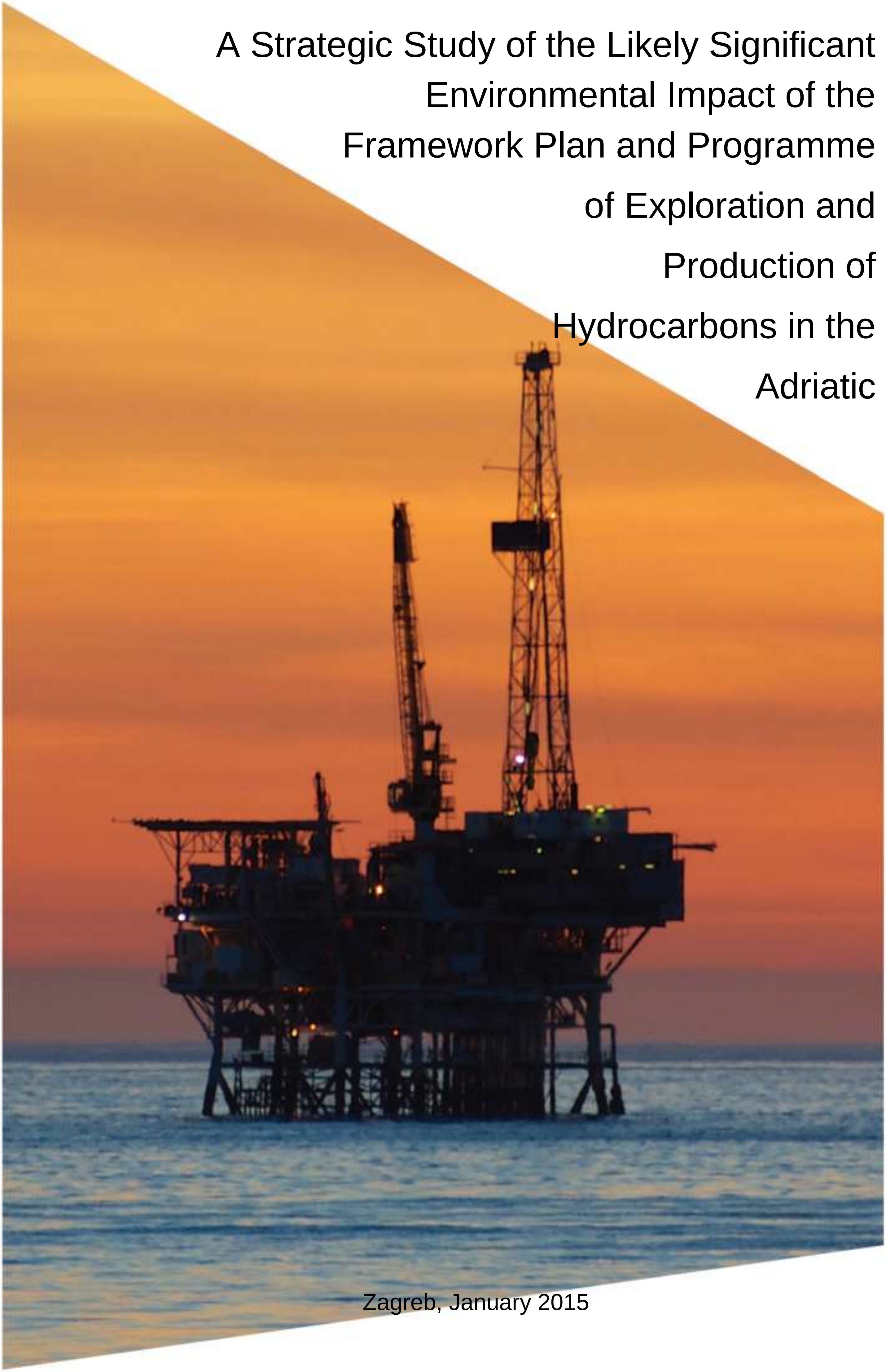
A Strategic Study of the Likely Significant Environmental Impact of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic



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1 Introduction

1.1 Strategic environmental impact assessment

Strategic assessment (hereinafter referred to as SEA) is a procedure that assesses, in the earliest phase, the likely significant impacts on environment and health that may occur due to the implementation of a plan/programme/strategy. This procedure includes determining the contents of the strategic study/ scoping, development of the strategic study and assessment of the integrity and professional rationale of the strategic study, especially with regard to alternative solutions of the plan and programme, the procedure of issuing the opinion of the committee, the procedure of issuing opinions of a body and/or persons defined by special regulations and opinions of the bodies of local, or regional self-government and other bodies, the results of transboundary consultations, if they were mandatory under the law, informing and the participation of the public, the procedure of issuing opinions by the ministry competent for environmental protection affairs and the procedure of reporting after the plan or programme has been adopted.

A strategic study is a baseline study submitted with the plan and programme and includes all required data, explanations and descriptions in textual and graphic form. The strategic study defines, describes and assesses the likely significant impacts on the environment and health that may occur due to implementation of the plan or programme, including alternative solutions that take into account the objectives and the scope of the plan and the programme. Its intention is to ensure that the consequences of the plan/ programme/ strategy on the environment and health are assessed during their preparation, before the final proposal is established and referred to the adoption procedure. The procedure of carrying out the SEA also gives stakeholders the opportunity to take part in the procedure, as well as ensuring that the public is informing and that it participates in the decision making process. The project authorities are provided with a framework for action and the possibility of including important environmental protection elements in decision-making.

Strategic assessment is carried out for plans and programs adopted at state, regional and local levels for large towns in the areas of agriculture, forestry, fisheries, energetics, industry, mining, transport, electronic communications, tourism, physical planning, regional development, waste management and water management, and provides a framework for projects subject to environmental impact assessment.

Directive 2001/42/EC of the European Parliament and Council on the assessment of effects of certain plans and programmes on the environment (the SEA Directive) has been in force since 2001. In the Republic of Croatia, the Environmental Protection Act (OG 153/13), the Regulation on strategic environmental assessment of plans and programs (OG 64/08- hereinafter referred to as the Regulation) and the Ordinance on the Committee for Strategic Assessment (OG 70/08) have been harmonized with the SEA Directive as a legal framework for the preparation of strategic studies. The stated regulations are also in compliance with the Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991), which bounds states to notify and consult in all large projects that might have a transboundary environmental impact.

This Strategic Study analyses the **Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic** (hereinafter: the FPP) adopted by the Government of the Republic of Croatia based on the Decision of the Government of the Republic of Croatia on the Implementation of the Procedure for Issuing Licenses and Publication of Public Tendering for Issuing Licenses for Exploration and Production of Hydrocarbons in the Adriatic, Class: 022- 03/14-04/98; File No: 50301-05/18-14-4; of 27 March 2014, and the Decision of the Government of the Republic of Croatia on Content, Terms and Conditions and Selection Criteria in the Tender for Exploration and Production of Hydrocarbons in the Adriatic (CLASS: 022-03/14-04/98; File No: 50301-05/18-14-2) of 27 March 2014.

The strategic environmental assessment procedure consists of steps stated in the table below (Table 1.1).

Table 1.1 Steps in the strategic environmental assessment procedure

Step	Purpose
Analytical review	Establish whether a SEA is mandatory according to the provisions of the Environmental Protection Act
Define the content of the strategic study	Define the scope and level of details that will be processed in the assessment
Preparation of the strategic environmental impact study and assessment of its integrity and professional rationale	Assessment of likely significant environmental impacts resulting from programme implementation
Public debate	Debate on the programme draft and Strategic study
Assessment of received comments on the Framework Plan and Programme and Strategic Study	Consideration of received comments, alternative solutions, grounds for the selection of an alternative
Report on the conducted Strategic Environmental Assessment	Overview of the manner in which the following was integrated in the final programme proposal: conditions of environmental protection established in the strategic assessment, manner of environmental status monitoring related to programme implementation, and manner of verifying the implementation of environmental protection measures which became part of the programme

In the event of the SEA procedure for the Plan and Programme, the Ministry of Economy of the Republic of Croatia (hereinafter: the Ministry) is competent for its implementation pursuant to the Environmental Protection Act. The Ministry carried out the procedure of the analytical review and on 25 August 2014 the Minister rendered the Decision on the Implementation of the SEA Procedure for the Plan and Programme (CLASS: 310-01/14-03/280, FILE NO.: 526-04-02-01/1-14-02). The Decision is enclosed in Annex 1 to this Strategic Study.

The provisions of the Act on Exploration and Production of Hydrocarbons (OG 94/13 and 14/14) apply to the exploration and production of hydrocarbons contained in the subsea of the internal sea waters or territorial sea of the Republic of Croatia, that is in the subsoil of the continental shelf of the Adriatic Sea to the line of delimitation with the neighbouring countries over which the Republic of Croatia, in compliance with international law, exercises jurisdiction and sovereign rights.

The Plan and Programme includes a portion of the Croatian continental shelf and the territorial sea, 35 833 km2 in area, in which 29 blocks are situated, the sizes of specific blocks amounting to from 1000 to 1600 km2. The eastern border of the tendering area is determined by the line 10 km away from the coast, and 6 km away from the external island line. The remaining borders of the project area are determined in compliance with the international agreements concluded with the neighbouring countries.

In accordance with the Plan and Programme, the flow and the scope of the activities are divided into the exploration and the production period and decommission period. The exploration period shall include exploration operations which include primarily 2D and 3D seismic survey acquisition and exploratory drilling, as well as many other analytical studies the joint purpose of which is to collect geological and geophysical data with the aim of obtaining accurate hydrocarbon potential assessment and recognition of geological structures (gravity, geochemical, magnetic, magneto-telluric, transient electromagnetic, and bathymetric surveys, seabed sampling, satellite gravity survey), environmental baseline survey and the environmental impact assessment of works. Pursuant to Article 19, paragraph 3 of the Act on Exploration and Production of Hydrocarbons the exploration period shall last for maximum five years.

Following the expiry of the exploration period and in the event of a commercial discovery, the production period shall commence and last until expiry of the period established in the Agreement with the concessionaire. The Agreement grants the right to exploration of hydrocarbons for a maximum period of 25 years. During the production period, the operations shall be carried out which include: development of the reservoir development studies, development drilling and well completion, construction of production plants and finally production of hydrocarbons.

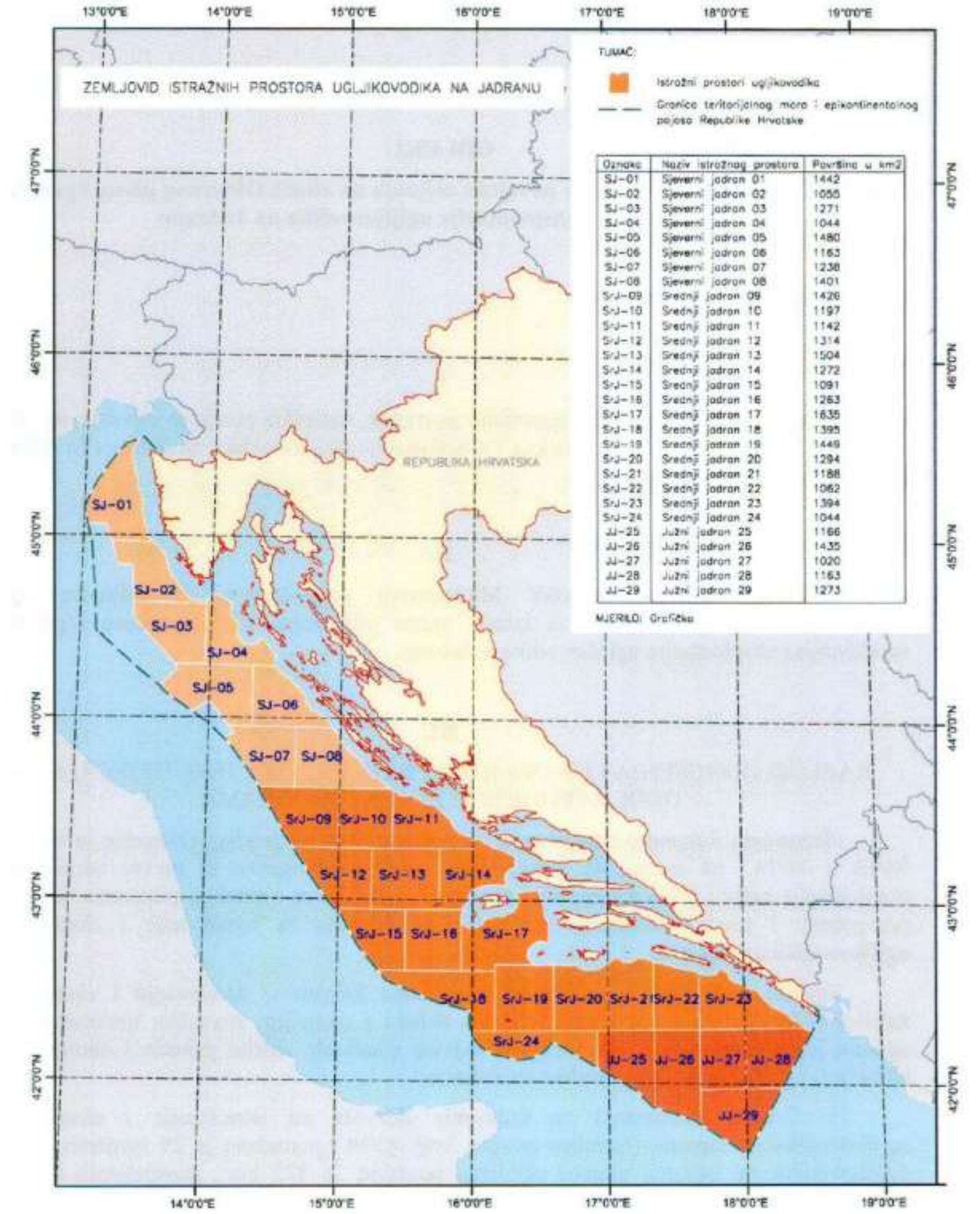


Figure 1.1 Map of exploration blocks for oil and gas in the Adriatic (source: Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic)

1.2 Defining the content (scoping) of the Strategic Study of the Framework Plan and Programme

The Ministry carried out the procedure of defining the content of the strategic study, pursuant to Article 7 of the Regulation, by obtaining the opinions of bodies defined by the special regulations on study content and level of data scope to be included in the strategic study, related to the area under the jurisdiction of this body.

The decision was adopted on 23 October 2014 (CLASS: 325-09/13-01/01, FILE No: 525-12/0903-13-46), and is enclosed in Annex 2 of this Strategic Study.

For the purpose of informing the public, the information on the implementation of the procedure for defining the content of the strategic study was published on the Internet site of the Ministry.
The procedure for defining the content of the strategic study involved the bodies of state administration and bodies of regional self-government units, stated in part IV Annex 2 of the Strategic study.
The operations foreseen by the implementation of the Plan and Programme have been identified for the purposes of strategic study development. Due to the strategic level of the document that was prepared at the level of the territorial sea and continental shelf of the Adriatic, and provides general solutions for exploration and the production of hydrocarbons, for the purposes of defining the content of the Study (scoping), the operations have been divided into those that will be performed during the exploration phase, production phase and post-production phase, and finally, the potential impacts have been defined for these activities.
The overview of the types of operations foreseen in the FPP and their impacts, and an overview of the expected impacts of FPP implementation on individual components of the environment is provided in Annex 3 of this strategic study, while the overview of potential impacts based on the judgement of the expert team of study developers by environment component with the decision on their further analysis in the strategic study is given in the table below.
An assessment of the significance of impacts on the respective environment component has been prepared for each identified operation resulting from the FPP likely to have an impact on the environment. In this strategic study an impact is considered significant if it is likely that it will result in the following:

- Changed life conditions and/or threatened species and habitats
- Permanent conflict with other activities in the area, such as fisheries, transport, energetics, telecommunications, tourism
- Permanent pollution of and/or harm to natural resources
- Worsened environmental baseline to a point exceeding limitations and standards stipulated by law
- Threatened human health, safety and quality of life
- Threatened cultural heritage and disrupted natural landscape
- Increased revenue from hydrocarbon activities

The results of the FPP implementation impact assessment for respective environment components are presented in the following table – the symbols related to the impact assessment have the following meaning:

++ potential significant positive impact
+ potential positive impact
0 no impact
- Potential negative impact
- - Potential significant negative impact

Table 1.1 Overview of potential impacts by environment component with a decision on their further analysis in the strategic study

Environment component	Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
Climate characteristics	**Exploration phase:** Maritime transport (-) Use of a part of the water area (0) Performance of different exploration operations (-) Installation of an exploratory drilling platform (-) Exploratory drilling (-) Accompanying activities (-) **Accidents (--)** **Production phase:** Maritime transport (-) Drilling of production wells (-) Installation of a production platform and pipelines (-) Hydrocarbon production and presence of a platform (-) Potential additional exploration operations (-) Accompanying activities (-) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (-) **Accidents (--)**	Maritime transport can have a negative impact on climate characteristics due to the increased emission of greenhouse gases. The emission of greenhouse gases is also expected during exploratory and production drilling, so these operations could also have an impact on climate characteristics. In case of accidents, a significant increase of pollutants in the air would occur, out of which a significant share would be greenhouse gases.	**YES, as a part of the objectives of "Preservation of existing air quality and climatic conditions" and "Reduced risk of accidents".**
Air	**Exploration phase:** Maritime transport (-) Use of a part of the water area (0) Performance of different exploration operations (-) Installation of an exploratory drilling platform (-) Exploratory drilling (-) Accompanying activities (-) **Accidents (--)** **Production phase:** Maritime transport (-) Drilling of production wells (-) Installation of a production platform and pipelines (-) Hydrocarbon production and presence of a platform (-) Potential additional exploration operations (-) Accompanying activities (-) **Accidents (--)**	An increase in maritime transport can increase air pollution. Installation of the exploratory drilling and production platform can have a negative impact on air quality due to the emission of pollutants in the air. In case of accidents (spilling of untreated drilling mud and formation water, oil spillage, shipwreck and hydrogen sulfide release from wells) the air quality could be significantly decreased.	**YES" as a part of the objectives of "Preservation of existing air quality and climatic conditions" and "Reduced risk of accidents", and within the component "Climate characteristics".**

Environment component	Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
	Removal phase: Removal of mining facilities and plants (-) **Accidents (--)**		
Seabed	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (-) **Installation of an exploratory drilling platform (--)** **Exploratory drilling (--)** Accompanying activities (0) **Accidents (--)** **Production phase:** Maritime transport (0) **Drilling of production wells (--)** Installation of a production platform and pipelines (-) **Production drilling (--)** Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (-) Accompanying activities (0) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (-) **Accidents (--)**	Installation of the exploratory drilling and production platform and drilling of wells can have a negative impact on the seabed, due to the disruption of the geological structure of the seabed. Also, the discharge of drilling mud and rock fragments can have a negative impact on the seabed in the immediate vicinity of the platform, where it settles. In case of accidents (spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release), the seabed could be disrupted due to hydrocarbon release.	**YES, as a part of the objectives of "Good status of the sea and seabed" and "Reduced risk of accidents" and as a part of the objectives "Sea and seabed pollution" and "Geological and oil-geological characteristics of the subsea and subsoil".**
Sea	**Exploration phase:** Maritime transport (-) Use of a part of water area (0) Performance of different exploration operations (-) **Installation of an exploratory drilling platform (--)** **Exploratory drilling (--)** Accompanying activities (-) **Accidents (--)** **Production phase:** Maritime transport (-) **Drilling of production wells (--)** **Installation of a production platform and pipelines (--)** **Hydrocarbon production and presence of a platform (--)** Potential additional exploration operations (-)	An increase in maritime traffic can increase maritime pollution due to the discharge of fuels, oils and lubricants during navigation of exploratory ships, tankers and other vessels. Installation of the exploratory drilling and production platform and drilling of wells can have a negative impact on sea quality, due to discharge of pollutants in the surrounding sea. In case of accidents, such as spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells, sea quality could be decreased.	**YES, as a part of the objectives of "Good status of the sea and seabed" and "Reduced risk of accidents" and within the component "Marine and seabed pollution".**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
		Accompanying activities (-) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (-) **Accidents (--)**		
Natural heritage	**Biodiversity**	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) **Performance of different exploration operations (--)** Installation of an exploratory drilling platform (-) **Exploratory drilling (--)** Accompanying activities (-) **Accidents (--)** **Production phase:** Maritime transport (0) Drilling of production wells (-) Installation of a production platform and pipelines (-/+) Hydrocarbon production and presence of a platform (-/+) **Potential additional exploration operations (--)** **Accompanying activities (--)** **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (-) **Accidents (--)**	The performance of different exploration operations, such as seismic surveys, can have a negative impact on biodiversity due to noise level increase in the environment. Installation of exploratory drilling and production platform and drilling of wells can have an impact on sea quality due to the discharge of pollutants in the surrounding sea waters, and thus have a negative impact on biodiversity in the sea environment. Also, by installing platforms and pipelines and discharging drilling mud and rock fragments, the impact on seabed and the benthic organisms that populate it is possible. The installed platform will in time be populated by different sea organisms and become an "artificial reef". Accident situations, such as spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells can disrupt the biodiversity of the area. The negative impact of helicopters – moving between platforms, exploration vessels and land – on birds is possible.	**YES, as a part of the objectives of "Good status of the sea and the seabed" and "Good status of marine species and habitats with special emphasis on marine mammals, turtles, fish, invertebrates and birds" and "Reduced risk of accidents".**
	Geodiversity	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0)	It is assessed that the implementation of the Framework Plan and Programme will not have a negative impact on this environment component.	**Not analysed.**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
		Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)		
Cultural-historical heritage		**Exploration phase:** Maritime transport (0) Use of a part of water area (0) **Performance of different exploration operations (--)** **Installation of an exploratory drilling platform(--)** **Exploratory drilling (--)** Accompanying activities (0) Accidents (-) **Production phase:** Maritime transport (0) **Drilling of production wells (--)** **Installation of a production platform and pipelines (--)** **Hydrocarbon production and presence of a platform (--)** **Potential additional exploration operations (--)** Accompanying activities (0) Accidents (-) **Removal phase:** Removal of mining facilities and plants (+) Accidents (-)	Performance of different exploration operations, such as seismic surveying, can have a negative impact on cultural heritage. Also, any drilling or platform installation activities near archaeological heritage sites can have a negative impact on them (e.g. wrecks of historically important sunken ships). Furthermore, the installation of a pipeline and the discharging of drilling mud and rock fragments can have an impact on the cultural heritage in the vicinity.	**YES, as a part of the objective "Protected submarine cultural heritage and natural landscape".**
Landscape features		**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) **Installation of an exploratory drilling platform (--)** Exploratory drilling (0) Accompanying activities (0) Accidents (-) **Production phase:** Maritime transport (0)	The installation of exploratory drilling or production platforms in places that are visible from land or where they disrupt the existing vistas important for boaters are possible negative impacts on landscape features. Accident situations, such as spillage of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells can disrupt landscape features. The implementation of the FPP will very likely cause negative impacts on the landscape, but since the precise locations of wells and accompanying infrastructure are not determined within exploratory and production areas i.e. the location of individual operations	**Not analysed, but the Study will provide general recommendations and measures for mitigation of negative impacts on the landscape within the component "Tourism", for which certain overlapping of impacts was identified.**

Environment component	Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
	Drilling of production wells (0) **Installation of a production platform and pipelines (--)** Hydrocarbon production and presence of a platform (-) Potential additional exploration operations (0) Accompanying activities (0) Accidents (-) **Removal phase:** Removal of mining facilities and plants (+) Accidents (-)	and facilities is not known, the evaluation will be analysed (in compliance with valid legislation and practice) through the mechanism of Environmental Impact Assessment/Acceptability Assessment for the Ecological Network. In addition, the study will give general recommendations and measures for the mitigation of negative impacts on the landscape within the component Tourism, with which certain overlapping was identified.	
Noise	**Exploration phase:** Maritime transport (-) Use of a part of water area (0) **Performance of different exploration operations (--)** Installation of an exploratory drilling platform (-) **Exploratory drilling (--)** Accompanying activities (-) Accidents (0) **Production phase:** Maritime transport (-) **Drilling of production wells (--)** Installation of a production platform and pipelines (-) **Hydrocarbon production and presence of a platform (--) Potential additional exploration operations (--)** Accompanying activities (-) Accidents (0) **Removal phase:** Removal of mining facilities and plants (-) Accidents (0)	The performance of different exploration operations, such as seismic surveys and the performance of exploratory and production drilling can cause an increase in noise levels in certain blocks.	**YES, as a part of the objectives of "Good status of the sea and seabed", "Good status of marine species and habitats with special emphasis on marine mammals, turtles, fish, invertebrates and birds" and "Harmonised implementation of the Programme with respect to other economic activities".**
Electromagnetic radiation	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed.**

Environment component	Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
	Production phase: Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)		
Chemical properties	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (-) Exploratory drilling (-) Accompanying activities (0) **Accidents (--)** **Production phase:** Maritime transport (0) Drilling of production wells (-) Installation of a production platform and pipelines (-) Hydrocarbon production and presence of a platform (-) Potential additional exploration operations (0) Accompanying activities (0) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (0) **Accidents (--)**	The drilling of wells can have a negative impact on chemical properties, due to the discharge of pollutants in the surrounding sea. Also, by discharging drilling mud and rock fragments during exploratory and production drilling, a negative impact on chemical properties is possible. Accident situations, such as spillage of untreated drilling mud and formation water, shipwrecks and hydrogen sulfide release from wells can disrupt the existing chemical properties of the area.	**YES, as a part of the objectives of "Good status of the sea and seabed", "Good status of marine species and habitats with special emphasis on mammals, turtles, fish, invertebrate and birds", "Harmonised programme implementation with respect to other economic activities", "Preservation of human health and quality of life" and "Reduced risk of accidents"**
Physical properties	**Exploration phase:** Maritime transport (0) Use of a part of water area(0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed, except at the level of status of physical properties and impact of physical properties on FPP implementation.**

Environment component	Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
	Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)		
Human health and quality of life	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) **Accidents (--)** **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (0) **Accidents (--)**	Accident situations, such as spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells can disturb the quality of life in the impacted area.	**Not analysed, except in the frame of accidents, i.e. as a part of the environmental objective "Preservation of human health and quality of life" and "Reduced risk of accidents".**
Waste management	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (-) Installation of an exploratory drilling platform (-)	During exploration and production drilling, large quantities of waste will be generated (discharge of drilling mud and fragments of broken rocks, discharge of wastewater and formation water), which will contribute to the increase of waste in the sea.	**YES, as a part of the objectives of "Harmonised implementation of the Programme with respect to other economic activities", "Reduced risk of accidents",**

Environment component	Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
	Exploratory drilling (-) Accompanying activities (0) **Accidents (--)** **Exploration phase:** Maritime transport (0) Drilling of production wells (-) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (-) Potential additional exploration operations (-) Accompanying activities (0) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (0) **Accidents (--)**		**"Good status of the sea and seabed" and "Preservation of human health and quality of life ".**
Ecological network	**Exploration phase:** Maritime transport (-) Use of a part of water area (0) **Performance of different exploration operations (--)** **Installation of an exploratory drilling platform (--)** **Exploratory drilling (--)** Accompanying activities (-) **Accidents (--)** **Production phase:** Maritime transport (-) **Drilling of production wells (--)** **Installation of a production platform and pipelines (--)** Hydrocarbon production and presence of a platform (-/+) **Potential additional exploration operations (--)** Accompanying activities (-) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (-) **Accidents (--)**	Performance of different exploration operations, such as seismic surveying, can have a negative impact on ecological network due to increased noise levels in the environment. Installation of the exploratory drilling and production platform and drilling of wells can have an impact on sea quality, due to the discharge of pollutants in the surrounding sea, and thus have a negative impact on the ecological network in the sea environment. Also, the installation of platforms and pipelines and discharge of drilling mud and rock fragments, the impact on the seabed in or near the Natura 2000 areas and benthic organisms that populate it is possible. Accident situations, such as spillage of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release can disrupt the biodiversity of ecological network of the area.	**YES, as a part of the objectives of "Good status of the sea and seabed", "Good status of marine species and habitats with special emphasis on marine mammals, turtles, fish, invertebrates and birds" and "Reduced risk of accidents".**
Socio-economic characteristics	**Exploration phase:** Maritime transport (0) Use of a part of water area (0)	A positive impact of FPP implementation on socio-economic characteristics is expected due to economic profit during hydrocarbon production.	**YES, as a part of the objectives of "Harmonised implementation of the Programme with respect to other economic activities",**

Environment component	Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
	Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) **Accidents (--)** **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (++) Potential additional exploration operations (0) Accompanying activities (0) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (0) **Accidents (--)**	Accident situations, such as spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells can have a significant negative impact on this component.	**"Reduced risk of accidents" and "Preservation of human health and quality of life".**
Geological and oil-geological characteristics	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (-) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (-) **Removal phase:** Removal of mining facilities and plants (0) Accidents (-)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**The impact on geological and oil-geological characteristics is not assessed; they have been analysed only at the level of status.**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
Hydrogeology		**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed.**
Economic characteristics	**Tourism**	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) **Accidents (--)** **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) **Accidents (--)** **Removal phase:**	Accident situations, such as spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells can have an impact on tourism. Disruption of landscape properties by installation of production platforms might reduce the attractiveness of the area for tourism.	**YES, as a part of the objectives of "Good status of the sea and seabed", "Protected submarine cultural heritage and natural landscape", "Harmonised implementation of the Program with respect to other economic activities", "Preservation of human health and quality of life" and "Reduced risk of accidents".**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
		Removal of mining facilities and plants (0) **Accidents (--)**		
	Forests and forestry	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed.**
	Agriculture	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed.**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
		Removal phase: Removal of mining facilities and plants (0) Accidents (0)		
	Fisheries	**Exploration phase:** Maritime transport (-) Use of a part of water area (-) Performance of different exploration operations (-) Installation of an exploratory drilling platform (-) **Exploratory drilling (--)** Accompanying activities (-) **Accidents (--)** **Production phase:** Maritime transport (-) Drilling of production wells (0) **Installation of a production platform and pipelines (--)** Hydrocarbon production and presence of a platform (-) **Potential additional exploration operations (--)** Accompanying activities (-) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (-/+) **Accidents (--)**	The performance of different exploration operations, such as seismic surveys and an increase in marine transport can have a negative impact on fisheries due to an increase in noise levels in the environment. Also, in compliance with the Ordinance on the relevant technical requirements, safety and protection in the exploration and exploitation of hydrocarbons on the seabed and subsoil of the Republic of Croatia (OG 52/10), and in compliance with valid international maritime transport regulations, a safety zone is defined around each platform where only authorised vessels can enter. Anchoring and fishing activity is also prohibited within the safety zone (an area with a diameter of 500 m as measured from the platform axis), i.e. on the routes of submarine pipelines. The impact on fishing caused by the removal of mining facilities and plants is two-fold. The positive impact is manifested through regained availability of the area for fishing and the negative through the destruction of newly formed habitats populated by fish. Accident situations, such as spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells can have a significant impact on fisheries.	**YES, as a part of the objectives of "Good status of the sea and seabed", "Good status of the marine species and habitats with special emphasis on marine mammals, turtles, fish, invertebrates and birds", "Harmonised implementation of the Programme with respect to other economic activities" and "Reduced risk of accidents".**
	Maritime shipping, maritime transport and waterways	**Exploration phase:** Maritime transport (-) Use of a part of water area (-) Performance of different exploration operations (-) Installation of an exploratory drilling platform (-) Exploratory drilling (-) Accompanying activities (-) **Accidents (--)** **Production phase:** Maritime transport (-) Drilling of production wells (-) **Installation of a production platform and pipelines (--)** Hydrocarbon production and presence of a platform (-) Potential additional exploration operations (-)	Increased traffic due to FPP implementation will in some cases have an impact on the increase of the already existing maritime transport. Accident situations, such as spilling of untreated drilling mud and formation water, oil spillage, shipwrecks and hydrogen sulfide release from wells can have a significant impact on transport. After facilities and plants are removed, the disruptions to maritime transport will be eliminated in this area.	**YES, as a part of the objectives of "Harmonised implementation of the Program with respect to other economic activities" and "Reduced risk of accidents".**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
		Accompanying activities (-) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (+) **Accidents (--)**		
	Game and hunting	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed.**
Infrastructure	**Water supply**	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed.**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
		Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)		
	Sewage	**Exploration phase:** Maritime transport (0) Use of a part of water area(0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (0) Accompanying activities (0) Accidents (0) **Production phase:** Maritime transport (0) Drilling of production wells (0) Installation of a production platform and pipelines (0) Hydrocarbon production and presence of a platform (0) Potential additional exploration operations (0) Accompanying activities (0) Accidents (0) **Removal phase:** Removal of mining facilities and plants (0) Accidents (0)	It is assessed that the implementation of the FPP will not have a negative impact on this environment component.	**Not analysed.**
	Tele-communi-cation and energy	**Exploration phase:** Maritime transport (0) Use of a part of water area (0) Performance of different exploration operations (0) Installation of an exploratory drilling platform (0) Exploratory drilling (-) Accompanying activities (0) **Accidents (--)** **Production phase:** Maritime transport (0)	The FPP implementation could cause negative impacts on infrastructure elements, but since the precise locations for wells and accompanying infrastructure are not determined within exploratory and production areas, i.e. the spatial position of individual works and facilities is not known, the evaluation will be processed (in compliance with valid legislation and practice) through the mechanism of Environmental Impact Assessment/ Acceptability Assessment of the Project on the Ecological Network. Due to the above mentioned, the infrastructure will not be analysed by all chapters in further stages of strategic study preparation, but the impact on this environment component will be assessed only in terms of accidents.	**Not analysed, except in the frame of accidents.**

Environment component		Operations	Potential impact and clarification of the impact on the environment component	Decision on further analysis of the environment component
		Drilling of production wells (-) Installation of a production platform and pipelines (-) Hydrocarbon production and presence of a platform (-) Potential additional exploration operations (0) Accompanying activities (0) **Accidents (--)** **Removal phase:** Removal of mining facilities and plants (0) **Accidents (--)**		

1.3 Consultations carried out during the preparation of the Strategic Study

During the preparation of the Strategic Study, consultations were carried out at the competent Ministries: Ministry of Environmental and Nature Protection (*Directorate for Environmental Impact Assessment and Sustainable Waste Management (Sector for Environmental Impact Assessment and Industrial Pollution), Directorate for Nature Protection, State Institute for Nature Protection),* Ministry of Agriculture (*Fisheries Directorate)* and Ministry of Tourism (*Department for Sustainable Development of Tourism, Service for the Valorisation of the Spatial Potential for Tourism).* On these occasions the baseline studies that were used in the preparation of the Strategic study were obtained. During the preparation of this strategic study the study developers presented, at a joint meeting with the members of the Committee and the Client's representatives, the manner and methodology of preparation of individual environment components.

The Decision on the Nomination of the Advisory Expert Committee with a list of Committee members is enclosed in Annex 4 of this Strategic study.

1.4 Main objectives of the Framework Plan and Programme

The Framework Plan and Programme are developed with the aim of accurate monitoring of the operations concerning exploration and production of hydrocarbons in the Adriatic, issuance of licences, conclusion of agreements, determination of fees, infringement provisions and quality inspection, monitoring and foreseeing of the status of hydrocarbon reserves in the Adriatic, as determined under the Act on Exploration and Production of Hydrocarbons. The implementation of the Framework Plan and Programme is also essential for better efficiency and management of hydrocarbons, as also guaranteed under the Constitution of the Republic of Croatia.

1.5 Technical Aspects of Exploration and Production of Hydrocarbons

1.5.1 Summary of Current Exploration and Production of Hydrocarbons in the Adriatic

In the relevant exploration block in the Adriatic, in the period from 1961 (Exploration Well Vis-1) to 2004 (Exploration Well Karla-1) 51 exploration wells were spudded. The final depths of the exploration wells were in the range from 1022 m (Exploration Well Vlasta 1) to 6519 m (Exploration Well Vlasta 1alX). The water depths on the exploration well sites were in the range from 33 m (Exploration Well Istra More 4) to 362 m (Exploration Well Mirjana 1). Gas occurrences were registered at 10 exploration wells and oil occurrences at 5 exploration wells. 4 exploration wells hold a status of gas exploration wells and 32 exploration wells were negative. To date the production of hydrocarbons has not taken place in the exploration block under consideration.

The area of the continental shelf of the Republic of Croatia includes three hydrocarbon production fields that are excluded from the exploration block. These production fields in the North Adriatic: "Izabela", "North Adriatic" and "Marica" have been subject to the production of natural gas and its transportation to the mainland for a long number of years.

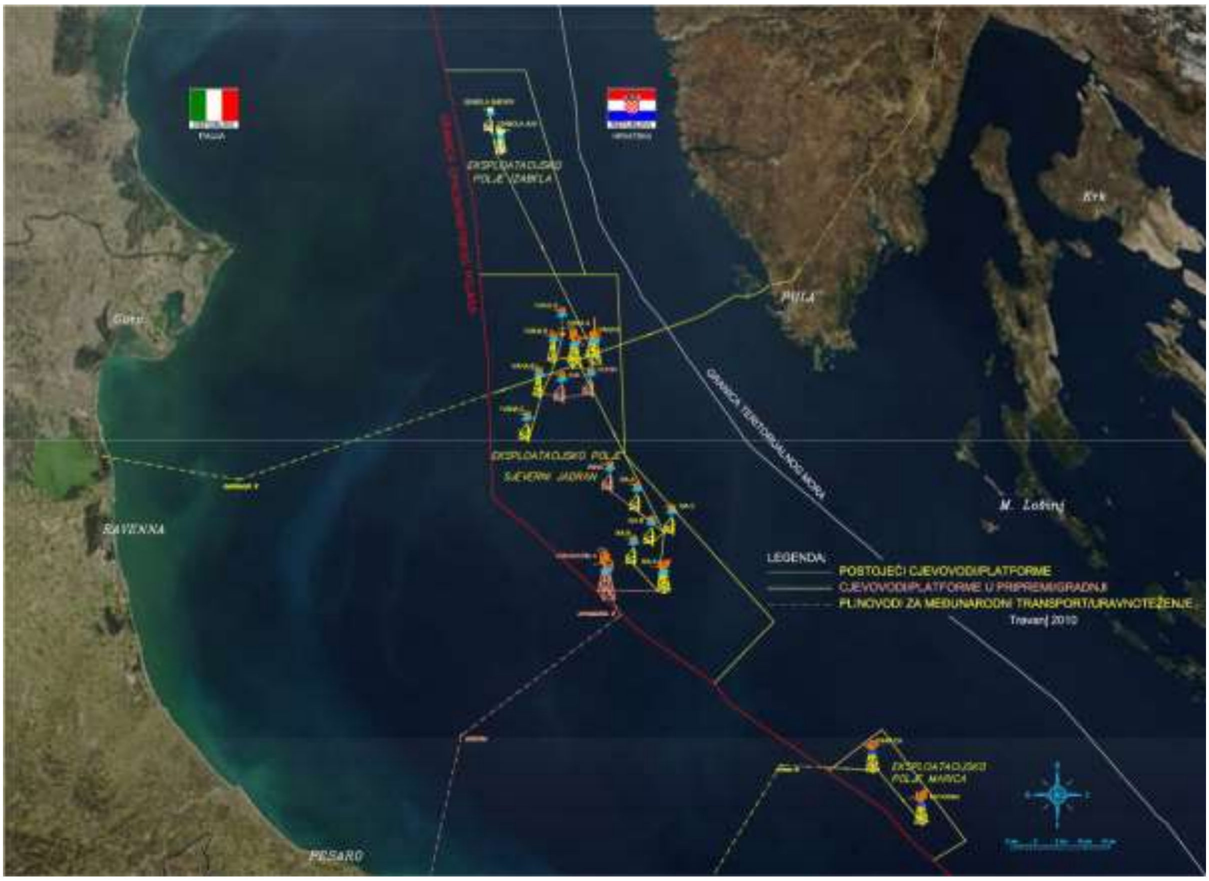


Figure 1.2 The location of production fields "Izabela", "North Adriatic" and "Marica" (Source: Ministry of Economy)

LEGENDA/KEY:

REPUBLIKA HRVATSKA – REPUBLIC OF CROATIA

REPUBLIKA ITALIJA – REPUBLIC OF ITALY

GRANICA EPIKONTINENTALNOG POJASA – CONTINENTAL SHELF BOUNDARY

IZABELA SJEVER – IZABELA NORTH

IZABELA JUG – IZABELA SOUTH

EKSPLOATACIJSKO POLJE IZABELA – PRODUCTION FIELD IZABELA

EKSPLOATACIJSKO POLJE SJEVERNI JADRAN – PRODUCTION FIELD NORTH ADRIATIC

POSTOJEĆI CJEVOVODI/PLATFORME – CURRENT PIPELINES/PLATFORMS

CJEVOVODI/PLATFORME U PRIPREMI/GRADNJI – PIPELINES/PLATFORMS UNDER CONDITIONING/CONSTRUCTION

PLINOVODI ZA MEĐUNARODNI TRANSPORT/URAVNOTEŽENJE – GAS PIPELINES FOR INTERNATIONAL TRANSPORTATION/BALANCING

TRAVANJ 2010 – APRIL 2010

EKSPLOATACIJSKO POLJE MARICA – PRODUCTION FIELD MARICA

GRANICA TERITORIJALNOG MORA – TERRITORIAL SEA BOUNDARY

There are two operating production platforms in the area of the production field "Izabela", fifteen platforms (1 compressor and 14 production platforms) in the area of the production field "North Adriatic" and two production platforms in the area of the production field "Marica".

The Table below (Table 1.3) includes a list of platforms, their purpose, type of substructure and the number of production wells associated with respective platforms. There are nineteen existing production platforms used for the production of natural gas from reservoirs, whereas Platform Ivana K is a compressor platform.

Table 1.3 The existing platforms in the territory of the North Adriatic

Name of platform	Purpose	Type of substructure	Number of wells
Production field "Izabela"			
Izabela North	Production	Lattice legged	3
Izabela South	Production	Four legged	3
Production field "North Adriatic"			
Ivana K	Compressor	Four legged	-
Ivana A	Production	Four legged	5
Ivana B	Production	Tripod	3
Ivana C	Production	Monopod	1
Ivana D	Production	Monopod	1
Ivana E	Production	Tripod	3
Ida A	Production	Monopod	1
Ida B	Production	Monopod	2
Ida C	Production	Monopod	3
Ika A	Production	Four legged	3
Ika B	Production	Monopod	3
Annamaria A	Production	Four legged	5
Irina	Production	Monopod	2
Ana	Production	Monopod	2
Vesna	Production	Monopod	1
Production field "Marica"			
Marica	Production	Four legged	3
Katarina	Production	Four legged	3
Total: 19 platforms			

Figure 1.3 depicts Production Platforms Ika A, Ika B, Marica and Katarina, and Figure 1.4 Production Platform Ivana A and Compressor Platform Ivana K. They are fixed frame (jacket) platforms resting on the seabed.

Figure 1.3 Production Platforms Ika A, Ika B, Marica and Katarina

Figure 1.4 Production Platform Ivana A and Compressor Platform Ivana K

The process of natural gas extraction from production wells and operation management over all platforms is automatically self-regulated. The overall hydrocarbon production process management is carried out by Platforms Ivana A and Annamaria A, the only permanently manned platforms. The internal pipeline cleaning and control system, as well as the cold vent platform system are installed on all platforms.

The high- and low-pressure vertical vent systems installed on the platforms are used for the facility relief. The horizontal vent system is also installed and used only as a gas-flaring facility for the production initiation or the workover rig. The emergency shutdown system has a possibility to affect all valves of the process shutdown system, the valves of the vent system and the fire protection system. The fire protection system is installed for fire and gas detection, which manually or automatically detects and performs executive actions against fire and flammable gases.

The current method of reservoir water disposal includes separation of natural gas from reservoir water on every production platform, transportation of reservoir water through subsea pipelines to the platforms where the treatment procedure is conducted to the level of total hydrocarbons of 40 mg/L, followed by discharge into the sea through the submersible caisson. As needed, the submersible pump is used to pump out the caisson content into the service boat which transports the content to the legal person certified for water disposal.

The reservoir water treatment plants are installed on the following platforms: Ivana A (receives reservoir water from Platforms Ivana A, Ivana B, Ivana C, Ivana D, Ivana E, Ana and Vesna), Ika A (receives reservoir water from Platforms Ika A, Ika B, Ida A, Ida B, Ida C and Irina), and Platforms Marica, Katarina and Annamaria A where reservoir water separated from gas on the respective platforms is treated.

1.5.2 Platforms

Pursuant to maritime regulations platforms are technical floating structures (mobile offshore structures for exploration and subsea production) or fixed offshore structures (fixed offshore structure for exploration and subsea production). They are used for hydrocarbon exploration and subsea production, and according to their purpose divided into drilling, production and compressor platforms.

- **Drilling platforms** are used for well spudding, completion and testing, as well as workover, SIMOPS and stimulation works.
- **Production platforms** are used for hydrocarbon recovery, preparation for transportation and transportation.
- **Compressor platforms** are used for hydrocarbon upgrading, preparation for transportation and transportation.

The platforms are positioned and orientated in accordance with the maritime regulations in force taking into account the impact of natural factors. The metal structure of the platform, metal facilities, platform installations and devices are protected against corrosion in compliance with the regulations in force.

A safety zone is designated around every platform, pursuant to international maritime regulations in force, the access to which is forbidden to unauthorised vessels. It is prohibited to moor any vessels, conduct fishing activities or enter by vessel into the forbidden area (within the perimeter of 500 m measured from the platform axis) within the safety zone that is along the routes of the sub-sea pipelines.

The basic classification of drilling and production platforms according to the working position they occupy is as follows:

1. **FIXED**

- Steel frame (jacket) platforms resting on the seabed,
- Compliant tower platforms resting on the seabed,
- Offshore concrete structures or concrete offshore platforms resting on or moored to the seabed,
- Tension-leg platforms (TLPs) moored to the seabed,
- Jack-up (self-elevating) rigs,
- Floating spar platforms moored to the seabed.

2. **MOBILE**

- Semi-submersible platforms,
- Drill ships,
- Floating production, storage and offloading systems (FPSO) for hydrocarbons.

Barges are used as auxiliary means for maritime drilling and production activities. Pipe-laying barges/cranes, diving support vessels and other marine and aviation operations are used to install the elements of the production platform (substructure, piles, conductor, processing/quarters module, etc.). Some examples of fixed platforms and mobile units are shown below in this section.

1.5.2.1 **Fixed platforms**

The subsections below provide some examples of specific types of fixed platforms and their areas of application.

1.5.2.1.1 Fixed steel frame (jacket) platform resting on the seabed

The fixed platform is an integrated steel frame (jacket) resting on the seabed with monopod (single legged), tripod (three legged) or four legged substructure (Figure 1.5). Its substructure is laid onto the seabed and its foundations are piled into the seabed. The substructure supports the surface deck structure fitted with processing and auxiliary units for hydrocarbon production. The installation of the fixed platform (depending on the characteristics of the hydrocarbon reservoir) is considered economically justified up to the water depth of **maximum 200 m**.

Figure 1.5 Steel frame (jacket) platform resting on the seabed (Source: http://www.ina.hr/UserDocsImages/Ina_casopis/zima09-10/44-45%20annamaria.pdf)

1.5.2.1.2 Compliant tower platform resting on the seabed

The compliant tower platform resting on the seabed is very similar to the fixed steel frame (jacket) platform resting on the seabed (Figure 1.6). Its foundations are piled into the seabed. A slender steel frame construction is more flexible than the conventional structure and more resistant to storm surges and periods (approximately 30 s). The compliant tower platform may be installed in water depths of **up to 500 m**.

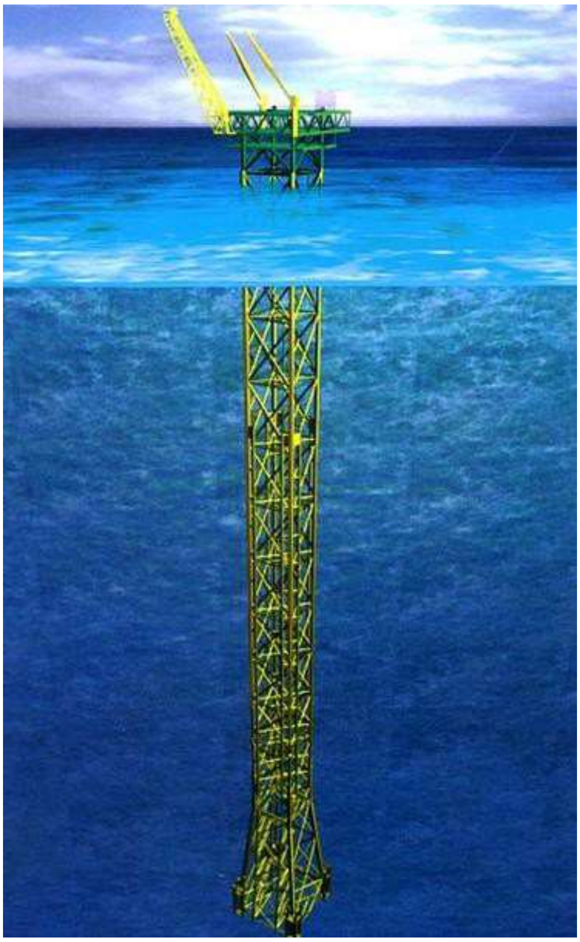


Figure 1.6 Compliant tower platform resting on the seabed (Source: http://www.offshore-technology.com/projects/baldpate/baldpate2.html)

1.5.2.1.3 Offshore concrete structures or concrete offshore platforms resting on or moored to the seabed

The offshore concrete structures or concrete offshore platforms have different applications for hydrocarbon exploration and production (Figure 1.7). Due to concrete which is resistant to corrosion caused by salt water and due to low concrete structure maintenance costs, such platforms have become especially attractive to oil industry in the last couple of decades. To date they have been used in water depths of **360 m**.

Figure 1.7 Concrete offshore platforms (Source: http://en.wikipedia.org/wiki/Offshore_concrete_structure#mediaviewer/File:Troll_A_Platform.jpg)

1.5.2.1.4 Tension leg platform moored to the seabed

The tension leg platform (TLP) moored to the seabed is a platform type held in place by a mooring system that is the platform is attached onto the seabed over steel tendons of a large diameter. The buoyancy of the hull is held in tension by the tendons. The Stateoil's Heidrun TLP is the only platform with a concrete hull, whereas all other tension leg platforms have a steel hull. They are used in water depths of approximately up to 2000 m. The platforms with minimum leg tension may be spudded at water depths of from **200** to **1200 meters**. Platform A is completed for both drilling and production, and Platform B only for production (Figure 1.8).

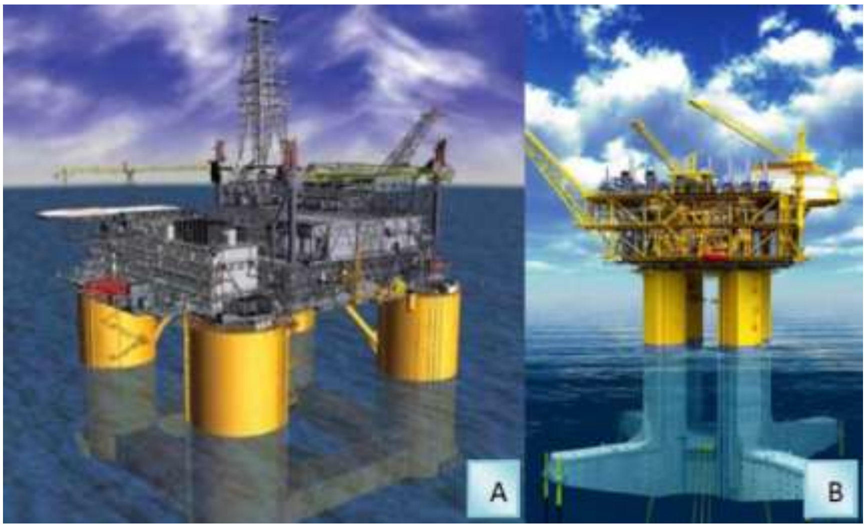


Figure 1.8 Tension leg platforms moored to the seabed (Sources: image on the left (http://www.offshore-mag.com/articles/print/volume-73/issue-01/gulf-of-mexico/shells-mars-b-develop-begins-take-shape.htmli); image on the right (https://www.rigzone.com/training/insight.asp?insight_id=305&c_id=12))

1.5.2.1.5 Jack-up rigs

The jack-up (self-elevating) rig is a mobile unit that may be moved that is towed to the location. When it reaches the location, its legs are hydraulically lowered onto the seabed (Figure 1.9). Once on the location, the jack-up rig is elevated to the working position, making this type of a rig safer for operation as it is unaffected by the marine conditions (waves of acceptable heights). The jack-up rigs are used in shallow seas of **up to 100 m**.

Figure 1.9 Jack-up rigs "Ocean King" (A) and "Labin" (B))

1.5.2.1.6 Floating spar platforms moored to the seabed

The floating spar platforms moored to the seabed consist of a cylinder hull (a large diameter cylinder) supporting a floating deck from the seabed (Figure 1.10). They were developed as an alternative to conventional platforms. On average, about 90% of the platform structure is under water. They are used in water depths of from **500 m** to **1700 m**, but with the state-of-the-art technology they may also be used in water depths of up to **3500 m**.

Figure 1.10 Floating spar platform (Source: http://en.wikipedia.org/wiki/Spar_(platform))

1.5.2.2 Mobile units

The subsections below provide short descriptions of some examples of specific types of mobile units and their areas of application.

1.5.2.2.1 Semi-submersible platforms

The semi-submersible platforms are usually towed to the location (Figure 1.11). Their main feature is that in principle they maintain their stability with small movements when exposed to the wind, waves and sea currents. The semi-submersible platforms have pontoons and caissons, usually two parallel pontoons with buoyant columns raising from the pontoon and supporting the deck. For the activities demanding a stable platform, the platform is additionally ballasted toward the seabed, the pontoons are submerged, and only the floating columns are above the water surface, providing the semi-submersible platform with significant buoyancy and a small surface at the water level. The only concrete semi-submersible platform is "Troll B" in the North Sea. The third generation of semi-submersible platforms is convenient for drilling at water depths of from **356 m** to **1040 m**, and the fourth generation of semi-submersible platforms is used for drilling at the water depth of up to **1750 m**. There are also semi-submersible platforms which may be used at water depths of up to **3048 m** (10 000 ft) (e.g. "West Hercules", "West Pheonix", "West Rigel", etc.).

Figure 1.11 Semi-submersible platforms (Source: http://en.wikipedia.org/wiki/Semi-submersible)

1.5.2.2.2 Drill ships

The drill ships have the functional ability of semi-submersible platforms, but also have a few unique features that separate them from other types of platforms: they have a ship-shaped design, greater mobility and can move quickly under their own propulsion from one to another drill site, which results in significant time savings (Figure 1.12). Inside the drill ship there is an opening, moon pool, providing access to the sea, where diving equipment is assembled and handled. They may be used at water depths of up to **3650 m**.

Figure 1.12 Drill ships (Source: http://www.2b1stconsulting.com/drillshipi; http://www.upstreamonline.com/live/article1329547.ece)

1.5.2.2.3 Floating production, storage and offloading systems (FPSOs) for hydrocarbons

The floating production, storage and offloading Systems (FPSO) for hydrocarbons are moored in place by various mooring systems, and are used for **deep and ultra-deep waters** (Figure 1.13). A central mooring system allows the vessel to rotate freely to best respond to weather conditions. It is usually tied to multiple production wells over a number of pipelines which transport oil and gas from the well to the vessel and store them in tanks in the vessel's hull, from where crude oil is transferred to shuttle tankers or barges for transportation. Besides the floating production, storage and offloading systems for hydrocarbons there are also floating storage and offloading systems (FSOs) (vessels without any production processing equipment) used in the same areas as a support to the development of oil and gas reservoirs. The floating storage and offloading systems (FSOs) are usually used as storage units in remote places away from pipelines or any other infrastructure.

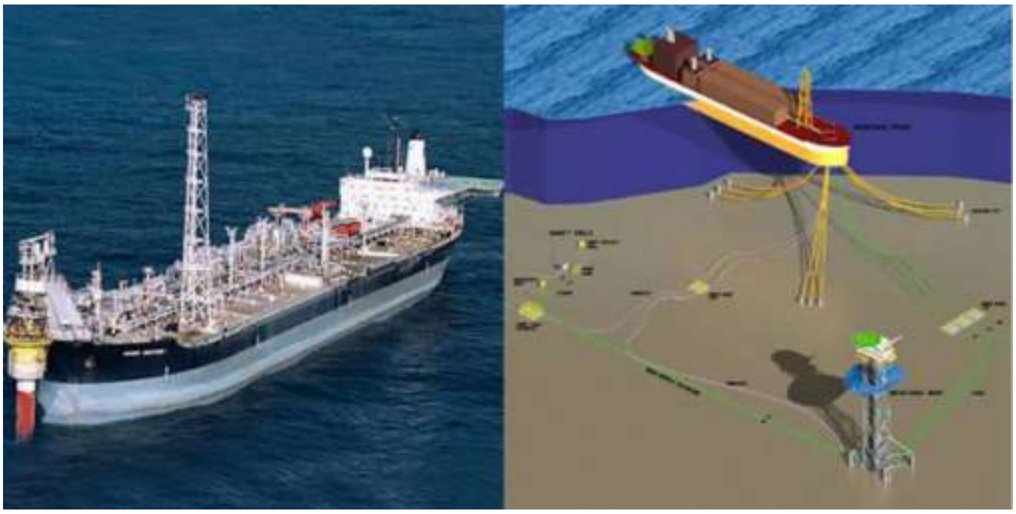


Figure 1.13 Floating production, storage and offloading systems for hydrocarbons (Source: https://www.rigzone.com/training/insight.asp?insight_id=299&c_id=12)

The floating production systems are mostly used in the Gulf of Mexico. The largest part of the platform floats above the sea surface. However, the wellhead is situated on the seabed, and additional precautionary measures should be put in place to avoid any leakage or eruption. The malfunction of the blowout preventer system *inter alia* caused a catastrophic explosion and oil spill in 2010 during drilling of the "Deepwater Horizon" platform on the "Macondo 252" well in the Gulf of Mexico. The floating production systems may operate in the areas where water depths are from **200 m** to **2000 m**. Table 1.4 shows a list of platforms and the respective water depths for their utilisation.

Table 1.4 Platforms and water depths

FIXED PLATFORMS	WATER DEPTHS (m)
Fixed steel frame (jacket) platform resting on the seabed	Up to 200
Compliant tower platform resting on the seabed	Up to 500
Offshore concrete structures or concrete offshore platforms resting on or moored to the seabed	Up to 360
Tension leg platforms (TLPs) moored to the seabed	Up to 2 000
Jack-up (self-elevating) rigs	9 to 100
Floating spar platforms moored to the seabed	500 to 1700 (up to 3 500)
MOBILE UNITS	**WATER DEPTHS (m)**
Semi-submersible platforms	Up to 3048
Drill ships	610 to 3650

Figure 1.14 shows production platform types as follows: (1, 2) fixed frame (jacket) platforms resting on the seabed; (3) compliant tower platforms resting on the seabed; (4, 5) tension leg platforms moored to the seabed; (6) floating spar platform moored to the seabed; (7, 8) semi-submersible platforms; (9) floating production, storage and offloading systems for hydrocarbons and (10) subsea completion and tie-back to host facility.

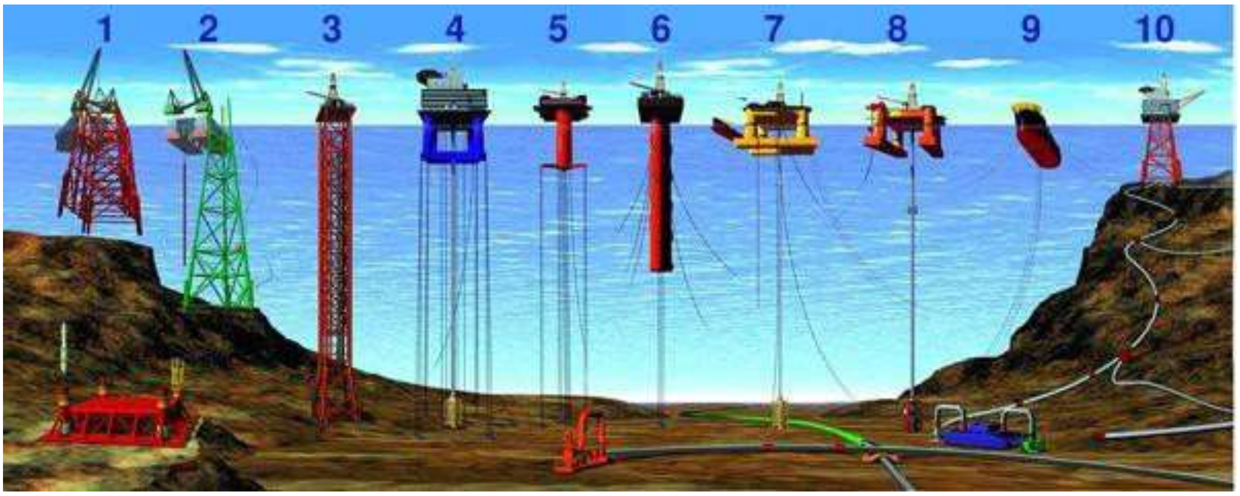


Figure 1.14 The comparative illustration of production platform types (Source: NOAA, 2010)

1.5.3 Hydrocarbon Exploration

Pursuant to the Act on the Exploration and Production of Hydrocarbons, exploration of hydrocarbons means any exploration and appraisal works and activities defined as such in the approved operational programme and aimed at determination of the presence, position and shape of hydrocarbon reservoirs, their quantity, quality and the production conditions, including but not limited to: (a) geophysical and other geological imaging, interpretation of data collected in such a way and their elaboration in a study, (b) drilling, deepening, swerving, fitting out, testing, temporary abandonment or termination of exploration wells, and (c) purchase or procurement of goods, services, materials and equipment which are necessary for the performance of the above-mentioned works.

Exploration of hydrocarbons is permitted only within the approved exploration block. The hydrocarbon exploration block is a block confined by the geographic coordinates of its peak points and restricted in its depth, a terrestrial and/or marine block section, which was, after an implemented public tendering procedure, designated for hydrocarbon exploration based on a licence. The Framework Plan and Programme (FPP) of exploration and production of hydrocarbons in the Adriatic includes a portion of the Croatian continental shelf and the territorial sea, **35 833 km^2** in area, in which **29 exploration blocks** are situated: 8 exploration blocks in the North Adriatic, 16 exploration blocks in the Central Adriatic, and 5 exploration blocks in the South Adriatic. The sizes of individual exploration blocks amount to from **1000 km^2** to **1600 km^2**. The eastern border of the exploration blocks is situated **10 km** away from the coast and **6 km** away from the external island line, whereas the remaining borders of the project area are determined in compliance with the international agreements concluded with the neighbouring countries.

The execution of mining works, which means any works conducted for the purpose of exploration and production of hydrocarbons, and the site rehabilitation works, requires mining facilities and plants. The term “mining facilities and plants” means any facilities, plants, equipment, tools, devices and installations used for the performance of exploration and production of hydrocarbons.

The water depth in the area of exploration blocks 1 to 8 situated in the North Adriatic is up to 100 m. The water depth in the blocks 1 to 4 is in full or in part below 50 m. The water depth in the area of exploration blocks from 9 to 24 situated in the Central Adriatic is on average from 100 to 200 m, but in places in the blocks 20 – 24 it also reaches the depth of up to 500 m.

The water depth in the area of exploration blocks from 25 to 29 situated in the South Adriatic is from 500 m to above 1000 m. The water depth in the area of exploration blocks 27 and 29 is above 1000 m, whereas in other blocks this depth is exceeded only in some sections. According to Det Norske Veritas (DNV, 2013), for offshore exploration and production of hydrocarbons the water depths are classified as follows: (1) shallow water depth of up to 300 m, (2) deep water depths of from 300 m to 1500 m and (3) ultra deep water depths of above 1500 m.

1.5.3.1 Geological Works before Exploration Drilling

The discovery and recovery of hydrocarbons in any area requires the presence of specific geological preconditions that is petroleum geological conditions. The essential conditions that have to be present are as follows:

- The circumstances in the geological history favourable for the formation of **source rocks** (rocks with cerogen as a source organic matter for hydrocarbon release) reaching their maturation in a specific geological period,
- The presence of **reservoir** (collector) rocks of adequate porosity and permeability to “receive” petroleum and/or gas into its pores/cavities,
- The presence of **seal or cap rocks** to prevent dispersion of migrating hydrocarbons, and
- The presence of an adequate **convex structure** in the subsoil made of porous and seal or cap rocks (**structural trap**) inside of which migrating hydrocarbons will accumulate and form a **reservoir.**

To date there is no DIRECT method of detecting petroleum that is a petroleum reservoir with CERTAINTY. All the methods applied are merely indirect methods resulting in the assumptions of a certain degree of probability indicating the presence of petroleum and/or gas in an area. The development of exploration techniques and technologies by all means increases the probability of reservoir detection. In other words, petroleum reservoir exploration is a demanding, time-consuming and responsible operation associated with excellent knowledge of geology of the area, primarily preceding any initiation of drilling.

The geological/petroleum geological explorations in principle may be classified into two groups or phases. Traditionally, they are:

A) Geological works before exploration drilling and
B) Geological works during exploration drilling.

Geological works before exploration drilling

The first phase begins with the process of familiarisation with the general geological composition and geological structure of the wider area, the Adriatic subsoil and coastal area in this particular case. The findings are primarily shown in geological maps resulting from geological mapping of the terrain surface. It is impossible to carry out direct geological mapping in the Adriatic. It is only possible to collect the data on the composition of the seabed deposits by taking samples from a vessel and the data on the surrounding terrestrial/coastal area which are in accordance with the geological logic “lowered/projected” into the depth, into the subsoil.

The details concerning the geological features of the Croatian subsoil based on drilling findings and the knowledge of stratigraphy, lithologic composition and tectonic relationships in the terrestrial and coastal area are indicated below in the section describing **Geological and Petroleum Geological Subsoil Features**.

It is extremely important to collect the data on the indications of petroleum and gas bearingness (leads) in the area of concern. In the terrestrial area, these are petroleum and/or gas outcrops, and in the marine area these are primarily gas occurrences or prospects based on the data in the neighbourhood. In this regard, it is interesting to note that the prospecting and analyses of the subsea gas manifestations (“brombolas”) were carried out practically 80 years ago. More specifically, “brombolas” were recorded on 14 well sites from the Brijuni Islands to the area in front of Novigrad, and many asphalt manifestations along the western and southern coast of Istria. Gas was identified as methane, and the asphalts were recognised as products of petroleum oxidation without any indications of an elevated degree of degradation (Đurasek et al., 1981).

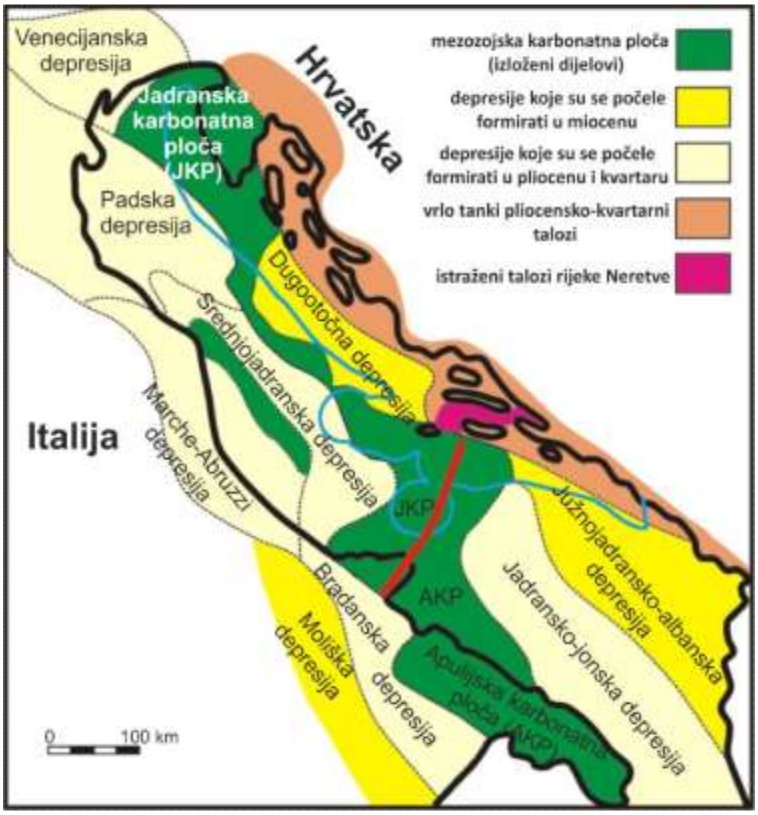


Figure 1.15 The map of depressions in the Adriatic subsoil ***(Source: VELIĆ and MALVIĆ, 2011)***

KEY:

- HRVATSKA – CROATIA
- ITALIJA – ITALY
- VENECIJANSKA DEPRESIJA – VENETTO DEPRESSION
- JADRANSKA KARBONATNA PLOČA (JKP) – ADRIATIC CARBONATE PLATFORM (ACP)
- PADSKA DEPRESIJA – PO DEPRESSION
- DUGOOTOČNA DEPRESIJA – DUGI OTOK DEPRESSION
- SREDNJOJADRANSKA DEPRESIJA – CENTRAL ADRIATIC DEPRESSION
- MARCHE-ABRUZZI DEPRESIJA – MARCHE-ABRUZZI DEPRESSION
- JUŽNOJADRANSKO-ALBANSKA DEPRESIJA – SOUTH ADRIATIC – ALBANIA DEPRESSION
- JADRANSKO-JONSKA DEPRESIJA – ADRIATIC – IONIAN DEPRESSION
- APULIJSKA KARBONATNA PLOČA (AKP) – APULIAN CARBONATE PLATFORM (ACP)
- BRADANSKA DEPRESIJA – BRADANO DEPRESSION
- MOLIŠKA DEPRESIJA – MOLISE DEPRESSION
- MEZOZOJSKA KARBONATNA PLOČA (IZLOŽENI DIJELOVI) – MESOZOIC CARBONATE PLATFORM (UNCOVERED PARTS)
- DEPRESIJE KOJE SU SE POČELE FORMIRATI U MIOCENU – MIOCENE DEPRESSIONS
- DEPRESIJE KOJE SU SE POČELE FORMIRATI U PLIOCENU I KVARTARU – PLIOCENE – QUATERNARY DEPRESSIONS
- VRLO TANKI PLIOCENSKO-KVARTARNI TALOZI – VERY THIN PLIOCENE – QUARTERNARY SEDIMENTS
- ISTRAŽENI TALOZI RIJEKE NERETVE – EXPLORED SEDIMENTS OF THE NERETVA RIVER

On the other hand in 1960 in Italy the first, very good findings were obtained in the subsoil. From 1960 to 1967 there were about 10 fields discovered in wider Ravenna subsoil. The first valuable reservoirs were found at the depths of about 1000 m, and others a bit deeper, at as many as 4000 m. Until 1970 two more fields were identified southernmore, along the coast of Marche and Abruzzi. In fact, the above-mentioned was preceded by the explorations and findings in the terrestrial part of the Po Depression (Figure 1.15), where until 1965 60 gas and petroleum fields were discovered, but the first large gas field was discovered as early as in 1944 nearby Caviaga in Lombardy. The foregoing fields were most indicative of the subsoil prospect since the above-mentioned Po Depression stretches further to the Po River Delta with the North and Central Adriatic (Kranjec, 1981; Vaniček, 2013). The decision to initiate the exploration of the Croatian part of the Adriatic subsoil was *inter alia* based on the above-mentioned circumstances.

In subsequent years the Croatian Platform "Panon" reached a record depth of above 6000 m, but it should be highlighted that its Mediterranean and European subsea drilling record was established in the Italian maritime zone. There is a deep well Amanda-1 situated in the Venetto Depression close to the demarcation line. It was used to drill through the Quarternary and Late Palaeozoic rocks, whereby the previously defined objective was accomplished in full.

The recovery of petroleum in Albania from largely Neogene rocks received a lot of attention. The first fields were already discovered before the Second World War, and very soon after that a couple of other fields were detected. Although they were terrestrial (from the Port of Vlorë, Qyteti Stalin to Elbasan and south of Tirana), they triggered other associations, in other words the assumptions about the likely geological circumstances for the discovery of commercial hydrocarbon reserves further on into the area of the Adriatic Basin (Kranjec, 1981).

There are various geophysical methods used to explore the geological composition and structure in the subsoil and the subsea. Such methods were used to discover the sites of many petroleum and gas reservoirs verified in the subsequent step – exploration wells. The basic settings and the execution of geophysical surveys are described below.

The types of geophysical surveys undertaken on land and offshore with the aim of exploration of hydrocarbon reservoirs are in principle identical or very similar. In the foregoing context, it is possible to single out the surveys regional in character with less detail, such as gravimetry and those with high resolution subsoil data such as seismic reflection surveys, that is, imaging or profiling.

1.5.3.1.1 Gravimetric Surveys

The gravimetric surveys are based on the observations of the Earth's gravitational field. Such surveys are used to measure relative gravity variations which affect the actions of rocks different in density (Šumanovac, 2012). The measurement results in a gravity anomaly map (Bouger anomaly map) in which it is possible to separate positive from negative anomaly areas. The positive anomaly areas correspond to high density shallow rocks, which may be associated with the presence of anticline traps at some depth. On the other hand, negative anomalies are associated with lower areas, synclines or the presence of low density rocks in the subsoil (salt, plaster).

The gravimetric surveys constitute a method used primarily for regional exploration of the entire basins to single out the structures adequate for hydrocarbon accumulation (Figure 1.16). As an example of effectiveness of this type of surveying it is important to indicate that the first gravimetric measurement in the Croatian part of the Pannonian Basin resulted in the discovery of the first fields without any hydrocarbon occurrences or outcrops situated above them. The application of this type of surveying in the Adriatic region might result in separation of potential hydrocarbon traps as positive anomalies.

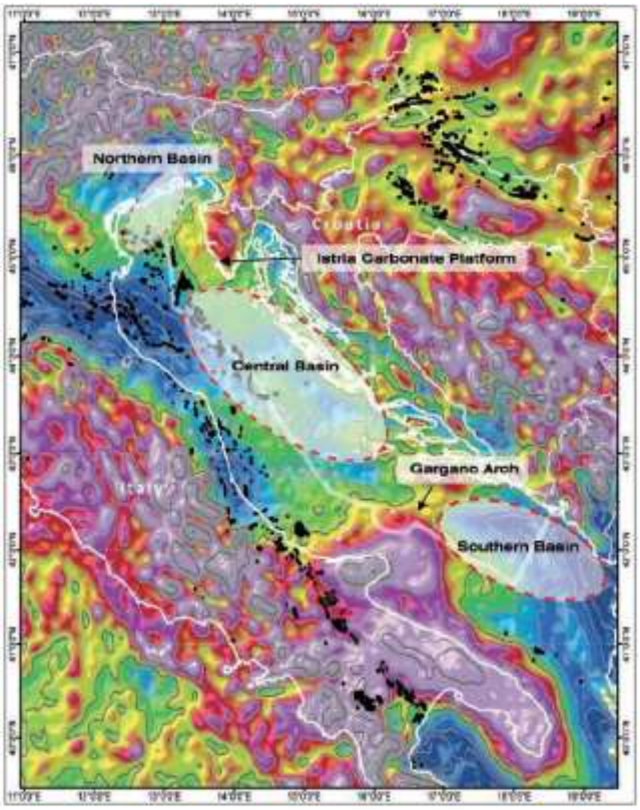


Figure 1.16 Bouger anomaly map of the Adriatic subsoil and its surrounding area (Source: Wrigley et al., 2014)

The offshore gravimetric surveys may include aerial imaging (from the aircraft or helicopter) or sea surface imaging (from the vessel). The application of the gravimetric data recorded in this way is by far less frequent when compared to the accuracy and resolution of the terrestrial imaging. For instance, terrestrial gravimetric imaging may achieve the accuracy of 0.3 μms^2 (1μms^2 = 0.1 mgal) whereas the sea surface imaging amounts to 1 – 5 μms^2, and the aerial from 10 to 50 μms^2 (Segawa et al., 2003, Murray & Tracey).

The collection of the data for gravimetric surveys does not have any special impact on the subsoil life as the method used is passive.

1.5.3.1.2 Magnetometric surveys

The magnetometric survey is a non-invasive method used to measure variation in the Earth's magnetic field. The measuring device is called magnetometer and it is dropped into the sea and boat towed. It contains solvents with electrons which move when stimulated by the magnetic field and provide the data required. It resembles a small torpedo and is towed behind the boat.

1.5.3.1.3 Seismic surveys

Any seismic survey is based on observation of movements of the seismic wave through the subsoil. Depending on the travel path of the seismic wave being observed, such surveys may be reflection or refraction surveys. For hydrocarbon reservoir exploration only reflection surveys are used (Šumanovac, 2012).

The imaging records travelling of the seismic wave from its surface source to the geological elements in the subsoil from which the wave reflects and its return to the receivers – geophones and/or hydrophones. The subsoil elements from which the waves may reflect as a rule are concordant borders between the rocks of different lithological composition, faults, discordances, caverns or borders between subsoil fluids, e.g. between gas and water. In case of marine exploration, the seismic wave source is the airgun (Suarez, 2000; Šumanovac, 2012). The collected seismic data may be illustrated as individual profiles (2D seismology), seismic volume in which case the survey covers the entire subsurface volume (3D) and the volume as a function of time (4D seismology). The latter imaging is only carried out on production fields, where for instance the movement of the water – petroleum contact, petroleum – gas or similar contact can be tracked after a specific time lapse in hydrocarbon recovery.

Imaging methods

For subsoil imaging most commonly a cable (streamer) towing vessel is used with an array of seismic wave sources and hydrophone receivers. The length of the streamer may reach 12 km, depending on the circumstances in which imaging is taking place. The problems occurring with this type of imaging are obstacles (petroleum platforms, fishing boats, islands) and sea currents which may affect the streamer motion vector. Where only a single array of this sort is used, the imaging results in a 2D seismic profile (Suarez, 2000). Where there is a number of such line arrays used, they may result in a seismic volume or 3D seismology (Figure 1.17). The submersible hydrophones, that is hydrophones towed close to the seabed, may also be used for imaging (Zachariadis et al., 1983), as well as the combination of a horizontal behind a boat or a vertical in the water column (Barr & Sanders, 1989) or only the vertical in the water column (Krail, 1994). For instance 3D seismic imaging of an area of approximately 360 km^2 would take three to four months (Miller & Crips, 2013).

Figure 1.17 3D seismic imaging with 4 streamer lines and a number of airguns (Source: Dragoset, 2005)

Seismic survey coverage of the Adriatic subsoil

The seismic surveying of the Adriatic subsoil region and the “Dinaric Alps” region belonging to the Adriatic islands is relatively densely covered by 2D seismic profiles. The total length of 2D profile available in the Data Room of the Croatian Hydrocarbons Agency amounts to 26 000 km (www.azu.hr). The positions of profiles recorded and available at the Croatian Hydrocarbons Agency are illustrated in Figure 1.18. In 2013 the Spectrum Company carried out detailed 2D seismic imaging and recorded 14 700 km of seismic profiles in total which on average constitute the network density of 5 x 5 km (http://www.spectrumasa.com) shown in Figure 1.19.

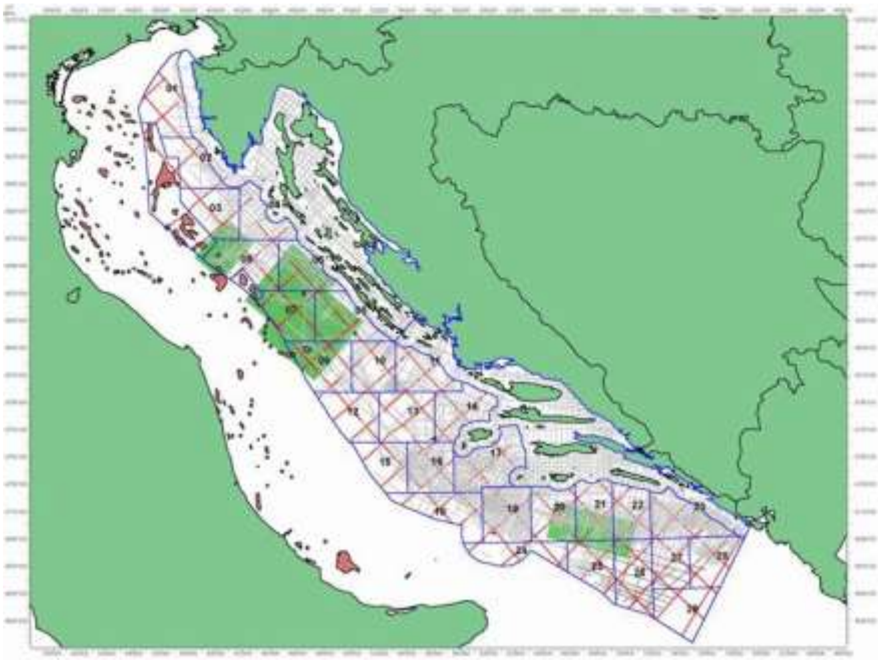


Figure 1.18 The position of recorded geophysical data in the Croatian part of the Adriatic subsoil – 2D seismic profiles are coloured grey, and 3D seismic volumes are coloured green (Source: www.azu.hr)

Figure 1.19 The map of geophysical profiles recorded in 2013 by the Spectrum Company (Source: http://www.spectrumasa.com)

In addition to 2D surveys, there are also a number of seismic volumes (3D) available the area of which amounts to 3300 km^2 (recorded in 1997/1998) and 1300 km^2 (recorded in 2012). The position of seismic volumes is visible in Figure 1.18.

In case of favourable prospects and based on the synthesis of all preliminarily conducted exploration works described above, **the first exploration well** should be located. Any subsequent well is spudded based on the data (leads) collected on the first well, and which data indicate specific prospects for reservoir discovery. There are 51 such wells spudded in the Adriatic. Their position is indicated in Figure 1.20. The well sites were primarily conditioned by the water depths. The respective depths are below 200 m. When this fact is taken into account, it is possible to make a conclusion that the sites are relatively proportionally distributed and that the well data (leads) may be used to make a good petroleum geological forecast and prospects for reservoir discovery.

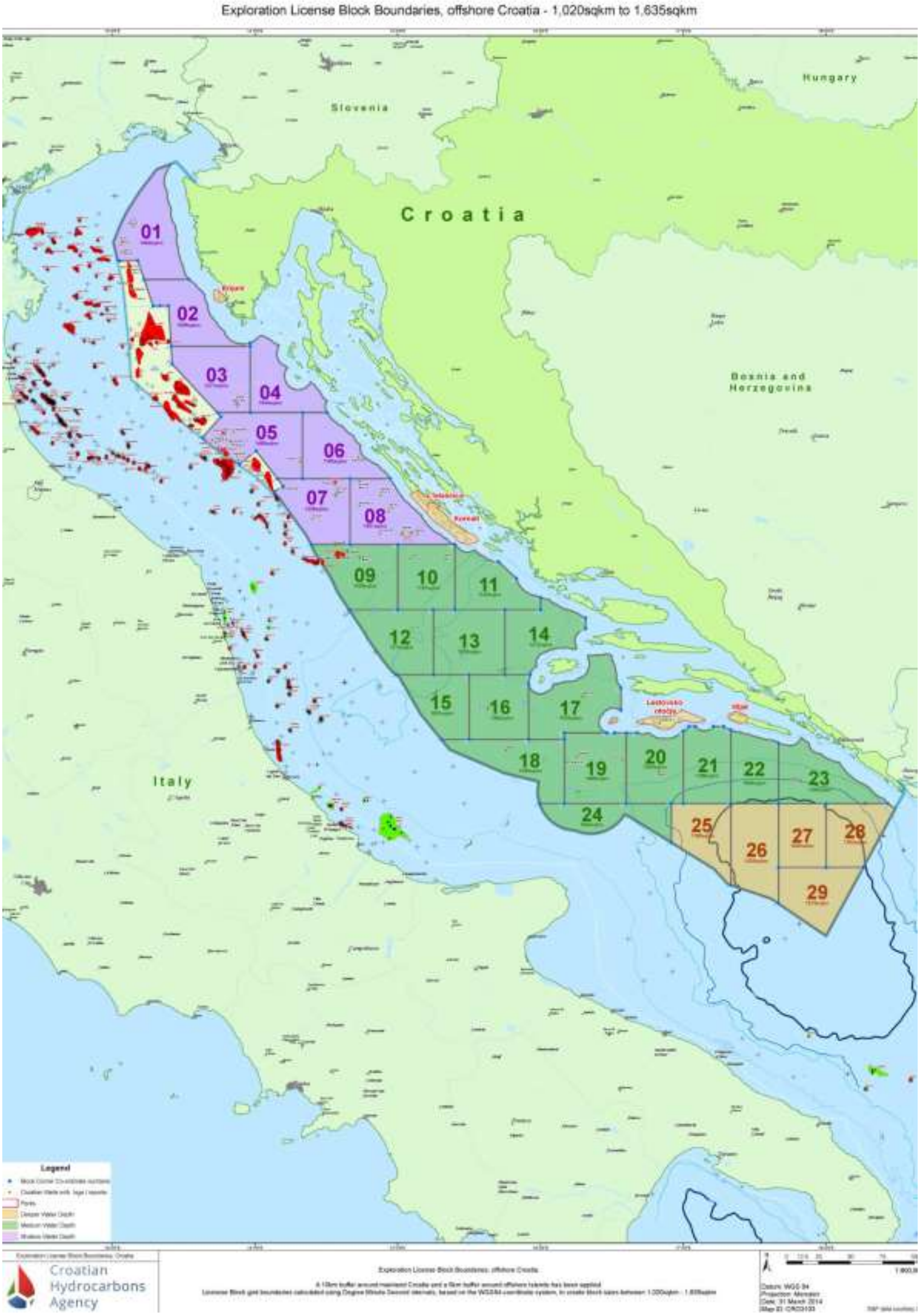


Figure 1.20 The map of production and concession blocks and well sites in the Croatian part of the Adriatic (Source: AZU (Croatian Hydrocarbons Agency)

In the Croatian part of the Adriatic subsoil 133 wells have been spudded to date, and 1358 in the Italian part. In accordance with the foregoing data on the scope of seismic imaging and drilling, the conclusion is that the Croatian part of the Adriatic subsoil is relatively moderately explored, especially in terms of the well fund.

In 1968 seismic imaging began, but there were also some geophysical and other tests carried out earlier. They included gravimagnetometric and aeromagnetic imaging in the southern part of the Adriatic. Some favourable circumstances in the structural and geomorphic and geological respect were also discernible before, especially in terms of Neogene and Quartary rocks on the islands. In 1968 the equipment for marine seismic imaging was purchased and placed in operation, and the electronic centre for digital processing was founded. The processing resulted in graphical maps of the geological subsoil structure which in principle corresponded to earlier maps. The conditions were made to detect the site of the first exploration well, which ensued in 1970. The first exploration wells were spudded in the subsoil west of Zadar, in front of Dugi Otok Island (Jadran-1). A French floating platform "Neptune Gascogne", towed on 31st August 1970, was leased to carry out drilling, and its operation finished on 13th October 1970, including the final tests and measurements. A depth of 2439 m was reached. The same platform was used to spud another three wells, including the record-breaking well Jadran-2 at a depth of 4639 m. Some wells are situated in Dugi Otok Depression (Figure 1.15) that is in the "extension" of Istria, where Mesozoic rocks are covered with the Neogene and Quartary "blanket" (Veseli, 1999). That was the beginning of the ensuing successful exploration in the North Adriatic subsoil with discoveries of many gas fields (Figure 1.21) within the production fields (Figure 1.20). Spudding of the deepest well in the world on the Kola Peninsula in Russia began the very same year, reaching 12 262 m in 1989.

Figure 1.21 The sites of gas fields in the North Adriatic subsoil

1.5.3.2 Geological Works during Exploration Drilling

From the geological perspective, the objective of spudding exploration wells is to collect as many data on the types of rocks as possible, primarily on the composition of source/reservoir rocks, their thickness and depth, as well as the hydrocarbon occurrences. In the process of drilling, a geologist continuously monitors the operation and makes observations. The geologist *inter alia* determines the depth at which the core should be drilled, monitors and records any potential petroleum and/or gas occurrences.

A significant portion of the geologist's activities are carried out by the so-called geological well monitoring in the total drill control (TDC) laboratory fitted with many instruments classified according to their purpose into:

- Instruments used to record gas occurrences,
- Instruments used to measure drilling parameters,
- Instruments used to measure drilling mud parameters, and
- A computer with auxiliary units.

The hydrocarbon stratum is very seldom manifested unambiguously on the surface. Most often hydrocarbons are extracted profitably from the stratum drilled without the slightest indications in cuttings from the shakers that would discover their presence. As needed, the cores are also extracted and treated with special care. In addition to their type identification, the rocks are also observed under the UV system to test the presence of hydrocarbons, even in traces. Small samples of the core are taken for a great variety of laboratory analyses. Meticulous observation of the well cuttings and the features of the drilling mud such as colour and density are an important source of data. The drilling mud is enriched with hydrocarbons in two ways: from the crumbled rock mass and by gas diffusion through the mud cake. The mud may contain three forms of hydrocarbons: free or separate (in bubbles and droplets), dissolved hydrocarbons (aqueous) in the water phase or adsorbed in solid particles.

There are a number of factors affecting the hydrocarbon content in the drilling mud, such as drilling mud flow, drilling velocity, rock permeability, differential pressure and fluid nature.

Although it is theoretically believed that coring of the first exploration well should be carried out in total, it is mostly not done. There are also other ways of obtaining data of very good and useful quality, such as by using geophysical well logging.

Geophysical **logging** is carried out in boreholes to obtain a record of physical properties depending on the lithological composition and types of fluids contained in the rocks. The logging is based on theoretical foundations identical to surface geophysics. The related geophysical methods have developed to such an extent that they provide much more data than otherwise obtained by core sample measurements.

Logging is performed by lowering a “logging tool” into a well where adequate transmitters and receivers are located, depending on the purpose of the “logging tool”. The data are transmitted over the cable to the instruments situated on the surface, where they are received, processed and stored. In a majority of methods the “logging tool” is lowered to the bottom of the well, and the measurement is carried out during the process of pulling “the logging tool” out onto the surface. Some logs are only carried out in open holes (resistivity logging, SP) and some may also be conducted in cased holes (Šumanovac, 2012). They are commonly classified as specified below (Velić et al., 2014).

I. OPEN HOLE LOGS

a) Direct natural phenomena
  - Spontaneous potential SP
  - Natural radioactivity: total (GR), ψ radioactivity, selective (NGT)
  - Temperature T

b) Provoked phenomena
  - Specific resistivity, that is conductivity of the virgin zone “Rt” using devices
  - EL (conventional electrical logging)
  - LL (laterolog)
  - IEL (induction electrical logging)
  - Specific resistivity of the invaded zone “Rxo” using devices
  - ML (microlog)
  - PL (proximity log)
  - MSFL (micro-spherically focused log – derived microlog)
  - HRDT (claw metre – specific logging of four resistivity curves to determine strata inclination)

According to their structure, the resistivity logging methods may be classified into non-contact and contact methods (Table 1.5).

Table 1.5 The outline of non-contact and contact resistivity logging methods in the subsoil

NON-CONTACT METHODS	CONTACT METHODS
EL conventional electrical logging	ML microlog (minilog)
IEL induction electrical logging	MLL microlaterolog
LL laterolog	PL proximity log
DLL dual laterolog	
DIFL dual induction focused log	

- Hydrogen presence (hydrogen index Hn) using devices
- GNT gamma-ray absorption
- GRN gamma-ray neutron logs
- SNP sidewall neutron porosity
- CNL compensated neutron log
- Strata density ρb using devices:
- CD compensated density log
- FDC Formation density
- LDt Lithodensity
- Velocity of sound propagation V, that is sonic interval transit time Δt using BHC devices

II. CASED HOLE LOGS

a) Direct natural phenomena

- Natural gamma-radioactivity GR using GRN device
- Temperature T

b) Provoked phenomena

- Neutron lifetime profile (Σ) using devices
  - NLL Neutron Lifetime Log
  - TDL
  - C/O, carbon/oxygen ratio
  - GST
- Velocity and amplitude of sound propagation (Δt and A) with CBL device
- Hydrogen presence with devices:
  - GNT gamma-ray absorption
  - N neutron log

III. LOGGING WHILE HYDROCARBON PRODUCTION (RECOVERY) (deposit production properties)

It is used to determine the type and the quantity of fluids obtained during production according to the depth.

PL - Production Log includes 6 different logging tools:

1. Fluid mass density
2. water content
3. Flow
4. Temperature
5. Borehole noise
6. Flow using nuclear method

The electronic data processing software EPILOG (continuous quantitative analysis of log diagrams) is used to draft a synthetic diagram indicating the following according to the depth:

- Lithological composition, porosity,
- Fluid content (water, petroleum, gas),
- Mass analysis of porosity and fluids,
- Formation mass analysis (% marl, % quartz, porosity, limestone/dolomite ratio),
- Calliper (well diameter).

1.5.3.3 Geological Works during Recovery, Monitoring of Development Well Spudding, Collection of Data while Drilling and after Drilling Completion

Any work conducted while drilling with the aim of conditioninig for recovery and during actual recovery is called **reservoir development**. It implies any activities from the moment of hydrocarbon discovery to the production termination. They are used in order to achieve homogenous depletion of heterogenous reservoirs, that is all reservoirs within a single block, irrespective of the efficiency of the natural recovery regime, and an increase in the petroleum and gas recovery efficiency in reservoirs with inefficient natural regime in the secondary and tertiary production phase, by oil recovery using water or gas injection in the secondary phase, that is, thermally and chemically induced petroleum separation in the tertiary phase. Due to complex geological reservoir composition and structure, the "by-passed" petroleum and gas reservoirs may be recovered by greater network density, fracturing, execution of horizontal holes and lateral holes out of the existing vertical wells (Belošić, 2001).

1.5.3.4 In general about potential hydrocarbon reservoirs

The presence of **gas** has been confirmed in the first 14 wells within clastite of Pliocene and Pleistocene age (**Pre-Cenozoic Oil Plays – Mali Alan formation**) and in **Cretaceous** limestone (**Pre-Cenozoic Oil Plays – Mali Alan formation**) in the area south and southwest of Pula. The carriers of gas accumulations are sand, sandstone and silts of Pliocene and Pleistocene age. The mean porosity of sand is 29 %. The presence of gas, even in carbonate sediments of Cretaceous age, has been proven in the wells Jadran -18/2, -18/4, -18/6, -18/7 i 18/8β, as has already been mentioned. They have been drilled under the Quaternary – Neogene deposits at depth intervals of 1225 to 1531 m. **Cretaceous collectors** are represented through perforated and cracked limestone and biomicrite type limestone, and dolomites and intramicrite. Bioclastic Cretaceous limestone with secondary porosity has only been defined in certain places. Collector properties of reference rocks are very good given that they have a porosity of 14 to 40 %, while the maximum permeability is up to 170 x 10^{-3}μm^2 . The composition of the discovered gas is as follows: CH_4 96.23 do 99.76 vol. %, CO_2 0.20 to 0.26 vol. % and N_2 0.20 to 0.79 vol. %. The gas reservoir in the bottom rocks of the Cenozoic are somewhat deeper, however they are still considered relatively shallow and in spatially smaller reservoirs. Such reservoirs discovered in 1980 are primarily located in structural – stratigraphic traps. Namely, the reservoirs are karst limestone filled with gas in a raised side-block of opposite facing faults, closed with Pliocene and Quaternary clay marls as barriers for fluid movement (Đurasek and others,1981; Milić and others, 1981).

Furthermore there are also indications for discovery of gas reservoirs in deposits of the Lower **Pliocene, Miocene, Oligocene** and **Eocene** – **Raša formation**.

The presence of gas has been proven in the Dugi otok depression well Jadran-11. There is also a possibility of petroleum accumulations in deeper Mesozoic and Paleogenic layers under favourable layer conditions and with the assumption of lateral migration of petroleum from the Ravni Kotari evaporite complex. Namely, in the wells Dugi otok-1 and Ravni Kotari-3 there was significant presence of petroleum and traces of petroleum in deep offshore exploration wells Jadran-9 inside rock of the **Early Mesozoic** (**Pre-Cenozoic Oil Plays –Baške Oštarije formation**).

On the basis of present day assessment of the geological composition and structure, based on geological interpretations of seismic profiles, and the results of deep exploration drilling in the Italian part of the Adriatic underground, it is assumed that the rocks of the Later Mesozoic are also prospective regarding hydrocarbon findings (**Pre-Cenozoic Oil Plays – Mali Alan formation**). However, there have also been opinions expressed that petroleum may not be expected in Mesozoic sequences except where there are evaporites present as isolators (wider areas of Ravni Kotari).

There are less widespread underground zones with smaller sea floor depths where even **Palaeozoic rocks** may be reached through drilling. In such places there may be accumulations of petroleum and gas, mostly due to temperatures which lead to the conclusions about the maturity of potential source rocks (**Pre-Cenozoic Oil Plays – Brušane formation and Baške Oštarije formation**) (Frank and others 1983).

All the facts put forward justify predictions that the Croatian part of the Adriatic underground also has reliable prospects for finding gas, and also good prospects for petroleum in economically significant quantities.

In light of positive/good perspectives for discovering hydrocarbon reservoirs, we highlight that after processing of data from wells and the results of additional seismic recordings, there were changes in compositions and thickness of the deposits (KRANJEC, 1981). Thus in the northern underground it is shown that with the depth of attitude there is an increase in the depth and heterogeneity of the composition of Quaternary and Neogenic deposits. The sequence of their members is also more complete which is reflected in a more indented and deeper periphery of the Istrian platform and moving from shallower curved areas in the deeper sector of the Dugi otok and Pad depression, and this trend is also observed further towards the southeast. This indicates the possibility of further finds of economic quantities of hydrocarbons, both in the youngest and in Paleogenic and Mesozoic rocks which in the **central** and particularly in our **southern underground** have a covering of a few thousand metres thick Neogenic-Quaternary sediment (maximum thickness amounts to more than 6000 m in the southern underground) (Vaniček, 2013). There are probably colourful deposits present here revealed with well JJ-1 and other sediments typical for molasses: multiple horizontal source and insulation rock, followed by tuffs and other pyroclastites. Their presence would indicate to greater thermal and diagenetic evolution, and this would also mean a higher assessment of the odds of petroleum finds. However, here there are deeper depths to the bottom of the sea and there is still no clearer idea about the existence of potential deposits with favourable physical values – porosity and impermeability.

Furthermore, early evaporites, tectonic erosion discordances, productive horizons and other reservoir conditions on the Italian and Croatian side have been confirmed; locally in our part of the underground, very young intrusions have been observed which may cause genesis of convex structures regardless of whether it is a case of volcanic masses or maybe salt, gypsum or anhydrite (Kranjec i dr. 1987).

Certain prospects are assigned to peri-platform deposits that extend over a length of 500 to 600 km along the entire edge of the Adriatic carbonate platform, from the coast of Istria to the coast of Dubrovnik (Grandić and others 2010). These sediments represent a possible regional widespread reservoir rock comprised of stratigraphic traps. Firstly, 12 seismic profiles that cut through transition zone between the Adriatic carbonate platform and Adriatic pool have been defined by petroleum geological interpretation. According to all the data good insulation rocks here are comprised of deposits of Cenozoic clay-marl composition. This was followed by some confirmation based on drilling, through the discovery of commercial reserves of petroleum in 2007, in the structure of Rovesti in the base of the Apulia carbonate platform. The covering rock of the Rovesti structure is located at a depth of 970 m, and according to interpretations of seismic profiles on the Croatian side could be somewhat shallower. The presence of source rocks is based on data from well Vlasta-1. With this, an integral petroleum geological scheme has been created which should certainly be taken into account when planning the following phase of exploration, primarily drilling.

1.5.3.5 Drilling wells

Based on the depth of the sea in the area under consideration (less than 50 m to over 1000 m), a jack-up drilling rigs (northern Adriatic), semisubmersible drilling rigs or drillships may be used.

To date, in the exploration area under consideration, from 1961 to 2004, 51 exploration wells have been drilled. In the exploration phase that may last five years, with a possibility of a one year extension, at least one exploratory well will be drilled for the purpose of confirming the presence of commercially attainable quantities of hydrocarbon in exploration areas for which a contract shall be concluded with a concessionaire. The drilling of one well, depending on the final depth of the well and possible problems during drilling (loss of drilling mud, jamming of tools, inflow of kick fluids, etc.), may last from 40 to 120 days (Regg and others, 2000). Each of these exploratory wells will be drilled to a predetermined depth or will be permanently abandoned in accordance with standards applied in the petroleum industry. During drilling, drilling mud composed of water and fragments of drilled rock and other waste waters will be released from the drilling rig into the sea in accordance with existing restrictions for release of waste waters.

To drill an exploratory well it is necessary to bring the drilling rig to the area of the location of the exploratory well. For the purpose of carrying out mining work, the drilling rig is equipped with mining machinery, equipment, tools, devices and installations.

For the needs of drilling a well there is a drilling rig on the drilling platform. The typical drilling rig is comprised of a bearing structure – a drilling derrick (derrick), crown block system, air-hoist, engine, gear-box, rotary table, drilling mud pumps, travelling blocks, system for preparation and filtering drilling mud, system for protection against blowouts – blowout preventer (BOP), drill tools (kelly, rigs and drill collar), drill bits, etc. After positioning the drilling platform and preparatory work, begins the work of constructing a specific part of the wellbore, into which a series of casings are installed which are cemented in accordance with the design project, by extruding cement slurry into the area outside the pipes of the annular space. A series (casing) of protective pipes, depending on their purpose, are called: drive pipe, surface casing, intermediate casing (one or more), production casing.

Extruding cement slurry is carried out with a cementing aggregate which is equipped with a device showing the value of pressure and its recording on a diagram. After the hardening of the cement slurry into cement stone, the impermeability (hermeticity) of the series of casings is testes at the pressure value stipulated in the verified mining project. The testing period for impermeability should be 15 (fifteen) minutes, and the results of impermeability testing are satisfactory if the drop in pressure does not deviate more than 10 % from the stipulated value. The results of testing are entered in the transcript (journal) that has as attachment an accompanying testing diagram. With an increase in depth, the diameter of the drill bits decreases or the well bore and casing diameter.

The construction of the wellbore usually begins with a drill bit with diameter 914.40 mm (36 inches) to a depth of 30 to 60 m. The wellbore must first be drilled with a drill bit with diameter 469.90 mm (18 ½ inches), and then widened to a diameter of 914.40 mm (36 inches). During the drilling of this interval, the wellbore, sea water is used which together with fragments of broken rocks move to the sea floor because in this phase the blowout preventer and marine riser have not been setup yet. After constructing the described part of the wellbore, a series of casings is installed into it – **drive pipe** with diameter 762.00 mm (30 inches) and it is cemented. The cement slurry is extruded through the drilling pipes into the outside pipe annular space until it appears on the sea floor. After cementing this series of casings, a diverter and marine riser are setup that ensure connection of the underwater well with the surface equipment on the platform or drillship and enables the return flow of drilling mud. After this, the construction of the following interval continues – the wellbore 660.40 mm (26 inches) to a depth of 300 to 600 m. The wellbore may first be constructed with a drill bit of diameter 311.15 (12 ¼ inches) and then expand to a diameter of 660.40 mm (26 inches). The **surface casing** with diameter of 466.73 mm (18 5/8 inches) is then installed in the wellbore which is then cemented. The cement slurry is extruded through the drill collars into the area outside the pipe in the annular space from the bottom to the wellhead.

After cementing, and before continuing drilling, a blowout preventer – BOP is installed on the surface pipe. After this, the construction of the wellbore continues of diameter 444.50 mm (17 ½ inches) into which the **intermediate casing** with diameter 339.73 mm (13 3/8 inches) is installed and cemented. For further construction of the wellbore, a drill bit of a smaller diameter is used and this a drill bit with a diameter of 311.15 mm (12 ¼ inches) for construction of the wellbore into which is installed casing with diameter of 244.48 mm (9 5/8 inches), while a drill bit of diameter 215.90 mm (8 ½ inches) is used for construction of the wellbore into which is installed casing of

177.80 mm (7 inches). Each casing, as a rule, is cemented from the bottom to the wellhead. The number, diameter and depth of installation of the casing depends on the final depth of the well. The final casing (production casing) is installed only in the event of discovery of a hydrocarbon reservoir (Image 1.22).

During drilling or destruction of the rock, the drill bit is continually in contact with the bottom of the well. For the drill bit to progress and deepened the wellbore, it is necessary to simultaneously create rotation of the drill bit, specific burdening of the drill (partially from the weight of drill collars) and continued elimination of fragments of broken rocks from the bottom of the well. The rotation of the drill bit may be achieved with the rotary table, with the top drive and bottom-hole motor. Continual of the rinsing of the wellbore during drilling is achieved by driving the drilling mud from the tank (suction drilling mud pool), using a mud pump, through discharge lines, riser pipe, flexible hose, travelling block, kelly, rigs and drill collars, drill bits, annular space between the rig tools and walls of the wellbore, exit pipe at the wellhead, to the system for filtering drilling mud.

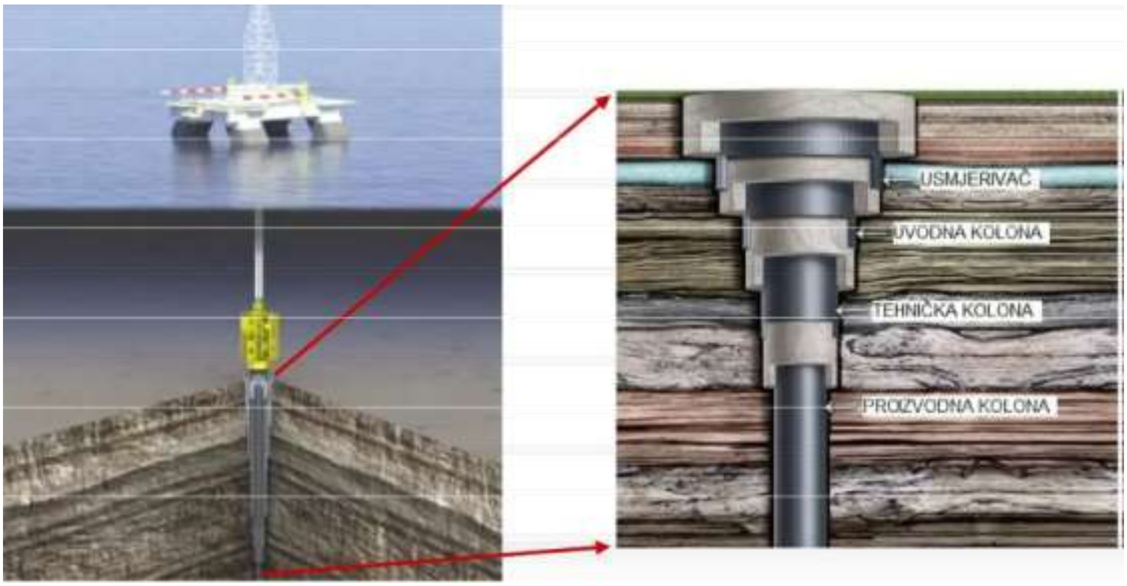


Image 1.22 Schematic overview of well construction

Drilling mud returning from the well contains fragments of broken rocks from which they must be removed before returning to the well. This is achieved by using the surface system for filtering drilling mud which encompasses a vibrator with vibrational sieves, desander and desilter, drilling mud pig, centrifuge, and gas separator (primary and vacuum). Gas is separated from drilling mud through primary separators is flared. At the part of the working floor of the drilling derrick there is a location for the work of the shift supervisor equipped with a system and devices for managing the drilling rig, devices and equipment controlling the work of the drilling rig, devices and equipment for monitoring drill parameters (with mandatory records of drilling parameters on the accompanying diagram) and connection devices.

The drilling rig is equipped with an appropriate blowout preventer (Image 1.23) with pertaining equipment and devices for checking pressure controls in the well **(secondary control of pressure)**. A constituent part of the blowout preventer and diverter, with pertaining equipment.

All pertaining equipment (kill and choke line with mechanical and hydraulic valves, adjustable and/or mechanical choke, distributor, etc.) has the same working pressures as the preventers. Work begins are carried out and/or are continued only after the blowout preventer with pertaining equipment has been functionally and pressure tested. Functional testing is carried out after every assembly of the blowout preventer. Pressure testing of the blowout preventer lasts about 15 (fifteen) minutes and is carried out: (a) after installation and cementing the services of casings, (b) after any kind of repair or servicing of any blowout device, (c) at least once every 15 (fifteen) days, (d) before drilling layers with increased pressures, (e) each time when there is a request by an authorised official person. In the period of testing, pressure drops are not permitted.

Image 1.23 Blowout preventer – BOP (Source: http://www.drilltech.cn/ufile/201465103760572.jpg)

A control system (remote panel/plate) is used for activation (functioning) of selected components of the blowout preventer which must be secured by closing the annular blowout preventer for a maximum of up to 30 seconds (for diameter to 508 mm (20 inches) or for a maximum for 45 seconds (for diameter 508 mm (20 inches) and more), and closing of ram blowout preventer, regardless of diameter and type of installed ram, for a maximum to 30 seconds. For management of the blowout preventer, an accumulator unit with a working pressure of at least 206.84 bar (3000 psi) is used. The control panel is located in at least two places: on the working floor of the drilling derrick or in the work station of the shift supervisor and in a safe location, sufficiently far away from the wellbore (usually in the drilling office). For preventing uncontrolled eruption of kick fluid (petroleum and/or gas and/or water) through a series of drilling tools, an internal preventer is used, as required in all phases of wellbore construction (drilling). During any manoeuvring of the drilling tools (extraction and/or lowering and/or addition), selected internal preventers must always be available (in working order serviced and pressure tested) on the working floor of the drilling derrick, with corresponding threaded connections (or additional equipment – crossings), so they may be used at all times and put into function. Chokes and distributors enable controlled flow of drilling mud and/or working fluid and/or kick fluid from the wellbore (in the event of inflow). Capping and killing of the well (after inflow of kick fluid) is done according to stipulated procedures and instructions of the approval holder for exploration of mineral raw materials and/or concessionaire, and contractor. The driller part of the crew are trained for fast capping of wells through well capping exercises which are conducted in stipulated time intervals are carried out on the platforms and courses for capping and killing wells (control of well pressures) held in authorised training centres, according to internationally recognised programmes.

During well construction, other than drilling, installation and cementing of casings, work enabling the receipt of information about the drilled rocks in the wellbore such as electrocarotage (EC) measurements and coring (taking rock sample – core) and work on repair of damage (e.g. breakage or jamming of tools) in the well are carried out. Insofar as during exploratory drilling a hydrocarbon reservoir is discovered, testing of the rock must be carried out (Drill Stem Test – DST). The DST is a procedure carried out during construction of the well, and includes lowering of a tester tool into the wellbore, isolating of the selected interval (potential reservoir) by activating a packer, creating negative pressure and causing the inflow of kick fluid into the wellbore. The purpose of this testing is establishing the presence of hydrocarbons and the economic feasibility of its exploitation. During testing data about flow, pressures (statics and dynamics) and temperature are measured, and a sample of the reservoir fluid is obtained for which the properties and composition are determined in a laboratory. The collected data is used to determined the reservoir possibilities and on the basis of these, a decision about the selected method of recovery, selection of well production equipment and about construction of a recovery well. During testing that lasting as long as necessary for obtaining required data (1 and 2 days), the recovered hydrocarbons are flared. These are small quantities of petroleum and gases.

Insofar as the results of the DST testing are negative, which means that the exploratory well did not detect a reservoir with commercially recovered quantities of hydrocarbon, a decision on the permanent abandonment of the exploratory well is rendered, and a dry well is declared. Before final abandonment of the well there must not be any pressure in the wellbore, and laying cement plugs prevents possible communication between layers in the open wellbore. A few cement plugs are placed in the wellbore (from the bottom of the well), and the last one must be at least 150 metres long. The casings are mandatorily cut under or at the level of the sea floor, and an iron plate is welded to them and the well is permanently abandoned. The competent body conducts supervision of clearing of the location to ensure that all waste ensuing from drilling has been removed from the sea floor (around each well).

However, insofar as the results of the DST testing is positive, exploitation (production) casing is installed and cemented in the wellbore. The well construction phase ends with this, after which well completion ensues. The well must be secured by setting up cement or mechanical plugs that isolate hydrocarbon intervals and may be temporarily abandoned so that it is accessible for later production of equipment and recovery of hydrocarbon.

Temporary abandonment of the well in the underground includes use of the system for temporary abandonment of wells in the underground and template for construction, equipping and connection of the well on the sea floor. The well suspension cap enables sealing and isolating of all installed casings (endings of casing hangers) and annular space between them. They are lowered using running tools. There is always the possibility of tie-back of casings with the objective of further work or connection of well exploitation.

1.5.3.5.1 Drilling mud

Drilling mud is a special fluid that is pushed into the well through a series of drilling tools. It comes out from jets on the drill bits and is returned through the annular space to the surface. While flowing through the well, the drilling mud carries out numerous tasks important for the effective and safe process of well construction. The drilling mud is designed so that its composition and properties correspond to the conditions in the wellbore, the composition and properties of the rock being drilled, while at the same time that it is economically and ecologically acceptable. The tasks carried out by the drilling mud during construction of the wellbore are (Gaurina-Međimurec, 2009.): (1) carrying out the fragments of broken rocks from the wellbore, (2) creation of a corresponding back-pressure on the walls of the wellbore, (3) maintaining the stability of the wellbore, (4) lubricating and cooling of drilling tools in the well, (5) keeping the fragments afloat during interruptions in the flow of drilling mud, (6) enabling measurement and other work in the well, (7) reducing the weight of a series of drilling tools, (8) reduction of damage to the reservoir rock, (9) preventing corrosion of drilling tools and casings, (10) increasing the drilling speed and (11) reducing harmful impact on the environment and achieving greater safety while work is carried out.

The drilling mud consists of continuous liquid phase in which various additives are added for adjustment of its properties in accordance with the requirements of the drilling process. The composition of the drilling mud may be simple (e.g. drilling mud for initial drilling; betonite suspension), but also very complex depending on the well conditions, such as pressure, temperature, rock composition through which drilling is to be carried out and others.

According to the continuous phase, drilling mud may be divided into water based mud (WBM) and non-aqueous drilling muds (NADF). Non-aqueous drilling muds may also be divided according to the continuous phase (oil or synthetic compounds) and shares of poliaromatic hydrocarbons (PAH) as: (a) oil based muds (OBM) that contain 2 to 4 % - PAH, (b) low toxicity oil based muds – LTOBM) that contain < 0.35 % PAH and (c) synthetic based muds – SBM) that contain < 0.001 % PAH (Gaurina-Međimurec, 2005; Satterlee, 2011).

Water based mud consists of fresh or salt water (> 90 %), weighting agent (usually barite; $BaSO_4$), clay (betonite or atapulgite) or organic polymers, various inorganic salts, inert molecules and organic additives which adjust the properties of the drilling mud for the effective execution of the drilling process. Drilling mud additives, other than barite and clay, are used in small quantities and are not toxic so that it is considered that water based mud has a negligibly negative impact on the environment (Neff, 2005).

During drilling intervals when water based mud is used, fragments and drilling mud they are contained in are released into the sea, in quantities of 0.2 to 2.0 m^3/h (Neff, 2005). In practice, water based muds are used most of the time in drilling (> 80 % cases) due to its low price, simplicity of preparation and negligibly harmful impact on the environment. When drilling conditions become more demanding and when the characteristics of water based mud is not sufficiently good to carryout specific tasks, it is necessary to use drilling mud with better properties, and these are for the most part oil based muds. Even though significantly better results can be achieved with oil based drilling mud, they are not the first choice due to their high price, possible harmful impact on the environment and more demanding disposal of waste drilling mud and oiled fragments in the drilling mud.

Oil based muds are composed of refined oil (diesel oil, mineral oil or some other oil) (> 95 %) that comprises a continuous phase in which there is a dispersed aqueous solution of calcium chloride (Neff et al., 2000). The other components of oil drilling mud are barite, clay, emulators, lignite, lime and other additives. Oil based mud is more expensive the water based mud and are used only when the well conditions require this (e.g. inhibition of shale and/or lubricating of tools). In the past oil based muds contained diesel or conventional mineral oils as their main ingredient. However, the industry has moved to use oil based mud based on mineral oils of low toxicity, and in recent times, to the use of drilling muds based on improved mineral oils and synthetic compounds (synthetic drilling mud).

Oil based muds enable the stability of the wellbore during drilling through water sensitive shale, good lubricating of drilling tools, they provide temperature stability, they reduce the possibility of differential jamming of drilling tools and damage to the reservoir rock. They are particularly effective during drilling of angle directed and horizontal wells. Due to the mentioned advantages and rock properties, the use of oil based mud it was preferred in the North Sea until the release of fragments from oil based mud was not restricted and in the end banned at the beginning of the 1990's (Neff, 2005). Fragments from oil based mud are released into the sea in many parts of the world. Oil based mud due to its toxicity and price are not released into the sea/ocean rather thy are returned to land for recycling and are used again during drilling of new wells. Oil based mud is increasingly rarely used due to the additional costs of the transport of waste drilling mud to the land, legislative restrictions and the development of synthetic drilling muds.

Synthetic drilling muds are emulsions of synthetic compounds (e.g. linear α-olefins, poly-α-olefins, linear alkyl benzenes, ethers, esters or acetyls) that comprise a continuous phase and salt water (Gaurina-Međimurec, 2005). They were developed in the mid 1990's, and during drilling they behave like oil based mud, however in terms of environmental impact, they are closer to water based mud (Melton and others, 2004; Gaurina-Međimurec, 2005). Synthetic drilling mud is used where the use of water based mud is not suitable, and where injecting or disposal of oil based mud to land is too expensive. Ethers are primarily used in the Norwegian part of the North Sea, however they have been replaced by linear alpha olefins (Jones and others, 2000). According to OGP (2007))0 % of fragments from drilling mud that are not water based, and which were released into the sea/ocean in 2006 originated from synthetic drilling mud. In some parts of the world, such as the North Sea, even the release of synthetic drilling mud is prohibited. As far as the release of fragments of rock from synthetic drilling oil is concerned, the percentage of retaining synthetic drilling mud on fragments is usually limited to legislation (Neff and others, 2000). According to the protocol of the Barcelona convention, there may be a maximum of 10 % of synthetic drilling mud on fragments. Synthetic drilling muds, due to their price are not released into the sea/ocean, rather they are returned to land where they are recycled and used again during drilling of new wells.

To ensure that the drilling mud fulfils the task for which it is intended, it is necessary to prepare it appropriately and to achieve its circulation through the wellbore. Circulation of drilling mud begins on the surface, where the drilling mud is suctioned from the drilling mud tank and with the aid of drilling mud pumps, it is pumped into the well, it passes through a series of drilling tools, exits through jets on the drill bit and is raised along the annular space of the wellbore, returning to the surface. At the surface, the drilling mud containing the fragments of broken rock, passes through surface filtering surface to separate the fragments. The broken rock fragments are usually the size of sand or gravel, they result from the work of the drill bit drilling through various geological formations and their removal from the bottom of the well and from the wellbore, and are a condition for drilling progress. They are continually released during drilling (if permitted) into the sea through a shunt line which is usually located a few meters under sea level, and the filtered drilling mud is pumped back into the well.

In the initial drilling phase, when the wellbore has a large diameter to a depth of 30 to 60 m, fragments of broken rock and seawater used as drilling mud are released at the sea floor. After constructing the wellbore, casings are built into it – the drive pipe and it is cemented from the bottom to the wellhead. After cementing of these casings, the diverter is assembled and the marine riser that ensure connection of the underwater well with the surface equipment on the drilling platform or drillship, and enable a return flow of drilling mud during drilling of all following intervals of the wellbore. In time the properties of the drilling mud worsen, so the used drilling mud is occasionally released into the sea (water based mud) or returned to the supplier for recycling (oil and synthetic drilling mud).

Circulation of drilling mud (circular flow) is essential during the drilling process, and is interrupted by turning off the drilling mud pumps, only when necessary due to carrying out certain work in the well (e.g. adding new rods, extraction and lowering of drilling tools, EC measurements, installation of a series of casings, etc.).

Occasionally lubricators are added to water based mud (diesel oil and plant or mineral oil), in concentrations of 5 – 150 g/L for the purpose of reducing torsion and tension of drilling tools (Neff, 2005). While carrying out work on repair to damage in a well (fishing and jamming of a series of drilling tools and/or series of casing and/or probes and EC cables and/or DST equipment, etc.), particular attention is given to additional safety and protection measures. If pills (raw petroleum, gas oil, heavy pills, acids) are used for repairing jamming of a series of drilling tools, it is mandatory to undertake additional safety and protection measures. The pill, that represents a small volume of the total drilling mud, may contain over 600 g/L diesel or mineral oils (Neff, 2005). After release of the jammed tools, the pill is separated from the drilling mud and is disposed of on land.

In accordance with that previously stated, it is to be expected that mostly water based mud will be used during drilling in the area under consideration, and only exceptionally, when so required due to well conditions, will synthetic drilling mud be used. The use of oil based mud is not expected.

During construction of the wellbore, in all phases of work, on the platform there must be a sufficient quantity of reserve barite for weighing the drilling mud, betonite (for making drilling mud), as well as essential additives (supplements) that ensure the stability of the drilling mud at a high temperature, and in the presence of harmful and dangerous gases (H_2S, CO_2). There must also be sufficient amounts of service water on the platform to make new drilling mud, as well as reserve drilling mud for carrying out the considered work. **Primary control of pressure** in the well is ensured by maintaining and controlling the necessary thickness of drilling mud.

During construction of the wellbore, partial or total loss of drilling mud may occur. In the event of the occurrence of total los of drilling mud or an underground eruption, work must not be continued before the total loss of drilling mud is rectified. During the construction of the wellbore, there must always be sufficient quantities of cement and pertaining additives for setting up at least two cement bridges of a minimum length of 100 metres in the considered diameter of the wellbore, and with the objective of necessary remediation of total loss of circulation of drilling mud or capping the zone of increased layer pressures.

1.5.4 Exploitation of hydrocarbon

After the exploration period (up to 5 + 1 year) comes the exploitation period (up to 30 years) during which the following activities will be conducted: drafting of a reservoir development study, development drilling and well completion, construction of process machinery and in the finality exploitation of hydrocarbon.

According to the Act on exploration and exploitation of hydrocarbon, exploitation of hydrocarbon means recovery of hydrocarbon from reservoirs and processing of hydrocarbon, transport of hydrocarbon through pipelines, when it is in technological connection with approved exploitation areas, storage of hydrocarbon and permanent disposal of gases in geological structures.

Exploitation of hydrocarbon is permitted only within the established exploitation area for hydrocarbon and within the borders of the verified mining project, whereby the exploitation area of hydrocarbon is bordered by the coordinate connectors of peak points and limited in depth, part of the area on land and/or sea in accordance with the established borders of the hydrocarbon reservoir and location terms and conditions from the executive location permit procured from the authority competent for spatial planning.

1.5.4.1 Development drilling and well completion

Development drilling implies the present of a drilling platform at the location of well construction, as well as during exploratory drilling. Development wells may, depending on the depth of the sea, be constructed on a fixed platform or moveable facilities, such as semisubmersible drilling rigs and drillships (anchored or dynamically positioned). The number of wells that may be drilled from one platform depends on the type of platform used, the size of the reservoir and drilling/exploitation strategy. The construction of exploratory wells has been described earlier, and the construction of development wells represents a similar process, except that it usually is of a shorter duration. The construction of one development well usually lasts from between 40 to 60 days compared to exploratory wells whose construction lasts between 70 to 90 days (Reggi sur., 2000). The construction of a development well is followed by its equipping that represents a connection between the phase of well construction and well exploitation.

Well completion implies a certain sequence of activities that begin after installation and cementing of production casings. These are: cleaning of the well, testing hermeticity, surveying connections between the cement stone and casings and connection of the cement stone and walls of the wellbore, determining the intervals for testing, perforation of casings and the cement stone, processing of the zone surrounding the well, setting up a sandbank (as required) and installation of tubing. After the production test confirms a favourable flow where damage of the reservoir is avoided, the well may begin exploitation (MMS, 2007b).

After the well is prepared for testing, the working fluid and method for establishing communication between the well and reservoir are selected. For renewed establishment of a connection between the reservoir and wellbore, through casings, cement stone and reservoir rock, perforation must be carried out. The optimal method of equipping and accessing a well implies accessing a well using production equipment (tubing, packer, in-depth control of equipment) on which the perforation tool is also lowered whereby nitrogen is used as a working fluid. There are two basic methods of completing a well: (1) through pipes of an uncovered reservoir interval and (2) through pipes of a covered and perforated reservoir interval. In Croatia wells, as a rule, are equipped with production (exploitation) casings or at least a liner, while the area outside the pipe is cemented.

Perforation is one of the most commonly used techniques for casing wells. It is carried out for the purpose of securing effective flow and communication between the well and the reservoir. Perforation implies perforating openings (perforations) through casings and the cement stone with satisfactory depth of perforation in the reservoir rock. Perforations may be made with: (1) bullet perforator, (2) expendable gun with shaped explosive charge, (3) hydraulic (erosion) perforator and (4) hydraulic (mechanical) cutters (Matanović and Moslavac, 2011). The expendable gun with shaped explosive charge is used most frequently. Their use is dependant on the rock strength and temperature at the depth of perforation. Perforation may be carried out under conditions of positive or negative pressure (depression). A proper approach implies creation of perforation with an expendable gun under negative pressure conditions. In this way it enables nearly instant rinsing of perforations and maximally reduces damage to the reservoir rock. Pressure testing of the blowout preventer must be conducted before perforation. Perforation is conducted only during the day and only when the well is filled to the top with drilling mud and/or working fluid of a suitable density. During perforation, and when extracting the perforator, the level of drilling mud/working fluid in the well must be continually checked. Explosive material is held on the platform however only for the time necessary for carrying out operations (the shortest time possible), and at a predetermined location (container). The handling, transport, loading and unloading explosive material is carried out in accordance with stipulated occupational safety measures. All possible sources of electrical potential (radio devices, cranes lifts and electro-welding devices, in a zone of 150 metres around the well, and all radio receivers, mobile, etc.) that could activate the detonator must be turned off to prevent unwanted activation of the explosive during equipping of the perforator or until the equipped perforator is not at a depth of 150 metres under the sea, whether upon descending, whether ascending.

Well testing is carried out in the cased wellbore or from it. Mostly tubing is used as the test series of tools. The following data may be obtained through testing of the well by using the method of increased pressure: geometry and size of the reservoir (interdigitation, hermeticity of the fault, reserve), depth of the contact fluid (water/petroleum/gas), reservoir pressures (initial, static, dynamic), formation damage, recovery capacity (productivity), permeability (in the zone of the wellbore and drainage area) and others. All equipment (surface, depth and emergency equipment) must be tested with water before beginning work, at a pressure value that is 20 % higher than the envisaged maximum working pressure. During pressure testing, a drop in pressure is not permitted. Depth equipment use during testing ensures: (1) prevention of flow of reservoir fluid into the annular space of the wellbore, (2) secure flow of reservoir fluid to the surface, (3) quality measurement of layer exploitation parameters (4) fast establishment of communication tubing – annular space of the wellbore, (5) quality kill through the annular space, (6) fast and safe capping of the well with the blowout preventer with manoeuvres of the test series, and (7) constant control of well pressure. Testing of layers during period without wind is prohibited, particularly if the appearance of hydrogen sulphide is expected (H_2S).

Testing of sea layers must be interrupted if the wind strength could rise to more than 8 Beaufort. Testing may not be carried out if the weather forecast does not guarantee stable weather for the first 24 hours. For the entire testing period there must be drilling mud/working fluid of a certain density and volume available (at least 1.5 of the volume of the wellbore to the depth of the tested interval). During testing lasting only for the time period necessary for obtaining the required data (1 to 2 days), the recovered hydrocarbon is flared.

In accordance with the Ordinance on significant technical requirements, safety and protection during exploration and exploitation of hydrocarbon for the underground of the Republic of Croatia (OG 52/10), it is prohibited to store or release into the atmosphere or sea hydrocarbon that has not been flared. Extraction of a test series is conducted with continual control of well filling and if necessary use of internal preventers. The extraction of the test series is prohibited if it contains kick fluid.

Stimulation work. Stimulation work may be conducted in well exploitation to using mechanical and/or chemical procedures to increase the flow of fluid from the reservoir. Stimulation work is conducted for two reasons: (a) to eliminate damage to reservoir rock with good permeability which has emerged in the drilling process or during operations (work) on preparation of the well for exploitation – it is applied processing with acid, solvents or surface active agents and (b) naturally low permeability of reservoir rocks that do not allow exploitation of hydrocarbon at a capacity sufficiently great for timely return of investments in drilling and well completion – in this case the stimulation is carried out through a type of hydraulic fracturing or acid fracturing. To carryout stimulation work, it is mandatory for the platform to be equipped with high-pressure pumps and mixers, surface high-pressure cables and shut-off devices, reservoir area and corresponding measuring instruments (tested with valid certificates). Equipment resistant to aggressive and harmful gases is used. All stimulation work must be carried out during the day and under favourable weather conditions. Mandatory use of corrosion inhibitors is necessary when using acid work fluids.

1.5.4.2 Installation of production platforms

Petroleum production will commence after the discovery of economically recoverable quantities of petroleum and the drilling of production wells in the blocks concerned. Submarine pipelines need to be laid and production platforms installed for this purpose. The selection of production platforms depends on a series of parameters, such as sea depth, type of reservoir, distance of the existing oil and gas infrastructure etc. The platforms are discussed in Chapter 1.5.2. According to sea depths in the blocks concerned and platform operating depths shown in Table 1.4, fixed jacket offshore platforms lean on the seafloor, towers lean on the seafloor, dynamically positioned floating ships for petroleum production, storing and shipping or submarine systems remotely operated from platforms installed in shallower sea waters or onshore. Work needed to start the production of discovered petroleum usually require more than seven years (Regg et al., 2000). On a production platform the following is carried out: oil and gas treatment and their preparation for transport, that is, liquid/gas separation, dehydration, acid gas removal (H2S i CO2) and gas compression. After being transported to the coast, further oil and gas treatment in facilities like refineries, gas treatment plants and petrochemical plants may be required. The need for such an onshore treatment plant, if any, has not been determined in this phase.

1.5.4.3 Petroleum transport

Gaseous petroleum and liquid hydrocarbons (e.g. formation water) are transported via submarine pipelines that can be dug in or laid on the seafloor. Depending on their use, pipelines are divided in: (1) flow lines - (from the production well to well submarine distributors and to production and/or compression platform, as well as between production platforms) and (2) transmission pipelines (from production and/or compressor platform to the shore or a vessel and alike). A part pertaining to the pipeline is also a safety belt along the pipeline route. Pipelines differ according to their characteristics (e.g. diameter, wall thickness, quality of material, resistance to external and internal pressure) and are designed, inter alia, in line with petroleum physical and chemical properties, physical environment (e.g. sea depth, terrain inclination) and required maintenance. Typical pipeline diameters vary from 100 to 1500 mm of outer diameter while the wall thickness ranges from 10 to 40 mm. Pipelines my be built as a single pipeline, by inserting a pipe into a pipe, as flexible pipes or as jointly laid pipe sets. Pipelines are usually made of steel for the purpose of reducing heat loss and increasing stability. They are protected with an anti-corrosion coating on the outside and/or concrete which makes them heavier in order to overcome the buoyancy, but they can be coated inside as well. (Cranswick, 2001; Guo at al., 2005) Deepwater pipelines usually require a high level of thermal insulation.

Pipelines are to be inspected in regular and stipulated intervals in accordance with applicable regulations. Submarine pipelines (as well as wellheads and other production devices laid on the seafloor, rigid and flexible pipes used for joining production devices with surface installations, together with connection devices) must be designed to meet the requirements of resistance, full tightness with respect to operating conditions, and they must be appropriately protected from corrosion, sea currents and other external factors pursuant to applicable regulations. Pipelines are protected by sacrificial anodes from external corrosion and leaks. Submarine pipelines must be equipped with appropriate number of normal work condition disturbance detectors (high pressure-low pressure, flow rate, etc.) such as pressure sensors and remotely operated valves, which are intended to protect the pipeline from possible overpressure and abnormally low-pressure conditions. (Cranswick, 2001). Protection devices must be installed in collectors, separators and devices under pressure in general. In case of pressure increase or decrease or any other disturbance in the pipeline, the fluid flow through the pipeline shall be suspended until the disturbance is removed. ON platforms, pipelines may be equipped with pipeline cleaner (cleaning stations) reception and transport devices. All surface pipelines on a platform shall be clearly marked with colours according to their intended use and applicable regulations, while the pipes shall also contain a fluid flow direction marking.

There are several methods for pipeline installation including S-lay, J-lay, reel barge, and tow-in methods (Cranswick, 2001) (Figure 1.24).

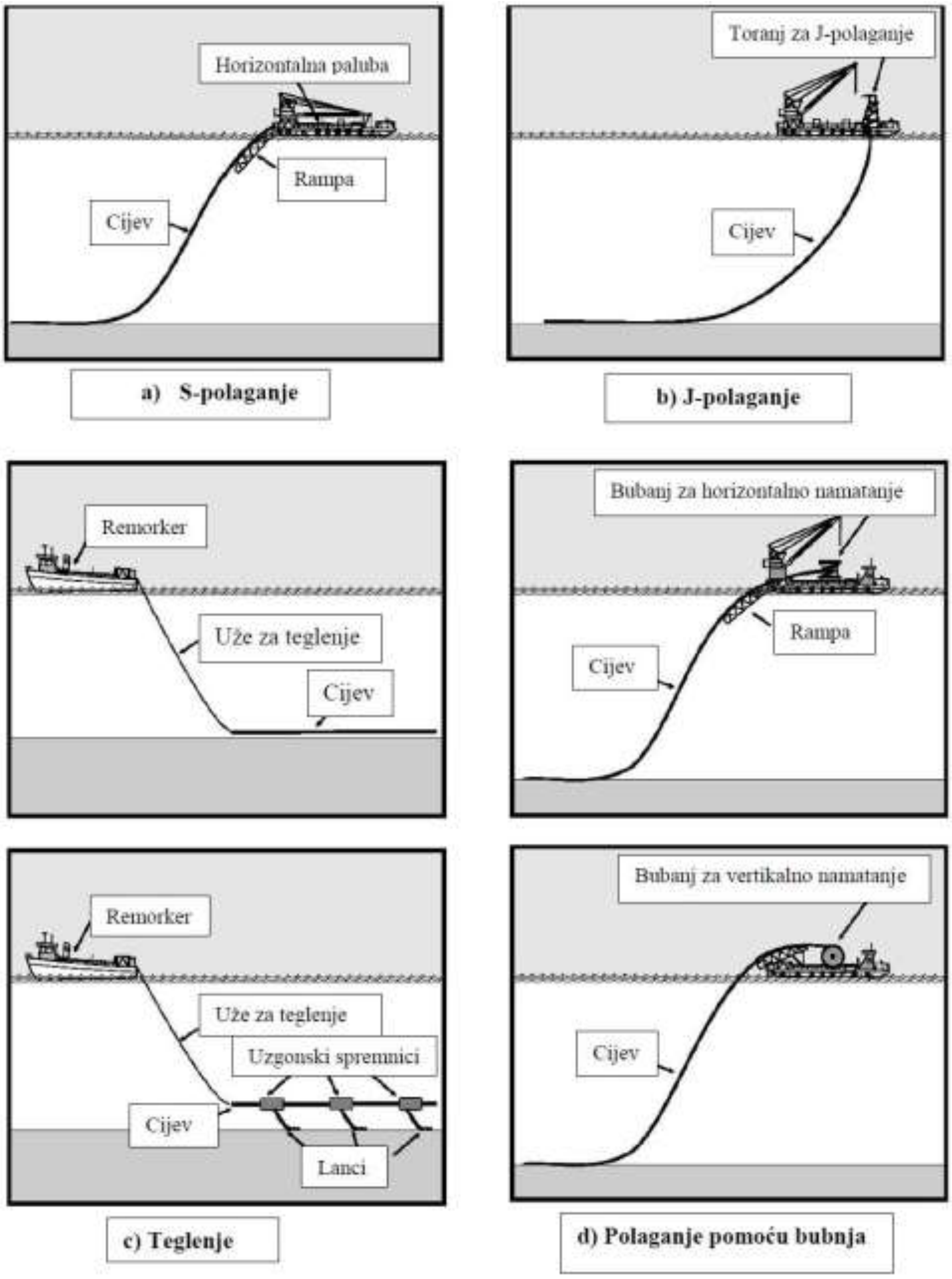


Figure 1.24 Examples of offshore pipe laying methods (source: Cranswick, 2001)

<a) S-lay, b) J-lay, c) tow-in, d) Reel barge method; horizontal deck; towing cable; pipe; stinger; J-lay tower; tugboat; buoyancy modules; chains; horizontal reel; vertical reel;>

S-lay (Figure 1.24a) – Sections of coated 12 to 25 m long pipes are welded on a lay barge and the welding area is then protected from corrosion. As the lay barge is moving forward, the welded pipe sections enter into pipe rams that by a controlled release of the welded sections drop the pipeline on the sea floor via a stinger. The stinger is used to control the bending stress of the pipe as it is being laid. The stinger position and stress parameters must be controlled in design intervals. This method is used for installations ranging from shallow to deep water.

J-lay (Figure 1.24 b) – J-lay barges have a tall tower on the stern for welding and anti-corrosion protection. Pipe sections of lengths up to 75 m can be handled. J-lay is almost always vertical and it can be used in deeper waters than S-lay. Normally, it is not used in waters 60 to 150 m deep due to restricted pipe angle and stress to which the pipe is exposed while being dropped down to the sea floor.

Towing (Figure1.24 c) – There are four variations of the tow-in method: surface tow, mid-depth tow, off-bottom tow, and bottom tow, and all of them require a towing ship. Buoyancy modules are added to the pipeline so that it floats at the sea surface. Once the pipeline is towed on site, the buoyancy modules are removed or flooded, and the pipeline settles, under control, to the sea floor, the mid-depth tow requires fewer buoyancy modules while off-bottom tow requires added pipe weight in the form of chains that pulls the pipes downwards. In case of bottom tow, once towed to the envisaged location, the pipeline is allowed to sink to the sea floor.

Reel barge method (Figure 1.24 d) – It is usually used for smaller diameter pipelines. The pipe is welded, coated and spooled onto a reel onshore and then it is prepared for pipe laying at the sea. When a horizontal reel is used, the pipes are laid applying the S-lay method, and when a vertical reel is used, J-lay is the most common method applied, although S-lay is also possible.

Lay barges may be moored or dynamically positioned. Smaller lay barges (in the 120 m long by 30 m wide size range) typically require 8 anchors weighing 14 000 kg each. Larger barges operating in 300 m of water typically require 12 anchors, each weighing 25 000 kg or more. In general, the larger the barge, the bigger the anchors (Cranswick, 2001). Maximum sea depth for large, conventionally moored lay barges using the S-lay method is approximately 300 m and is based on the anchor chain and water depth ration 5 to 1. In case of pipelines from wells to production platforms located in deep waters, pipe laying by conventionally moored lay barges will be restricted to pipelines sections in waters up to 300 m of depth.

In the areas where (1) intensive fishing activities are present (e.g. by bottom trawling nets), (2) the conditions cause separation or significant sediment movements or (3) where is required by law, a trench and pipeline burial may be required. Trench digging methods are: conventional digging involving dredging, dragging, water jet and mechanical digging of a trench (Cranswick, 2001). Disturbance and sedimentation sea floor area varies depending on the trench digging method, sea floor topography changes, sediment thickness and sea currents. Pipeline installation in deep water areas may be demanding in terms of rout selection and pipeline construction.

1.5.4.4 Removal of mining facilities and plants (decommissioning)

Decommissioning is a process of dismantling production and transportation facilities and recovery of the area where production was carried out in accordance with concession requirements and/or law. Pursuant to the Mining Act (OG 56/13 and 14/14) (Title IV: Rehabilitation) each mining economic entity shall execute rehabilitation of the land where mining activities were carried out. If the concessionaire does not execute rehabilitation or the successive rehabilitation of the land where the mining activities are carried out, pursuant to the verified mining project on the basis of which the concession has been granted, the body competent for mining affairs which granted the concession shall order the implementation of the rehabilitation activities within appropriate time. If the concessionaire does not execute the rehabilitation, this will be done by a third party, and costs will be borne by the concessionaire. Rehabilitation shall be conducted by implementing all necessary measures for securing the areas which exclude the possibility of danger to people, property and the environment.

There are various production platform removal methods (MMS, 2005a) that can be generally divided in explosive and non-explosive. Selected method application can be managed by divers, Remotely Operated Submarine Vehicle - ROV, or it can be done from the surface. The Concessionaire should be required to abide by the best international structure safe removal practice.

When selecting the method, the contractor must take the facility size and type, water depth, cost-effectiveness, possible environmental impact and weather conditions into account.

The platform removal includes pipe and cable cutting between deck modules, separation of modules, pad eyes installation (on the deck) used to tie the cargo down and fixing the structure. Dismantling the topsides is conducted in reverse order in which they were installed (http://www.rigzone.com/). To prepare a platform for decommissioning, tanks, processing equipment and piping must be flushed and cleaned, and residual hydrocarbons must be disposed of.

For submarine pipelines, the most common international practice is to abandon the pipeline and to leave it on the sea floor (Scandpower Risk Management Inc., 2004). Before abandonment, the pipeline must be completely cleaned up to an immeasurable hydrocarbon level. In some cases, after the pipeline is been completely cleaned, the pipe can be used as scrap iron, i.e. as a secondary raw material.

1.5.5 Accident situations

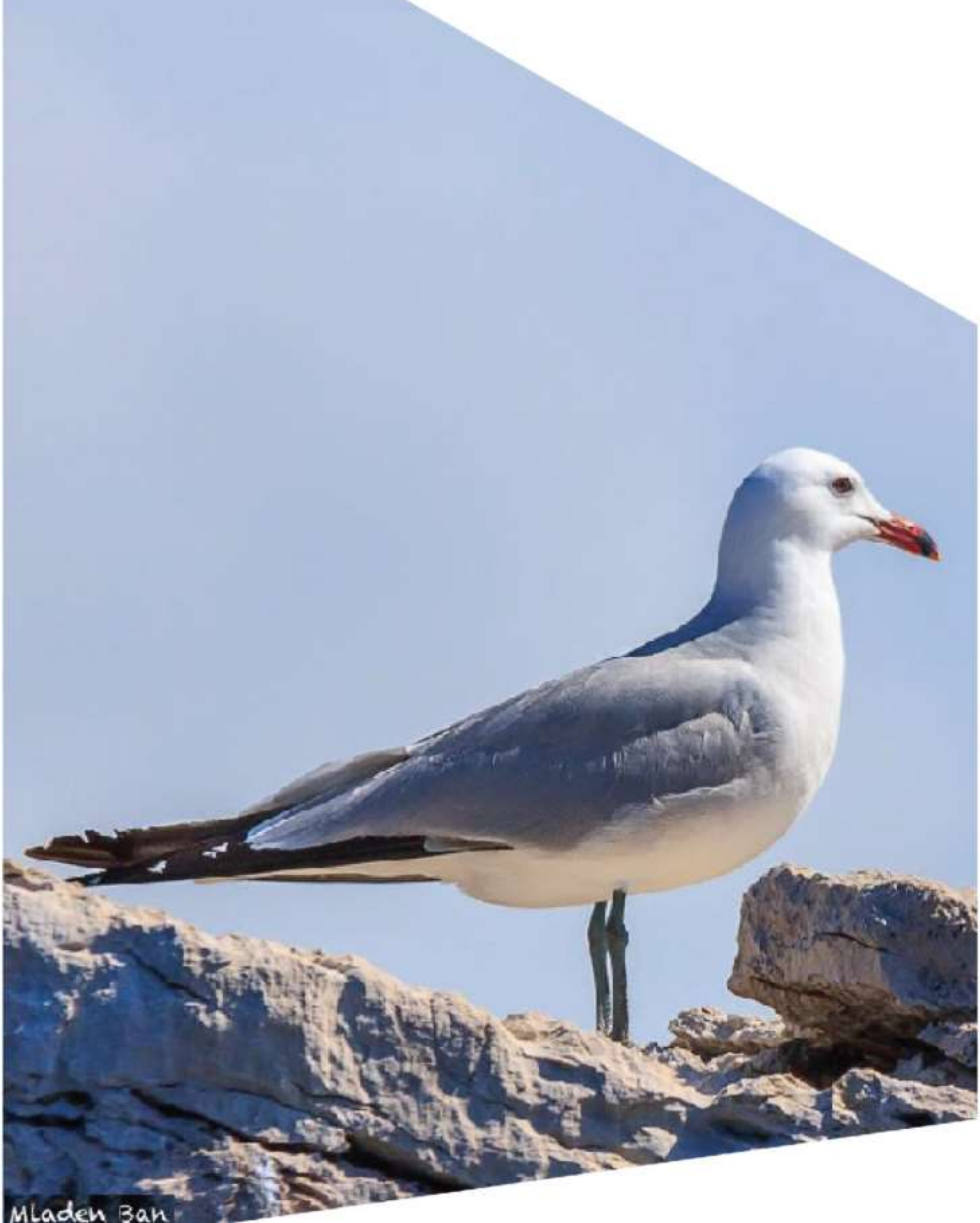
Some of the potential accidents during hydrocarbon exploration and exploitation that should be taken into account (1) petroleum spills and (2) release of Hydrogen sulphide (H_2S). Petroleum spills may happen at any phase of hydrocarbon exploration and exploitation. The potential sources are: (1) petroleum spills as a consequence of eruptions, (2) diesel fuel spills, (3) oil and synthetic mud spills and (4) leakage of fluid from seismic cables.

Accident situations are avoided by maintaining the working safety of the well and collection-transport system according to stipulated supervision and maintenance, and in accordance with the rules of the profession. All employees on the platform must be acquainted with the dangers and procedures in emergency situations. Drills for emergency situations must be held regularly on the platform (at least once a month). The stipulated records should be kept for drills held. The platform must have: mining documents, mining projects, plant ledgers, attests, reports, maritime documents and an operative plan for environmental protection interventions.

According to the General provisions of the Intervention plan for unexpected sea contamination (OG 92/08) – the Intervention plan for unexpected sea contamination is a document of sustainable development and environmental protection that establishes procedures and measures for predicting, preventing, limiting, and readiness for and reactions to unexpected sea contamination, and to extraordinary natural events in the sea for the protection of the sea environment. The intervention plan is harmonised with international treaties in the area of marine environment protection signed by the Republic of Croatia.

The intervention plan is implemented in the event of unexpected sea contamination with oil and/or oil mixtures of a size greater than 2000 m^3, with hazardous and harmful substances, and during extraordinary natural events in the sea. For contamination with oil and/or oil mixtures smaller than 2000 m^3, for a smaller scale and strength of extraordinary events at sea, the Count intervention plan for unexpected sea pollution is implemented that, with the prior consent of the central authority of the government administration for environmental protection, is adopted by the representative body of the county.

2 Correlation between the Framework Plan and Programme and other plans, programmes and directives



2.1 International directives, strategies, planes and programmes

This Chapter provides an overview of some of the more relevant directives which have been transferred into Croatian legislation and which are important for the implementation of the Framework Plan and Programme (Tables 2.1 and 2.2).

Table 2.1 Correlation between the Framework Plan and Programme's objectives and international conventions

International convention	Correlation between the document and the Framework Plan and Programme's objectives
International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	The Convention aims at the prevention of pollution of the marine environment by discharging harmful substances or spills containing such substances, as well as at protecting the marine environment from pollution from ships, improving the protection and monitoring of marine pollution from ships, especially oil tankers. Ships transporting oil must have the capacities to keep the waste containing oil on board until they have the opportunity to discharge the oil to reception facilities on land. This involves the fitting of appropriate equipment, including an oil-discharge monitoring and control system, oily-water separating equipment and a filtering system, slop tanks, sludge tanks, piping and pumping arrangements. The objectives and principles of the MARPOL Convention relate to the following Strategic Study objective: • Good status of the sea and the seabed.
Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) (1976)	Contracting Parties will, individually or jointly, take all the appropriate measures to protect and conserve biological diversity, rare or sensitive ecosystems as well as wild fauna and flora species which are rare or endangered, including their habitats. It is necessary to take all measures to prevent and minimize the pollution resulting from exploration and production of the continental shelf and seabed. In order to contribute to the sustainable development of the Mediterranean Sea the Member States must: a) apply the precautionary principle so that where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation; b) apply the "polluter pays" principle; c) create the project's environmental impact assessment/appropriate assessment of the project impact on the ecological network for the proposed activities which are likely to cause a significant negative impact on the marine environment and which are subject to approval by competent state authorities; d) promote cooperation between the States undergoing the environmental impact assessment which refers to activities under their jurisdiction but which are likely to have a significant negative impact on the marine environment of other States or areas outside the limits of national jurisdiction; e) oblige to promote the integrated coastal zone management, taking into account the protection of areas of ecological and landscape interest and the rational use of natural resources. Stated Convention principles relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds • Protected underwater cultural heritage and natural landscape • Protection of human health and the quality of life.

United Nations Convention on the Law of the Sea (UNCLOS) (1982)	In conformity with the provisions of this Convention and other rules of international law, a Coastal State may adopt laws and other regulations relating to innocent passage through the territorial sea in respect of marine scientific research and hydrographic surveys. In accordance with this Convention it shall be necessary to: – establish measures to mitigate and prevent pollution of the marine environment; – establish measures regarding the management, environment and sustainable control of the natural marine resources. States and competent international organizations shall, in accordance with this Convention, make available by publication and dissemination through appropriate channels information on proposed major programmes and their objectives as well as knowledge resulting from marine scientific research. For this purpose, States, both individually and in cooperation with other States and with competent international organizations, shall actively promote the flow of scientific data and information and the transfer of knowledge resulting from marine scientific research. Stated objectives relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds • Protection of human health and the quality of life.
United Nations Framework Convention on Climate Change (UNFCCC) (1992)	It is necessary to limit all activities (transport, certain technologies etc.) which in a certain way cause emissions of greenhouse gases, i.e. affect climate change. The Government must take protection measures in order to foresee and prevent or reduce climate change and unfavourable effects caused by the change. Stated Convention provisions relate to the following Strategic Study objectives: • Maintaining the existing quality of air and climatic conditions • Protection of human health and the quality of life.
Convention on Biological Diversity (1992)	The Convention requires the integration of biological diversity conservation measures into all sectors, especially those which are directly using natural resources. Biological diversity conservation and sustainable management require drafting of national strategies, programmes and plans, or including the biological diversity conservation measures into the existing strategies, programmes and plans. Activities which affect or may affect biological diversity must be identified and monitored. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds • Protected underwater cultural heritage and natural landscape.
Stockholm Convention on Persistent Organic Pollutants (2001)	It is necessary to ensure reduction or elimination of the production, use, discharge, import and export of highly toxic substances for the purpose of protecting human health and the environment. Objectives and principles of this Convention relate to the following Strategic Study objectives: • Maintaining the existing quality of air and climatic conditions • Protection of human health and the quality of life • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds.
Vienna Convention for the Protection of the Ozone Layer (1985)	Parties shall take appropriate measures in accordance with the provisions of this Convention to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer. The Vienna Convention principles relate to the following Strategic Study objectives: • Maintaining the existing quality of air and climatic conditions • Protection of human health and the quality of life.

Convention on the Conservation of Migratory Species of Wild Animals (CMS) (1979)	The Convention aims to include the conservation of wild animals and plants into national plans, strategies and programmes. Several Agreements have been concluded within this Convention, one of them is the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area, a tool for the conservation of marine biodiversity in the Mediterranean and Black seas. The objectives of this Convention relate to the following Strategic Study objectives: • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds.
Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991)	The Parties shall, either individually or jointly, take all appropriate and effective measures to prevent, reduce and control significant adverse transboundary environmental impact from proposed activities. The Party of origin shall ensure that in accordance with the provisions of this Convention an environmental impact assessment is undertaken prior to a decision to authorize or undertake the proposed activity. The Parties shall give special consideration to the setting up, or intensification of, specific research programmes aimed at: - Improving existing qualitative and quantitative methods for assessing the impacts of proposed activities - Achieving a better understanding of cause-effect relationships and their role in the integrated environmental management - Analysing and monitoring the efficient implementation of decisions on proposed activities with the intention of minimizing or preventing impacts - Developing methods to stimulate creative approaches in the search for environmentally sound alternatives to proposed activities, production and consumption patterns - Developing methodologies for the application of the principles of environmental impact assessment at the macro-economic level. Stated objectives relate to the following Strategic Study objectives: • Protection of human health and the quality of life • Minimised risk of accidents.
Convention on the Transboundary Effects of Industrial Accidents (Helsinki, 1992)	The Convention shall promote cooperation of the Parties in the event of accidents and exchange information and technologies. Parties will take the appropriate measures to protect human beings and the environment against industrial accidents by preventing such accidents as far as possible, by reducing their frequency and severity and by mitigating their effects. Measures regarding prevention, preparedness and response, including the measures for renewal, will apply for that purpose. Stated provisions relate to the following Strategic Study objectives: • Protection of human health and the quality of life • Minimised risk of accidents.
European Union Directives	**Correlation between the document and the Framework Plan and Programme's objectives**
Directive 2013/30/EC on safety of offshore oil and gas operations	This Directive establishes minimum conditions for safe offshore exploration and exploitation of oil and gas and at the same time improves the response mechanisms in case of an accident. Member States must require from the operators to ensure taking all appropriate measures to prevent major accidents relating to offshore oil and gas operations. Special attention must be given to sensitive ecosystems, such as those which play a role in minimising the climate change (e.g. seagrass), and other ecologically protected areas. This Directive relates to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds • Protection of human health and the quality of life • Minimised risk of accidents.
Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment	The preparation of an ecological assessment of the plans and programmes which are likely to have a significant impact on the environment. Principles and objectives of this Directive relate to all Strategic Study objectives.

EU Water Framework Directive (2000/60/EC)	The Directive shall contribute to: - The provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use, - A significant reduction in pollution of groundwater, - The protection of territorial and marine waters, and - Achieving the objectives of relevant international agreements, including those which aim to eliminate pollution of the marine environment. For point source discharges liable to cause pollution, a prior regulation, such as a prohibition on the entry of pollutants into water, shall be required or prior authorisation or registration based on general binding rules. For diffuse sources liable to cause pollution, measures to prevent or control the input of pollutants shall be required. Member States may authorise injection of water containing substances resulting from the operations for exploration and extraction of hydrocarbons or mining activities, and injection of water for technical reasons, into geological formations from which hydrocarbons or other substances have been extracted or into geological formations which for natural reasons are permanently unsuitable for other purposes. Such injections shall not contain substances other than those resulting from the above operations. The Framework Water Directive, i.e. its principles relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protection of human health and the quality of life • Minimised risk of accidents.
Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EC) (Natura 2000)	The Birds Directive emphasises that habitat loss and degradation are the most serious threats to the conservation of wild birds. It therefore places great emphasis on the protection of habitats for endangered as well as migratory species. The Directive bans activities that directly threaten birds. Measures taken pursuant to the Habitats Directive aim to maintain or restore a favourable conservation status of natural habitats and species of wild fauna and flora. The Directive protects more than 1000 animals and plant species and more than 200 habitat types. The implementation of these two directives shall take place primarily through the creation of the ecological network Natura 2000. The strategic assessment analyses the ecological network areas and the potential impact on them and suggests protection measures. Marine areas within Natura 2000 are protected by protection measures to ensure they are not over-fished, or affected by pollutants from sewage or shipping traffic. Stated objectives relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds.
Marine Strategy Framework Directive (2008/56/EC)	The Marine Strategy is an essential part of the environmental component for the future EU strategy for marine areas management and it has been created with the aim of achieving and using the maximum economic potential of the oceans and seas while protecting the marine environment. The Directive identifies European marine regions according to geographical and ecological principles. Each Member State shall cooperate with another Member State or third country within the marine region and should develop a strategy for marine waters. Those strategies must contain a detailed assessment of the environmental status, a definition of a "good environmental status" on a regional level and clearly establish the environmental targets and monitoring programmes. In conformity with this Directive, the marine environment is a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas ecosystems which are clean, healthy and productive. Stated objectives relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds.

2.2 National strategies, planes and programmes

Table 2.2 Correlation between the Framework Plan and Programme's objectives and strategic and planning documents

Strategic and planning documents	Correlation between the document and the Framework Plan and Programme's objectives
Spatial Planning Strategy of the Republic of Croatia (OG 76/13) ***(Strategija prostornog uređenja Republike Hrvatske (NN 76/13))***	Managing the Croatian part of the Adriatic will be based on an Integral Coastal Zone Management Plan which covers the coast, continental shelf–national territorial waters and the Croatian maritime border, and which includes the Plan for the Use of the Sea (surface and underwater area) with important fisheries and mariculture functions. The use of the area and development of the Croatian Adriatic are mainly directed towards the following: • The overall area of the Croatian part of the Adriatic, and especially the islands, deserve the status of a protected area • Spatial solutions with the aim of unifying development with increased conservation and improvement of the spatial status will be promoted • In terms of use of space, those programmes which are connected to the sea and the coastline with regard to their location, and which do not deteriorate the environmental quality, will be given priority. Setting up of all underwater infrastructure installations will be based on the assessment of the eligibility of those facilities' positioning, avoiding, whenever possible, bays, straits and natural highly valuable areas. Areas of exceptional oceanographic and biocenological features: so far, Lim Bay and Mali Ston Bay are under special protection. Protection of the sea surrounding the islands of Brusnik, Jabuka and Palagruža is a priority. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protected underwater cultural heritage and natural landscape • Harmonised implementation of the Programme with regard to other economic activities • Protection of human health and the quality of life.

<table>
<tr>
<td>Energy Strategy of the Republic of Croatia (OG 130/09) (Strategija energetskog razvoja Republike Hrvatske (NN 130/09))</td>
<td>The Strategy aims at the establishment of a harmonised relations development system with regard to security of energy supply, competitiveness and conservation of the environment, which will provide the citizens of Croatia and the Croatian economy with a quality, secure, available and sufficient energy supply. Such energy supply is a prerequisite for economic and social development.
• The energy system of the Republic of Croatia is completely integrated with the energy system of the European Union and the energy system of Southeast Europe. An open system allows for energy market development and competition improvement, attracting of domestic and foreign investments to the energy market.
• The Republic of Croatia is becoming ever more dependent on energy imports. It is currently importing more than 50% of its energy needs. In the Croatian balance of primary energy consumption oil and oil products are represented with 50% and natural gas with 25%. Consumption of these forms of energy will grow in the future, while domestic oil and natural gas production is going to decrease due to exhaustion of deposits.
• The Republic of Croatia's main source of oil and natural gas supply will be the domestic production from the remaining reserves, Northern Africa and the Middle East, the Russian Federation and Caspian region. Energy sector development in this area will be based on the development of energy markets, but also on the geopolitical planning and negotiations on participation in strategic projects that could bring the Republic of Croatia increased security of supply and economic benefits.
• The European Commission has proposed a five-point EU Energy Security and Solidarity Action Plan:
  • Infrastructure needs and the diversification of energy supplies
  • External energy relations
  • Oil and gas stocks and crisis response mechanisms
  • Energy efficiency
  • Making the best use of the EU's indigenous energy resources.
• The Strategy's fundamental principle is also to establish a completely open energy market in the Republic of Croatia, regulated in the area of natural monopoly, as a part of a single regional and European energy market. There are several fundamental starting points to achieve that objective:
  • Independent regulation of the energy sector
  • The role of the Government of the Republic of Croatia in securing market functioning
  • Securing mandatory oil and oil products stocks
  • Using the energy transit possibilities.
• Stated objectives and provisions relate to the following Strategic Study objectives:
  • Good status of the sea and the seabed
  • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds
  • Protected underwater cultural heritage and natural landscape
  • Protection of human health and the quality of life
  • Minimised risk of accidents.</td>
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<tr>
<td>Strategy of Maritime Development and Integrated Maritime Policy for the period 2014 – 2020 (OG 93/14) (Strategija pomorskog razvitka i integralne pomorske politike Republike Hrvatske za razdoblje od 2014. do 2020. godine (NN 93/14))</td>
<td>Strategic objectives:
1. Sustainable growth and competitiveness of the maritime economy in the area of:
  o Shipping and maritime transport services
  o Port infrastructure and port services
  o Education and seamen's living and working conditions.
2. Safe and ecologically sustainable maritime transport, maritime infrastructure and maritime space of the Republic of Croatia.

In accordance with the development of the Strategy of Marine Environment and Coastal Zone Management of the Republic of Croatia which ensures the achievement and maintenance of a good marine environment status until 2020, special attention must be given to environmental protection, conservation and enabling the recovery of the marine and coastal environmental systems and to protect the biological diversity and sustainable use of the sea and coastal zone. It is also necessary to give attention to the conservation of the marine protected areas and ecologically significant EU's NATURA 2000 sites and to the reduction of pollution, i.e. load in the marine and coastal environment to prevent negative impacts and risks to human health and/or health of the ecological systems and/or use of the sea and coast.</td>
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</table>

	Significant negative effects of maritime transport on the marine environment are those causing sudden and operative marine pollution from maritime facilities, especially accidents during oil and oil products transport, and discharging ship-generated waste and cargo residues into the sea. Stated objectives and provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds • Protected underwater cultural heritage and natural landscape • Protection of human health and the quality of life • Minimised risk of accidents.
Strategy and Action Plan for the Protection of Biological and Landscape Diversity of the Republic of Croatia (OG 143/08) (*Strategija i akcijski plan zaštite biološke i krajobrazne raznolikosti Republike Hrvatske (NN 143/08)*)	The Strategy identifies the following general strategic objectives: • Maintain the overall biological, landscape and geological diversity as an underlying value and potential for further development of the Republic of Croatia • Meet all obligations arising from the process of accession to the European Union and alignment of the legislation with the relevant EU directives and regulations (Habitats Directive, Birds Directive, CITES Regulations) • Fulfil the obligations arising from international treaties in the field of nature protection, biosafety, access to information, etc. • Ensure integral nature protection through co-operation with other sectors • Establish and evaluate the state of the biological, landscape and geological diversity, set up a nature protection information system with a database connected to the state's information system. Stated objectives and provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds.
Water Management Strategy (OG 91/08) (*Strategija upravljanja vodama (NN 91/08)*)	The purpose of water protection is to protect human health and the environment, which implies achieving and conserving a good water status, to prevent water pollution, to prevent the change of hydromorphological characteristics of waters under such risk and to rehabilitate the distorted water status, and it covers the following: • Protection of surface and groundwater as a drinking water reserve (existing and planned) • Protection of surface water and groundwater, coastal water (sea), protected areas, – areas of special water protection for the purpose of protecting human health and conserving the water and water-dependent ecosystems, as well as conserving biological diversity within the integrated water resource management • Improvement of the ecological functions of waters and coastal waters (sea) where the water quality has been distorted and achievement of the prescribed water quality for certain purposes where the said water quality does not meet the requirements, by participating in the planning and progressive implementation of complete protection measures and systematically monitoring the conducted measures' effect on the basin and coastal waters (sea) • Reduction of the amount of harmful substances at the source of pollution applying the water protection measures and the control of the built facilities and wastewater treatment devices operation • Contribution to sustainable development rationally using the water resources. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protection of human health and the quality of life.

Contingency Plan for Accidental Marine Pollution (OG 92/08) **(*Plan intervencija kod iznenadnih onečišćenja mora (NN 92/08)*)**	The Contingency Plan for Accidental Marine Pollution (hereinafter referred to as: the Contingency Plan) is a sustainable development and environmental protection document which establishes the procedures and measures for predicting, preventing, restricting and preparedness for as well as response to accidental marine pollution and unusual natural marine phenomenon for the purpose of protecting the marine environment. The Contingency Plan is harmonised with international treaties governing the area of marine environment protection to which the Republic of Croatia is a party. The Contingency Plan is implemented in case of accidental marine pollution caused by oil and/or oil mixture if the amount of pollution exceeds 2000 m^3, hazardous and noxious substances, and in case of unusual natural marine phenomena. A county contingency plan in case of accidental marine pollution, which is adopted by a county representative body, subject to prior approval of the central state administrative body in charge of environmental protection, shall be implemented in case of pollution caused by oil and/or oil mixtures if the amount of pollution does not exceed 2000 m^3 or sudden natural phenomenon at sea of minor size and intensity. The Contingency Plan shall be implemented in marine areas, on seabed and marine subsoil of the Republic of Croatia which include the maritime domain, internal sea waters, territorial sea and the protected ecological and fishery zone.
	Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protection of human health and the quality of life • Minimised risk of accidents.
Operational Programme for Fisheries 2007 – 2013 **(*Operativni program za ribarstvo 2007. – 2013.*)**	The strategic vision of the development of the fisheries sector is based on the principle of sustainability. Therefore, the overall objective of the Operational Programme is to contribute to achieving of a competitive, modern and dynamic fisheries and aquaculture sector through sustainable exploitation of resources. The following long-term effect indicators could measure the achievement of this strategic vision: - Decrease of fishing capacity - Increase of production capacity in aquaculture The following long-term effect indicators have been proposed: - Decrease of fishing capacity - Increase of production capacity in aquaculture Given the short duration of the Operational Programme, it is envisaged that in this limited period the Republic of Croatia will use the funds from the EFF alongside the national co-funding for achieving of the following objectives: - Modernisation of existing farming aquaculture facilities so as to contribute to increase of production and increase of competitiveness of the aquaculture sector.
Operational Programme for Fisheries 2013 – 2020 **(*Operativni program za ribarstvo 2013. – 2020.*)**	The Operational programme aim is to achieve the following objectives which are also the objectives of the EMFF: - Promoting competitive, environmentally sustainable, economically viable and socially responsible fisheries and aquaculture - Fostering the implementation of the Common Fisheries Policy (CFP) - Promoting a balanced and inclusive territorial development of fisheries and aquaculture areas - Fostering the development and implementation of the Union's Integrated Maritime Policy (IMP) Stated objectives have been structured within six EMFF priorities: 1) Promoting environmentally sustainable, resource efficient, innovative, competitive and knowledge–based fisheries. 2) Fostering environmentally sustainable, resource efficient, innovative, competitive and knowledge–based aquaculture. 3) Fostering the implementation of the CFP by collecting and managing data for the purpose of improving scientific knowledge and by providing support to monitoring, control and enforcement, enhancing the institutional capacity and the efficiency of public administration, without increasing the administrative burden. 4) Increasing employment and territorial cohesion by pursuing the following specific objective: the promotion of economic growth, social inclusion and job creation, and providing support to employability and labour mobility in coastal and inland communities which depend on fishing and aquaculture, including the diversification of activities within fisheries and into other sectors of maritime economy. 5) Fostering marketing and processing by pursuing the improvement of market organisation for fishery and aquaculture products and the encouragement of investment in the processing and marketing sectors. 6) Fostering the implementation of the Integrated Maritime Policy.

Management Plan for Bottom Trawlers Fisheries	The objective of the Management Plan for Bottom Trawler Fisheries is to increase the biomass of demersal resources in the period 3 – 5 years up to the level ensuring the sustainability of the target stocks population size (66th percentile for certain indicators for the most important species in terms of economy) thus ensuring the reduction or sustainability of fishing mortality on a reference level, providing for the sustainability of the stability of catch and long-term yield sustainability.
Management Plan for "Srdelare" Purse Seine Nets	The objective of the Management Plan for "Srdelare" Purse Seine Nets is based on the implementation of a precautionary approach to management, which is primarily reflected in the retention of the current trends of biomass and recruitment of the species targeted with this fishing gear. The socio-economic objective is to maximize the revenue from fishing, as well as to provide sufficient employment for participants fishing with this type of gear. The biological objective is to keep fishing at or above the level necessary to maintain productivity and recovery of exploited stocks.
National Strategic Plan for the Development of Aquaculture 2014 – 2020 (*Nacionalni strateški plan razvoja akvakulture 2014. – 2020.*)	General objectives of the Plan: - Reinforce the social and business and political environment with regard to aquaculture development - Increase the total production to 47000 tons complying with the principles of economic, social and environmental sustainability - Increase the national consumption of aquaculture products
Spatial plans	**Correlation between the document and the Framework Plan and Programme's objectives**
Istria County Spatial Plan (Istria County OJ, No 02/02, 01/05, 04/05, 10/8, 7/10, 13/12) (*Prostorni plan Istarske županije (SNIŽ, br. 02/02, 01/05, 04/05, 10/8, 7/10, 13/12)*)	Development objectives and County organisation principles: Conduct systematically active environmental protection and prevention of environmental pollution, which means to set up and structure a natural resources and environmental management system, avoid solutions with an uncertain and long-terms impact on the quality participation of citizens' associations and to conduct rehabilitation of registered pollutants and the most endangered parts of the environment. With regard to the sea and sea coast conservation: • Conserve the favourable physical and chemical features of sea water or improve them if they deteriorated • Conserve the favourable matter and structure of the seabed, coast, coastal areas and estuaries • Conserve the biological species significant for a habitat type; not to introduce foreign (allochthonous) species and genetically modified organisms • Conduct an appropriate system for management and control of the ships ballast water for the purpose of preventing the spread of invasive alien species through ballast water • Prevent illegal construction on the sea coast and rehabilitate the unfavourable status whenever possible. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protected underwater cultural heritage and natural landscape • Protection of human health and the quality of life.
Šibenik-Knin County Spatial Plan (Official Journal No 11/02, 10/05, 03/06, 05/08, 06/12, 09/12, 04/13, 02/14, 08/14) (*Prostorni plan Šibenski-kninske županije (Službeni vjesnik, br. 11/02, 10/05, 03/06, 05/08, 06/12, 09/12, 04/13, 02/14, 08/14)*)	In accordance with the special terms of use, development and protection, the County area is divided into: 1 Areas of special terms of use – areas of special values regarding natural and cultural heritage outside the town's construction area in which any new construction is forbidden: – protected nature sites: national parks Krka and Kornati (except for the purpose of using national park or if otherwise determined by a spatial plan of the area of special features. Exceptionally, the ban does not refer to the infrastructure but special protection measures need to be taken. 2 Areas of special limitations regarding use – areas of special natural characteristics (landscape, soil, water and sea) and cultural heritage, with limitations in construction and in which construction can be allowed taking into consideration the special protection of space: – protected coastal area which covers all islands, islets (an islet is a part of land completely surrounded by the sea and of a surface area from 1 to 100 ha) and rocks of land completely surrounded by the sea and of a surface area of less than 1 ha), a coastal coastline and a maritime belt 300 m from the coastline. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed

	• Protected underwater cultural heritage and natural landscape.
Primorje-Gorski kotar County Spatial Plan (OJ No 14/00 and 10/05) (*Prostorni plan Primorsko-goranske županije (SN, br. 14/00 i 10/05)*)	The sea, coastal area and islands are the fundamental features of this County and they are of an exceptional importance for the County area. One of the biggest threats regarding marine pollution due to maritime transport, in addition to the accidents involving ships transporting liquid cargo, is the pollution by oily wastewater and oily waste from ships. To prevent the afore mentioned pollution it is necessary to: • Build a plant for the processing of oily water and oily waste from ships in the Rijeka port area with the aim of finding an independent and long-term solution to the disposal of the stated type of waste for the entire County. Sinking waste in the sea, residues and noise in the marine environment are also considered physical disturbances in the marine environment. Measures for the prevention and reduction of marine pollution with hydrocarbons from the karst subsoil and the subsoil are: • Rehabilitate the subsoil polluted with hydrocarbons (area of the INA Oil Refinery at Mlaka and Urinj) and the subsoil (a part of the Bay of Bakar water area) and continue with the ongoing activities • Conduct continuous control of all existing plants with reservoirs for hydrocarbons and other hazardous substances on the karst coastal and island area whose content might pollute the sea • Base the industry development on the selection of the latest technological processes taking into consideration the approach of the "best available methods" and "best environmental practices". Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protection of human health and the quality of life.
Lika-Senj County Spatial Plan (County Journal No 22/10, 19/11) (*Prostorni plan Ličko-senjske županije (Županijski glasnik, br. 22/10, 19/11)*)	It is necessary to identify the boundary of the maritime demesne in the coastal area and, in accordance with that, the terms of use of the land and the sea, and to prevent the occupation and enclosing of that space. According to this Plan, research will be carried out on the basis of which areas and protection measures and use of the protected subsoil will be defined. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protected underwater cultural heritage and natural landscape.
Zadar County Spatial Plan (County Journal No 2/01, 6/04, 2/05, 17/06, 3/10, 15/14) (*Prostorni plan Zadarske županije (Službeni glasnik, br. 2/01, 6/04, 2/05, 17/06, 3/10, 15/14)*)	The area of the Croatian part of the Adriatic must be planned in its entirety as an integrated space management plan – in accordance with the Mediterranean Action Plan within the Barcelona Convention. The Plan sets forth protection measures which need to be carried out to prevent pollution caused by maritime transport and port-related activities: • Supplement the equipment for the prevention of pollution spread and removal (boats – cleaners, floating containment booms, skimmers, pumps, containers, specialised vehicles, dispersants etc.) at the existing specialised companies' • Secure the reception of oily water and waste oil in the port • Build in the reception and processing devices for the sanitary water from the boats, containers for the waste oil, fuel residue and oily water disposal in marinas and local ports • Determine the manner of servicing ships on land and out on the sea. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Protection of human health and the quality of life.

Split-Dalmatia County Spatial Plan (County Journal No 1/03, 8/04, 5/05, 5/06, 13/07, 9/13) **(*Prostorni plan Splitsko-dalmatinske županije (Službeni glasnik, br. 1/03, 8/04, 5/05, 5/06, 13/07, 9/13)*)**	The marine area of the Split-Dalmatia County, according to the spatial, physical and chemical and biological features of the sea, is divided into: • Semi-enclosed bays (Kaštel, Marina and Trogir Bays) • Channels (Split, Brač, Hvar, and Vis Channels) and • Open waters of Central Adriatic. Marine space is further divided due to the identification of ecologically significant sites which are of particular importance for the development of biological species, on which a certain form of protection exists or is proposed, as well as areas eligible for fishing on the sea which is carried out in the County marine areas: • Trogir and Marin Bay water area • Drvenik Veliki and Drvenik Mali Islands water area • Šolta Island water area • Split Channel • Brač Channel • Kaštel Bay • Hvar Channel • Neretva-Korčula Channel • Vis and Biševo Channels and • Jabuka Island water area. Provisions of this Plan, which refer to the sea, relate to the following Strategic Study objectives: • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds • Protected underwater cultural heritage and natural landscape.
Dubrovnik-Neretva County Spatial Plan (Official Journal No 06/03, 03/05, 03/06, 07/10, 04/12, 05/12, 10/12, 09/13) **(*Prostorni plan Dubrovačko-neretvanske županije* (*Službeni glasnik, br. 06/03, 03/05, 03/06, 07/10, 04/12, 05/12, 10/12, 09/13)*)**	In terms of geographical positions the County area is divided into the following: • continental region: towns of Ploče, Metković and Opuzen and municipalities of Dubrovačko primorje, Konavle, Kula Norinska, Pojezerje, Slivno, Zažablje and Župa dubrovačka • Continental and island region: Town of Dubrovnik • Island region: Town of Korčula and municipalities of Blato, Lastovo, Lumbarda, Mljet, Smokvica and Vela Luka, • Semi-island region: municipalities of Janjina, Orebić, Ston and Trpanj. The following regions have been singled out in the County area based on the geomorphological analysis of the continental part of the coastal area, bathymetric, physical and chemical and biological features: • External coastal zone and open sea • Koločepi Channel • Mljet Channel • Neretva, Korčula and Pelješac Channels • Župa Bay • Mljet Lakes • Omble estuary and Gruž port • Mali Ston Bay • Neretva estuary water area. Planning, management and protection of the sea as the most significant renewable natural resource in Croatia has a strategic meaning for a sustainable spatial development and as a large and complete ecosystem it ensures the conditions for a good quality of life. Areas important for spawning and preservation of younger, economically significant organisms must be protected. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds • Protected underwater cultural heritage and natural landscape.

National Park Kornati Spatial Plan (OG 118/03) **(*Prostorni plan Nacionalnog parka Kornati (NN 118/03)*)**	The Spatial Plan prescribes the following protection measures: • The natural appearance and features in nature zones must stay intact and unchanged and if they are distorted, measures for natural renewal of such areas must be taken. • Since the sea and its flora and fauna are perhaps the most important element of this area, the main task is to conserve that flora and fauna. Fishing is allowed in the park in accordance with the Ordinance on Internal Rules (OG 38/96) (*Pravilnik o unutarnjem redu (NN 38/96)*). Recreational fishing is allowed in certain areas but under surveillance and in accordance with the permit issued by a public institution. The conservation of flora and fauna is contingent on the mindful activities on the sea (sailing, anchoring, diving) as well as on land due to the possible changes in the sea water quality. A strict protection zone has been separated and defined within the area of National Park Kornati regarding the areas around the islet of Purara and cliffs Klint and Volić which are located nearby. The strict protection zone has been set 500 m from the coastline of those islets. Visits within the zone are forbidden without a special permit by the Park Management and without being accompanied by the Park supervisor.
National Park Mljet Spatial Plan (OG 23/01) **(*Prostorni plan Nacionalnog parka Mljet (NN 23/01)*)**	The Spatial Plan prescribes the objectives of good status conservation and protection of the sea, by conducting a rehabilitation of the existing status, which will be achieved by: • Taking measures to prevent accidental pollution • Organising collection of wastewater, waste oil and solid waste from ships.
National Park Brijuni Spatial Plan (OG 45/01) **(*Prostorni plan Nacionalnog parka Brijuni (NN 45/01)*)**	The main objectives and fundamental principles of protection and development of National Park Brijuni refer to environmental protection as an integral part of the area's development and use, both in terms of creation of the spatial planning documents and the space management system.
Nature Park Telašćica Spatial Plan (OG 022/2014) **(*Prostorni plan Parka prirode Telašćica (NN 022/2014)*)**	Protection of the sea is regulated by Article 106 of the Spatial Plan: • The Plan prohibits the discharge of oily water, waste oil, sanitary water from ships and all types of solid and liquid waste. • Protection measures from unusual pollution (for example, potential accidents of possible fuel leakage etc.) are taken over from the valid Spatial Plan of the Zadar County. • In the event of sudden marine pollution, the procedures and measures consist of the following operations: - Stopping the substance, oil and/or oil mixture discharge - Preventing further spreading of the discharged substance, oil and/or oil mixture - Collecting the discharged substance, oil and/or oil mixture from the sea surface or seabed, if appropriate - Disposing of the collected waste. Stated provisions relate to the following Strategic Study objectives: • Good status of the sea and the seabed • Good status of the maritime species and habitats

3 Data on the existing state of the marine environment and possible development of the environment, without the implementation of the Framework Plan and Programme

3.1 Physical characteristics

Oceanography is the study of the systems and divisions of oceans and seas and their depths, flows and deposits, physical and chemical properties of seawater, the transformation of various forms of energy in the oceans, heat relationships and ice, water currents with general oceanic circulation, interdependence with atmospheric processes, with oceanographic prognoses, biological processes and their application in daily life.

Physically speaking (sea) water and air are fluids with varying properties affected by temperature and pressure, and are of varying density and varying movement properties. A significant difference is that water contains dissolved matter (salts), which air generally does not. Pollution is excluded.

Specificity of research

In the oceans and seas, measurements and observations are primarily *in situ*, i.e. at a particular site, and it is difficult to conduct experiments. Processes in the sea are, as a rule, observed, and conclusions made on the basis of such observations. However, the development of numerical modelling and satellite measurements has led to great progress. Monitoring instruments and devices are set up on a variety of different basis, including ships, buoys, bathyscaphes, submarines, platforms, aircraft, helicopters, satellites and other.

The oceans and seas encompass a much greater area than land, where all forms of life and work are developed. Therefore, all that is on the Earth's terrestrial surface is present in even greater extent in/on the aquatic expanses of the oceans and seas. The development of oceanography determined its divisions, including in this case, *ecological oceanography*, which is a part of biooceanography that studies the relationships between living organisms and their environment, which includes the physiological adaptations of plants and animals to the environment and the geographical classification of plants and animals in relation to climate. A specificity is the “intentional” and “unintentional” disposal of waste.

3.1.1 Topography and bathymetry of the seabed

In the Adriatic Sea, depth gradually increases from north to south. The maximum depths in the Gulf of Trieste are 25 m, and do not exceed 50 m until the parallel of Kamenjak Cape. Towards the southeast, the depths are up to 100 m until the line connecting the Kornati islands and Giulianova, while in the area of Jabuka Islet, they sharply descend to 270 m. At the line connecting Primošten-Pescara, the seabed displays a lateral groove that has a total length of 64 nautical miles and average width of 10 miles. This is the Jabuka Pit, which extends towards the southeast to the Palagruža threshold, with an average depth of 170 m. This threshold divides the northern/central Adriatic from the southern Adriatic, where the seabed drops abyssally into the Southern Adriatic Pit, which has a circular shape and maximum depth of about 1240 m. Towards the Strait of Otranto, the seabed rises gradually, creating a submarine threshold with depths of 600 to 800 m. This threshold was created by the extension of the Apuglia carbonate platform from the Italian coastline towards the Albanian and Greek coastlines. The relief of the Adriatic seabed is shown in Figure 3.1 and the longitudinal section shown as a block-diagram of depth is shown in Figure 3.2.

Figure 3.1 Bathymetric maps of the Adriatic Sea (source: Peljar, 1999)

The map of seabed sediment distribution coincides closely with the bathymetric map, which is expected given the mechanisms of deposition of clastic (grainy) sediments (Figure 3.3). Details on the composition of the seabed deposits are available in the study by the Ministry of Environmental and Nature Protection entitled *Početna procjena stanja i opterećenja morskog okoliša hrvatskog dijela Jadrana* (Screening assessment of the state and burden of the marine environment in the Croatian part of the Adriatic), compiled in September 2012 at the Institute for Oceanography and Fisheries, Split (Peljar, 1999). The Adriatic sediment map separates coarse sand, fine sand, silty sand, sandy silt and silt. In general, a zonal distribution is observed from the coastline towards the west, from coarse sands towards increasingly silty deposits. Sandy silt is founded closes to the shoreline near Šibenik and Dubrovnik (Figure 3.3). These data are significant in the planning of drilling and the selection of an appropriate drilling rig.

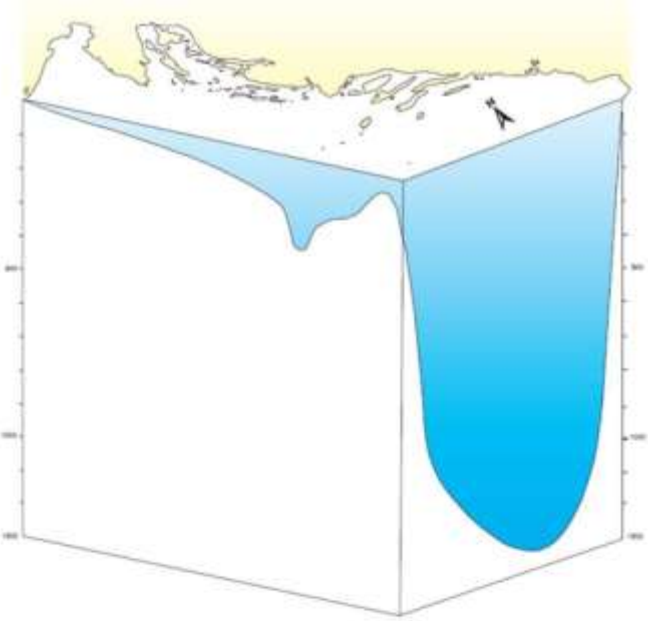


Figure 3.2 Longitudinal section of the Adriatic Sea shown as a block diagram (source: Peljar, 1999)

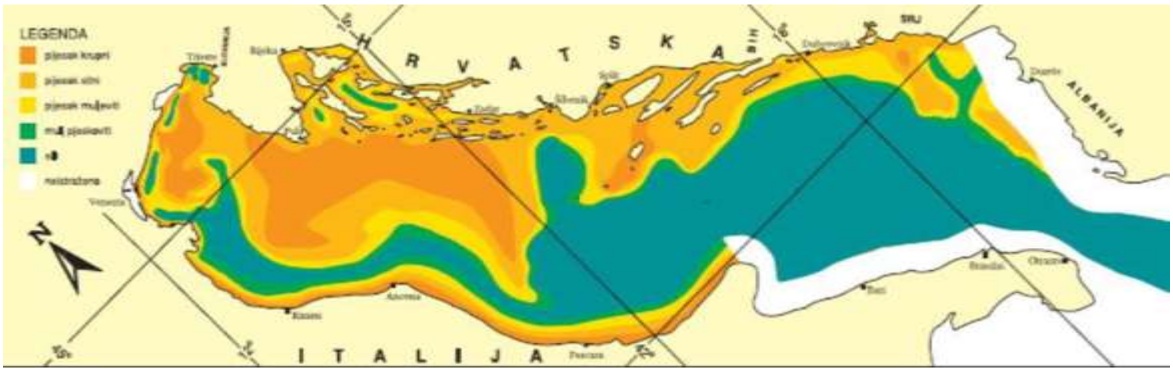


Figure 3.3 Sediment map of the Adriatic Sea (source: Peljar, 1999)

	Legend
pijesak krupni	Coarse sand
pijesak fini	Fine sand
pijesak muljeviti	Silty sand
mulj pjeskoviti	Sandy silt
	Silt
neistraženo	Not investigated

3.1.2 Heat energy

Heat is an energy state of matter, the energy of the overall molecular movement of that matter, while the ***temperature*** of a body is the indicator of the energy state of its matter and is relative to the average kinetic energy of the moving matter molecules. The quantity of heat that passes from one body to another due to a difference in temperature between those bodies is part of the internal energy of those bodies. This transfer of heat from one body to another causes an increase in temperature of the body receiving the heat (and a drop in the temperature of the body emitting the heat), and may cause changes to the aggregate state or other changes. Heat energy is generally emitted through the processes of ***radiation, convection and conduction***. Radiation is the expansion of energy in the form of electromagnetic waves that can spread in a vacuum or in a space. Convection is the spread of energy relating to the movement of matter particles that hold more or less energy. Conduction is the spread of energy through space, with the interaction of the matter of the space and the energy.

Solar energy (***short-wave radiation***) is the fundamental energy sources for the Earth's surface, regardless of the aquatic or terrestrial surfaces, including the atmosphere. Other than the Sun, ***all other energy forms are negligible***. This pertains to the heat of the Earth's interior and submarine volcanoes (with the exception of the deepest parts of the seas), wave motion, marine tides and currents, oxidation, radioactivity, and radiation from space. Considering that the mean air temperature over the entire Earth does not change significantly, this means that the Earth must return the same amount of energy back into space via ***long-wave radiation***. ***Aquatic surfaces*** are warmed and cooled differently than terrestrial surfaces. The transfer of heat energy in water takes place through the processes of ***radiation, convection and conduction*** of heat.

Through the year, the exchange of heat between the Adriatic Sea and the atmosphere display pronounced changes. With the changes in radiation, there are also the influences of different air masses, air currents, inflows and evaporation. In the summer months, the input of heat energy into the sea is highest during June and July, due to the pronounced solar radiation, particularly on the southern Adriatic. The inflow of warm sea currents from the Mediterranean Sea add to this. At that time, a ***thermocline*** is formed in the sea, which holds until the autumn, when it weakens and dissipates due to the negative heat balance on the surface and due to convection processes.

In the winter period (October to February), solar radiation is weaker, and due to evaporation caused by frequent strong winds, heat loss occurs. During longer periods of gale force Bora winds (north-easterly, cold and dry wind), the energy losses are known to be substantial (e.g. in the northern Adriatic). The consequence is a strong cooling of the water column, increase of density, convection processes and the emergence of high density water masses. On the annual scale the Adriatic Sea has the highest heat losses in the northern parts, though winds (Bora) also causes strong evaporation in other parts of the sea.

3.1.3 Properties of sea water

Sea water is ordinary freshwater in a ratio of 96.5% with the addition of 3.5% dissolved matter, and therefore seawater has a lower freezing point with increasing salinity (leads to the separation of the aquatic and salt phases). Water density increases with increasing salinity and decreasing temperature.

Salinity (S) is the total quantity of dissolved matter (salts) in a certain quantity of sea water, or this can also be described as the measure of salt concentration in sea water. In the laboratory, it is determined using a salinometer (on a pumped water sample), while *in situ*, it is measured using a hydrographic probe. It is expressed on a unitless scale or (in the earlier literature) in g/kg, ‰, 10^{-3}, or ppt. The majority of dissolved matter is comprised of sodium and magnesium salts, with a lower content of calcium and potassium salts in the form of chlorides or sulphates, carbonates and bromides. Various chemical elements are also found in sea water. Some gasses are present both in the atmosphere and in the sea (N_2, O_2, CO_2), though hydrogen sulphide (H_2S) is an important gas in the sea.

All the components of sea water play an important role in the sea, and their quantities affect living organisms. Therefore, the nutritional elements (effects on metabolism, organism shells) and phytoplankton blooms (phosphate consumption) are studied. In the seas, there is the gradual dissolution and decomposition of organic and inorganic matter. At that time, geochemical processes in the sea act to dissolve certain matter, while binding to other matter, and in those processes take on the role of sea cleaners. Often, living organisms also act as cleaners.

<u>Salinity of the Adriatic Sea</u>
The surface division of the salinity of sea water is the consequence of the ratio of evaporation and precipitation, while in smaller areas, it also depends on inflows of fresh water and the melting of ice at higher latitudes, and on currents and turbulent mixing. Together with temperature, salinity affects the density of the sea, and determines the properties of the water mass, etc. In the analyses of seawater salinity, auxiliary scales are applied to more easily monitor the salinity of an area. These are isohalines, as the lines that connect all points of equal salinity in the oceans or sea, and these are usually zonally oriented.

In the Adriatic Sea, the surface water balance is positive (receipt of precipitation and terrestrial waters is greater than evaporation), and so the values of surface salinity decrease from the southern towards the northern Adriatic. The freshwater input from the Po River and other rivers reduce salinity in the northern Adriatic in a narrow belt along the Italian coast (salinity 33–37‰), while water with a higher salinity (38–39‰) enters along the Croatian coast from the Ionian and Mediterranean Sea. Seasonal changes in salinity are observed in the northern Adriatic, particularly due to the season changes in flow of the Po River, which has the highest flows in the autumn (most precipitation) and spring (snow melt) periods, and in that area, a halocline is created in the surface layer and measures 5–20 m (Figure 3.4).

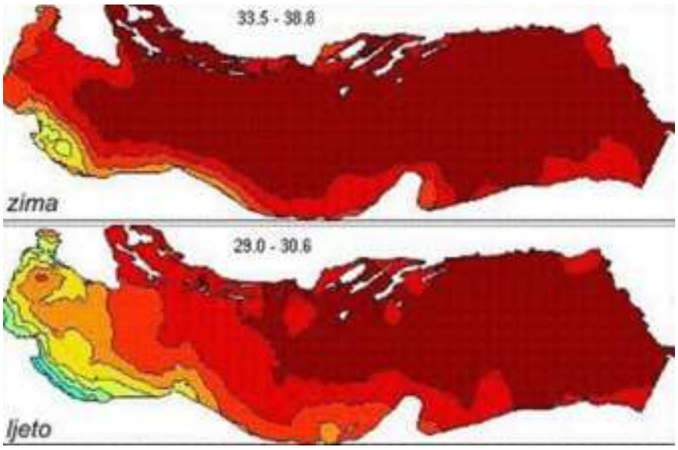


Figure 3.4 Division of mean salinity on the surface of the Adriatic Sea

	Legend
zima	winter
ljeto	summer

In deeper layers of the Adriatic Sea, salinity increases from the northern Adriatic (37.5–38.5‰) towards the southeast (38.5–39.0‰). The seasonal changes are poorly pronounced. The water flowing out of the Adriatic Sea has a lower salinity (Otrant: surface inflow 38.5–39.0‰, bottom outflow ≈ 38.5‰) (Figure 3.5). Salinity drops to under 30‰ during periods of high inflows of terrestrial waters.

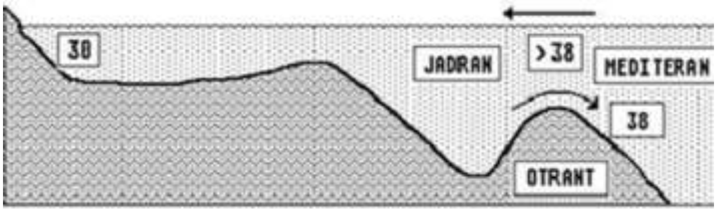


Figure 3.5 Salinity and water exchanges in the Adriatic Sea

	Legend
Jadran	Adriatic
Otrant	Otrant
Mediteran	Mediterranean

3.1.3.1 Temperature, pressure and density of sea water

The division of sea water temperatures depends on the heat exchange on the sea surface and in the coastal areas. The properties of water are important in relation to the changes in aggregate state (ice, water, steam), waves, currents and turbulent mixing in the sea and more. Together with salinity, temperature affects sea density, and determines the properties of the water masses, etc.

Isotherms, lines that connect all points of equal temperature, are typically zonally positioned (east – west). The highest temperatures follow the areas with the highest heat balance on the sea surface, and therefore have pronounced seasonal changes. An analysis of the isotherms of ocean surface temperatures show that temperatures > 20°C cover ≈ 53% of the ocean surfaces, while temperatures > 25°C cover ≈ 35% of the ocean surfaces. As a rule, temperature drops with increasing depth. With a progression into the sea depths, there is a layer in which the temperature suddenly changes, this is the thermocline. There are permanent, annual (or seasonal) or daily thermoclines. They are often associated with pycnoclines. In closed seas with temperatures near the isotherms, the influence of temperature changes can be seen to depths of up to 1000 m (Mediterranean Sea, Adriatic Sea).

<u>Temperature of the Adriatic Sea</u>

In the winter months, the lowest surface sea temperatures are in the northern Adriatic (7–10°C), and these increase towards the southern Adriatic (13–14°C). In the summer period, temperatures are less variable (22–26°C),though the sea is somewhat warmer on the western coast (by 1°C), while in the autumn months, the colder waters of the Po River reduce the temperature along the Italian coast. Meanwhile, in periods other than summer, temperatures are generally higher along the Croatian coast of the Adriatic due to the general cyclonic water currents. The Adriatic Sea is generally warmest in August and coldest in February (Figure 3.6).

Heat radiation on the surface of the Adriatic Sea has pronounced changes. In the spring period, the surface layer of the sea warms and a seasonal thermocline is formed, which is present to depths of 10–30 m. The thermocline is most pronounced in summer, when the sea surface temperatures are from 22 to 26°C. In autumn, solar radiation weakens and the thermocline weakens, but deepens to a depth of approx 100 m. In winter (January/February), the thermocline disappears, and the processes of convection and mixing equalise the temperature through the water column (Figure 3.7).

In deeper layers of the Adriatic, temperatures range between 11°C in the northern Adriatic and the Jabuka Pit to 14°C in the Southern Adriatic Pit and in the Strait of Otranto. The thermohaline properties of the Adriatic are created by the balance of heat and masses on the sea surface, the topographic and climatic properties of the area, and the exchange water masses with the Mediterranean Sea in the Strait of Otanto.

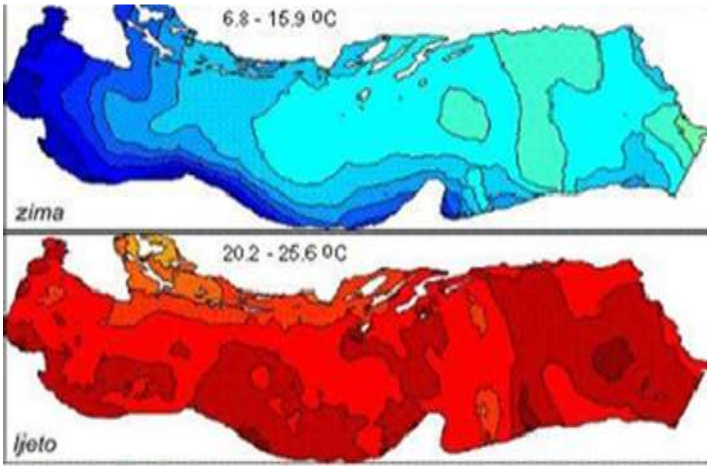


Figure 3.6 Division of mean temperature (°C) on the surface of the Adriatic Sea (Galos, 2000)

zima	winter
ljeto	summer

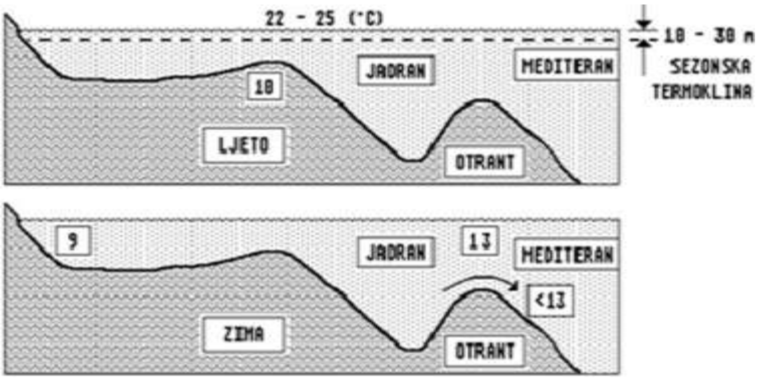


Figure 3.7 Temperature (°C) and exchanges of sea water in the Adriatic Sea

	Legend
sezonska termoklina	seasonal thermocline
ljeto	summer
Jadran	Adriatic
Otrant	Otrant
Mediteran	Mediterranean
zima	winter
Jadran	Adriatic
Otrant	Otrant
Mediteran	Mediterranean

<u>Pressure</u>

Pressure p in the sea is determined from the hydrostatic equation, i.e. the balance (Laplace equation) with sea density ρ, or more often the mean sea density, and depends on changes in depth ∂z and gravity g. In oceans, like in the atmosphere, the basic equations of fluid statics apply. This is most often expressed in decibars (1 dbar = 104 Pa; 100 hPa) as an increase in pressure of 1 dbar corresponds to an increase in depth of 1 m (Table 3.1).

$$\partial p = - g \rho \partial z \text{ or } \partial p / \partial z = - g \rho$$

Table 3.1 Association between pressure p and sea depth H (air pressure pA)

$p - p_A$ (10^4 Pa)	100	500	1000	2000	4000	8000
H (m)	99.14	495.27	983.41	1973.42	3928.88	7788.94

Density of seawater
The density of seawater determines the cinematics and dynamics of the oceans and seas, which is dependent on the density of sea water in the aggregate state of water and temperature. Small horizontal differences in density can cause very strong sea currents. The highest density of fresh water at 3.98°C is ρ_{fw} = 1000.0 kg m^{-3}. The density of seawater depends on salinity, temperature and pressure in the sea. The *density anomaly* is also applied, i.e. σ_t (sigma-*t*), [$\sigma_t = (\rho - 1)\cdot 1000$], and density is reduced by 1000 kg m^{-3}. There are other scales relating to the density of seawater (specific mass *s*, specific volume *α*). Isopycnics are lines that connected points of equal density, and they are also zonally oriented. Typically, colder and less saline waters have a higher density than warmer, more saline waters. In the sea, there are zones of sudden density increases with depth, usually at 500–1000 m, this is the *pycnocline*. The annual changes in the density of seawater are small, $\Delta\sigma_t \approx$ 1–2. Changes in the density of the Adriatic Sea are small, though the water may be thermally stable or instable, depending on density, and there are currents of the waters of the Mediterranean Sea and Adriatic Sea.

3.1.3.2 Other properties of seawater

The water mass is a great volume of seawater determined by the sea properties, particularly temperature and salinity. Water masses are not static, but are in motion, and as a result there may be collisions of water masses. There are various methods for their study (e.g. TS diagrams).

With regard to water masses, they can be stable or unstable, i.e. with vertical movements of seawater (raising, lowering) and in addition with regard to sea currents. These movements take place through processes on the molecular scale (diffusion), via mesoscale turbulent gyres and in synoptic scales such as the processes of *upwelling* and *downwelling;* Figure 3.8).

Deep convection occurs in the Adriatic Sea in the area of the Southern Adriatic Pit. In winter, due to pronounced losses of energy from the sea, the surface layer cools significantly and the water column becomes unstable. This colder and denser water sinks and mixes with deep water until the water density is equalised. The process of deep convection can extend to depths of ≈ 800 m.

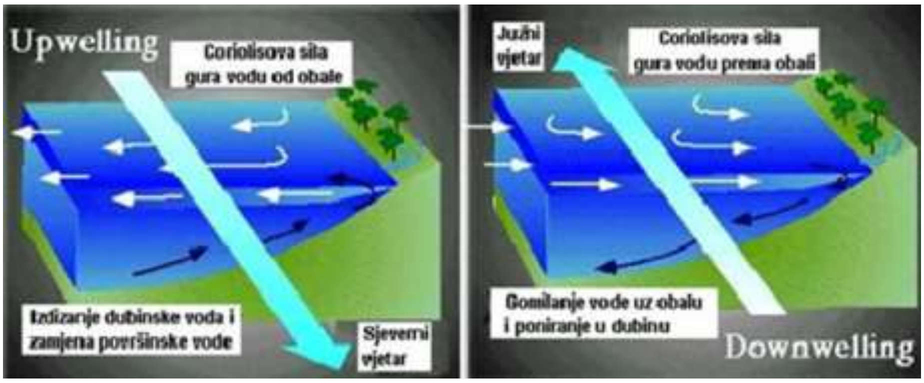


Figure 3.8 Dynamics of coastal upwelling and downwelling (2004)

	Legend
	Upwelling
Coriolisova sila gura vodu od obale	Coriolis force pushes water from the shore
Izdizanje dubinske vode i zamjena površinske vode	Deep water rises up to take the place of the surface water
Sjeverni vjetar	Northern wind
	Downwelling
Coriolisova sila gura vodu prema obali	Coriolis force pushes water towards the shore
Gomilanje vode uz obalu i poniranje u dubinu	Water accumulates at the shore and sinks to the bottom
Južni vjetar	Southern wind

3.1.3.3 Acoustic properties of the sea

Electromagnetic waves aid in transferring information from one place to another. In oceanography, this is primarily valid for the surface sea layer and through the spread through the air, i.e. atmosphere, and space. For the transfer of information from the sensor to the receptor in the sea, sound waves are usually used. Sound waves are able to spread through water and give or transport information (similar principles as in seismology).

Sound waves (compression, longitudinal) waves arise due to the compressibility of the sea, though this is very weak. It is often said that water is incompressible, which is valid in normal conditions. However, in conditions of very high pressure values that act on water, compressibility of water occurs. For the incompressibility of seawater, the sea level must be higher by 32 m.

Acoustic waves spread in all directions from the source, and represent the spread of sound. These waves have their trajectory, moving water particles in lines parallel to the direction of the spread of the wave, but they do not exclusively spread in a linear fashion. Instead there are curves to their trajectories or they are reflected. Breaking the wave depends on changes in density, i.e.

the temperature or salinity of seawater. The vertical speed of sound waves is much lower than their horizontal speed. This is due to the spread of sound waves primarily in a horizontal direction (an almost two-dimensional property).

The typical speed of sound in the oceans is 1480 m/s, though this depends on temperature, less on pressure and much less on the salinity of sea water:

$$c_z = 1448.96 + 4.591\,T - 0.05304\,T^2 + 0.0002374\,T^3 + 0.0160\,D +$$
$$+ (1.340 - 0.01025\,T)(S - 35) + 1.675 \times 10^{-7} D^2 - 7.139 \times 10^{-13}\,T\,D^3$$

where: cz is the speed in m/s, T is the temperature in ºC, D is the depth in metres, and S is salinity, accuracy ≈ 0.1 m/s.

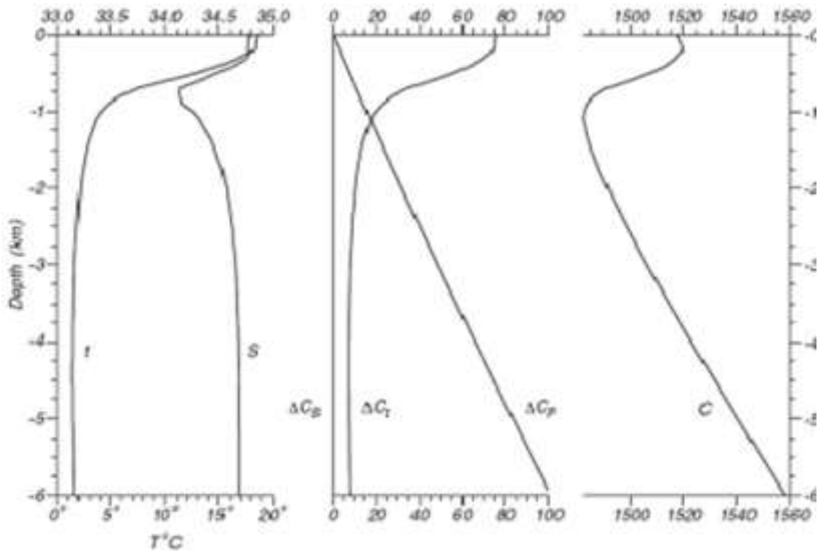


Figure 3.9 Sound channel in the ocean. Left: change in temperature T and salinity S with depth (km) (cruise of the R.V. Hakuho Maru KH-87-1, station JT, 28.01.1987, 33º52.90' N, 141º55.80' E, northern Pacific Ocean). Middle: changes in the speed of sound due to changes in temperature (ΔCp). Right: speed of count that is depth dependent (lowest speed at ≈ 1 km depth) (Stewart, 2006).

The highest speed of sound is at a temperature of 74°C. At the sea surface, the speed of sound ranges from 1400 m/s (Finnish Sea) to 1550 m/s (Red Sea), while in the Philippine Trench at a great depth of 10,000 m, the speed of sound reaches 1631 m/s (in an atmosphere of ≈ 340 m/s). The approximate values of the change in the speed of sound are: 40 m/s for a 10°C increase in temperature, 16 m/s for a 1000 m increase in depth and 1.5 m/s for a 1 increase in salinity. It is evident that the influence of salinity is the weakest of these factors (Figure 3.9).

The changeability of the speed of sound due to temperature and pressure creates a vertical ***sound channel*** in the ocean, in which the lowest speed occurs at a depth of ≈ 1000 m (10–1200 m depending on the geographic area, in high latitudes this approaches the sea surface). The sound in the channel travels over large distances. Namely, the sound waves that would start under an angle less than the horizontal direction outside the channel are bounced back in towards the centre of the channel. Very low frequency sounds (< 500 Hz) in the sound channel can travel very far, and can even be detected at distances of 1000 km, occasionally half way ≈ globe and is not interrupted by land.

The absorption of sound by unit distance depends on the strength of the sound I:

$$dI = -\,k_z I_0\,dx$$

where I_0 is the starting strength, and k_z is the coefficient of absorption that depends on the sound frequency. The solution is:

$$I = I_0 \exp(-\,k_z x)$$

For a sound frequency of 1000 Hz, k_z = 0.08 dB/km, while for 100 000 Hz, k_z = 50 dB/km. Decibels are calculated as: dB = 10 log (I/I_0), where I_0 is the initial strength of the sound, and I is the strength after absorption. For example, at a distance of 1 km, a sound of 1000 Hz is muffled only by 1.8%, i.e. I = 0.982 I_0, while a sound of 100 000 Hz is reduced to $I = 10^{-5} I_0$. A sound signal of 30 000 Hz, which is typical for echosounders for the measurement of ocean depths, is muffled only slightly on the path from the sea surface to the sea bed and back.

It is believed that sound waves are not significant in fundamental oceanographic considerations, except for special purposes. The use of sound waves becomes pronounced in the measurements of individual properties, positions (levels) or movements of seawater. As such, salinometers, as devices that determine the salinity of sea water, determine salinity independent of the speed of sound waves, while validating other physical properties of the sea water, such as: density, the fracture index and electrical conductivity. Often, instruments used to measure salinity are also associated with other instruments, i.e. such as those to measure water currents. Sound waves can reveal various sources of sounds/murmurs over great distances and can directly detect various objects. Examples are the hum of submarines, listening and revealing the position and paths of whales at distances of up to 1700 m, revealing the position of submarine volcanic eruptions, and for many other needs. However, in oceanography, measurements of the sea depth, marine currents and waves are very important.

Ocean depth is measured from ships using echosounders, which measure the time necessary for a sound bundle of 10–30 kHz to travel from the sea surface to the sea bed and back. The interval between the sending of the pulse and the receipt of its echo, multiplied by the speed of the sound, gives twice the ocean depth. Accuracy is ±1%. It should be noted that the horizontal discrimination of such measurements is often very weak.

Satellite altimeters measure the position and shape of the sea surface. As local shapes of the surface depend on changes in gravity due to underwater forms, this can also be used to measure ocean depth. A combination of ocean depth measurement from ships and measuring positions and forms of sea surfaces from the satellite gives depths to an accuracy of ± 100 m with a horizontal discrimination of ± 3 km.

There are current meters that send out sound waves and measure the Doppler shift (in the frequency) of sound waves that are refracted from the movement of sea water particles. These are Doppler current metres. They use multiple bundles of sound waves in various directions, and can determine the direction and speed of marine currents in dozens of sea layers, which can depend on the frequency of the emitted signal. Wave meters (ondographs) measure short-period (< 1 min) oscillations of the sea level *in situ*. These are, for example, inverse ultrasound depth meters installed on the sea bed.

3.1.3.4 Optical properties of the sea

The sun's rays reach the Earth's surface and transfer energy in the area of short-wave radiation (0.2–4 µm), which encompasses the visible spectrum (0.4–0.76 µm). The visible spectrum of the sun's rays enters at an angle onto the sea surface, which depends on the time of day and year, and on the state in the atmosphere. The depth of penetration of certain sections of the spectrum into the water determines the optical properties as visibility, i.e. transparency, the colour of the sea water, limit of assimilation, which contribute to the degree of warming of the sea water.

In addition to reflection and refraction of light (which is dependent on temperature and salinity) at the border of the sea and the atmosphere, the diffusion and absorption of light in the sea, i.e. the weakening of light (extinction) is also important.

Light weakening is pronounced. The blue part of the spectrum penetrates the deepest, followed by greens and yellows, while oranges and red are weaker, and the infrared spectrum (heat) is weakest. Of the radiation input, at a depth of:

1 cm there is	73%,		
1 m there is approx.	38%,	100 m	0.45% radiation, while at
10 m	16%,	300 m	there is complete darkness for the human eye.

Transparency is a concept that is related to the penetration of light rays into the sea depth. Transparency increases with the decrease of nutrient particles, where there is no inflow from land and where water sinks due to high salinity (no inflow from the depths), and there is no plankton. In such conditions a strong blue colour with purple tones is prominent (Sargasso, Mediterranean and Adriatic Seas).

Sea *phosphorescence* is created by marine organisms (flagella, crustaceans, polychaetes, medusa and tunicates) as a result of their internal processes. The strength of this phosphorescence is not strong, and thus can only be seen at night. These include rays and round forms, light surfaces, balls, circles, lines; depending on whether these organisms are still or at motion. The greenish phosphorescence is usually seen on summer nights, and may appear at the peak of a wave or in a boat's wake. There are larger organisms and deep-sea fish that also produce light.

3.1.4 General sea state

Dependent on water movements. The water in the seas and oceans is in constant movement, both in relation to the seashore and in relation to the seabed. The movements of seawater are vector scales that describe the direction and amount of movement of water particles, and can occur in different ways. These are sea currents, wave movements and gyres. Water movements are caused by higher forces. With the basic forces, such as the gravitational pull of the Moon and the Sun, gravity, pressure differences (force gradient) is also an important force. This includes the Coriolis force due to the Earth's rotation. Movements with curved trajectories also include centrifugal force, while drag and resistance reduce currents or cause them to stop.

Sea level represents the border surface between the atmosphere and the ocean or sea. It changes its position in space and time through the action of many factors. There are long-period (> 1 min, tides) and short-period changes (oscillations of sea level), waves. There are simple and complex changes to sea level. Simple changes are due to changes in the water mass relating to evaporation, precipitation, inflow of rivers and ground waters, creation or melting of ice. Furthermore, changes in atmospheric pressure inversely affect sea level (1 hPa ~ 1 cm), while temperature affects the thermal expansion and contraction of water. Complex factors are in the tides (with horizontal water movements – tidal currents), winds (currents, waves), gravity (waves), seiches (waves within 'basins'), storm surges (anomalous raising/lowering of sea level caused by the action of atmospheric pressure and winds on the sea), seismic disturbances (tsunami waves), due to distributions of temperature and salinity of seawater (density and water movements), surface pressure (and movements) and stability (vertical, and water movements).

The sea state is a scale of the appearance of waves on the sea surface that is ranked with the numbers from 0 to 9, similar to the corresponding scale for wind on land or sea (Beaufort scale).

Changes in sea level. Significant changes in sea level are observed on the oceans and seas, which show not only seasonal changes, but general multi-year global trends. Over the past century, the sea level has risen by ≈ 18 cm. Seasonal changes in sea level are the results of expansion/contraction of the sea column under the influence of heating/cooling of the surface layer, of changes in atmospheric pressure and winds, and of the water balance at the sea surface, depending on changes in circulation in the sea, tectonic shifts and more. These fluctuations of sea level can amount to tens of centimetres over the course of the year, though on average do not exceed 10 cm.

The Adriatic Sea exhibits seasonal oscillations of sea level, primarily due to the seasonal changes in the heat radiation balance at the surface, and changes in atmospheric pressure of the air and winds are important, as they change sea level with an inverse barometric factor of ≈ -2 cm / hPa (Vilibić et al., 2002). Changes in the water balance on the sea surface affects changes to the level of the Adriatic Sea. The amplitude of seasonal changes of sea level is ≈ 6 cm. The multi-year change to the mean sea level in the Adriatic is several centimetres (Figure 3.10). The flooding of coastal areas in the northern Adriatic (low pressure and strong southerly wind Scirocco) can be pronounced.

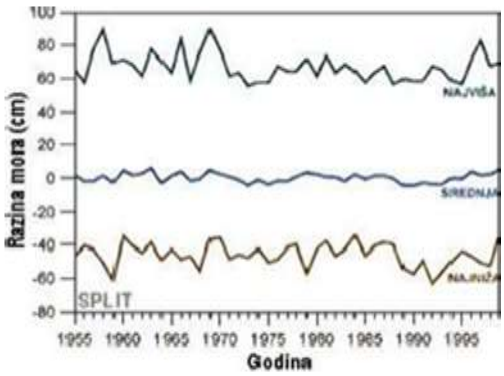


Figure 3.10 Maximum, mean and minimum annual sea levels

	Legend
Razina mora (cm)	sea level (cm)
Godina	year

The change in sea level depends on the *water balance* on the sea surface, i.e. whether there is more or less water. Such changes can be the result of evaporation or precipitation, and in the coastal areas due to inflows of surface and ground waters from land. The surface of the Adriatic Sea receives increased precipitation in late autumn and early winter. Evaporation is increased during the winter months, and decreased during the summer period. Due to larger temperature differences between the sea and the air in the winter than in the summer months, evaporation is more prominent in winter. The winds also blow harder and more often in winter, further spurring evaporation. River inflows are pronounced, particularly from the Po River, which contributes almost 1/3 of the complete inflow into the Adriatic Sea. The lowest river inflows occur during summer and early autumn, while during the remainder of the year there are inflows of precipitation waters (particularly in winter) and snow melt (spring). The water balance on the surface of the Adriatic is positive, i.e. the Adriatic receives more water than it loses.

Storm surges are changes to the mean sea level under the influence of atmospheric pressure and winds on the sea, with a favourable shape and topography of the seabed and shore. In open waters, oscillations can be up to 1 m, while in coastal areas, due to the topography, this can reach several metres and cause flooding with damages and the destruction of coastal structures. Such anomalies of raising (or lowering) the mean sea level depends on the strength and distance from the cause of the disturbance. Storm surges on the Adriatic appear following long-lasting (multi-day) blowing of the south-westerly Scirocco wind along the entire Adriatic, or a larger part of the sea. This often leads to the flooding of certain coastal areas in the northern Adriatic (particularly Venice). Such Scirocco winds are associated with broad Geneva cyclones and anticyclones that expand over the eastern Mediterranean. The raising of the sea level in the northern Adriatic can be caused not only by winds, but also as a result of a strong drop in atmospheric pressure.

In addition to the positive surges that flood coastal regions, there are also negative surges that follow the long-lasting presence of gale force north-easterly Bora winds, which force the water mass towards the Italian coast of the Adriatic Sea. The influence of atmospheric pressure to the wind is significant, and the sea level can be reduced by more than 30 cm.

3.1.5 Sea currents

Marine currents are the movement of sea water parcels, generally in a horizontal direction. This is a narrow current of water (thickness of several hundred metres, width of several tens of metre, and more than a thousand kilometres in length) moving at a rate of 0.1 to 4 m/s, which appears at the surface and at various sea depths. Surface currents are more pronounced than currents with changing depth. Currents show changes in direction and rates in relatively small areas, particularly in coastal areas. Marine currents arise through the activity of meteorological or other natural processes: action of wind, the Sun and Moon, fluctuations of sea level, due to the temperature and salinity of sea water (density), atmospheric pressure, evaporation and precipitation, freezing of water and melting of ice, and more. The direction of movement, for horizontal movements, is expressed using the geographic sides of the world denoted in the direction of water flow. Careful, these are contrary to the expressions in meteorology! These are the directions that a ship sails! There are a series of divisions of sea currents depending on the causes for their development and their properties, including warm and cold currents, depending on the temperature of the current in relation to the surrounding sea water.

3.1.5.1 Geostrophic currents

Geostrophic currents (basic currents for consideration) arise in the open sea when sea water is under the influence of horizontal division of pressure, and the water parcel is at rest (point (0), Figure 3.11). The gradient force G acts on the water parcel, initiating movement in which the Coriolis force C_o appears, turning the parcel to the right, where it is found at point (1) (parcel accelerates), then at (2), to finally come into a balance between these two forces, i.e. the gradient and Coriolis forces, to be a geostrophic balance. The water parcel continues to move due to languidity (negligible drag) parallel with the isobars, and the low pressure is on the left side (northern hemisphere).

Due to the action of resistance/drag, the rate of flow is reduced, the Coriolis force is reduced and the balance between the gradient and Coriolis force is lost. The gradient force becomes dominant over the Coriolis force, and the water parcel moves towards the lower pressure areas. With the turning of the current, the force of resistance/drag is regained. The force of resistance/drag cannot be expressed with a simple expression, as it depends on many factors temperature, salinity, convection, stability, changes in current, etc.).

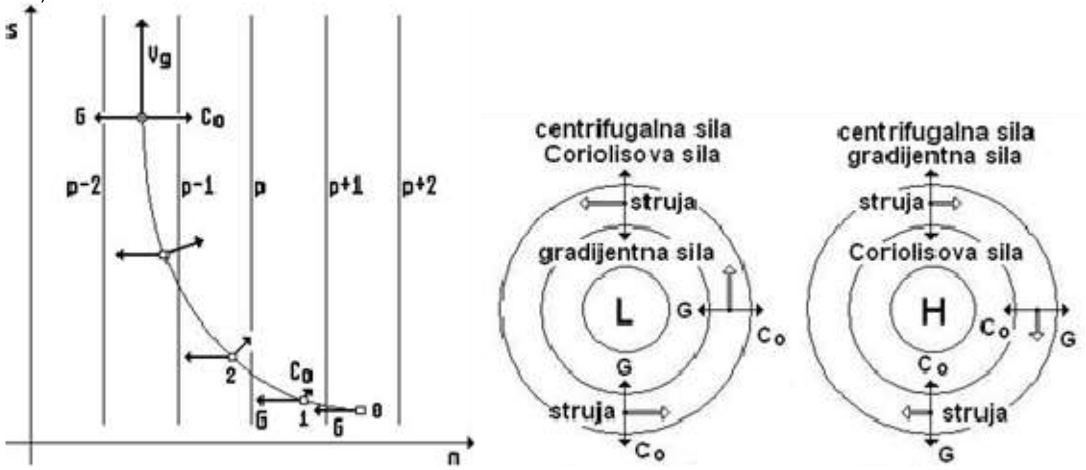


Figure 3.11 Achieving a balanced state for geostrophic flow with straight isobars (left) and geostrophic flow in the sea in the northern hemisphere under curved isobars.

	Legend
centrifugalna sila	Centrifugal force
Coriolisova sila	Coriolois force
struja	Current
gradijentna sila	Gradient force
struja	Current
centrifugalna sila	Centrifugal force
gradijentna sila	Gradient force
struja	Current
Coriolisova sila	Coriolois force
struja	Current

Current – a "thermal wind" is a change in the geostrophic current with depth due to the horizontal division of temperature (density) of water in the layer between the levels at which the corresponding geostrophic currents are found. The current "thermal wind" flows parallel to the isopycnics, with water of lower density on the right side ("*light water on the right*") for the northern hemisphere (and on the left in the southern hemisphere). Changes in water temperature give rise to changes in water density, making the vertical changes in density much greater than the horizontal changes.

The relations of the isobars and isopycnic surface, i.e. the barotropic and barocline fields, show the types of currents in the water column. Normally, the density of sea water increases with depth, while temperature and salinity decrease. However, pressure prominently increases with depth, and the isobars or isopycnic surfaces are usually sloped. The slope of the isobar surface is ≈ 10^{-5}, and the isopycnic surface ≈ 10^{-3}, meaning that the isopycnic surfaces are much more sloped than the isobaric surfaces. When the slopes of the isobar and isopycnic surfaces are the same, there is no vertical shift in the current, making it a barotropic plane. Flow is also present when the sea level is sloped. Then the current at the surface is equivalent to that at the depths. A barotropic state is when the planes of equal density (isopycnics) are parallel to the planes of equal pressure (isobars). With the sloping of the sea surface, the isopycnic surfaces also slope, and there is the presence of a horizontal pressure gradient with the current – barotropic current. To preserve the barotropic state, the sea must be uniform, as the isopycnic and isobaric surfaces must be parallel through the entire water column. This is possible in vertically homogenous seas.

A barocline field is when the current increases with height (decreases with depth). The barocline state occurs when the planes of equal density intersect the planes of equal pressure. When the slope of the isobars is relative to speed, there is geostrophic current, while when the horizontal density gradients and corresponding slopes of the isopycnics are relative with the changes in speed by depth or with the vertical shift, then there is thermal current. This state is found in stratified seas, when the current alters with depth, that is barocline current. A barocline current in open sea areas can be determined using classic dynamic balance methods, these are geostrophic currents.

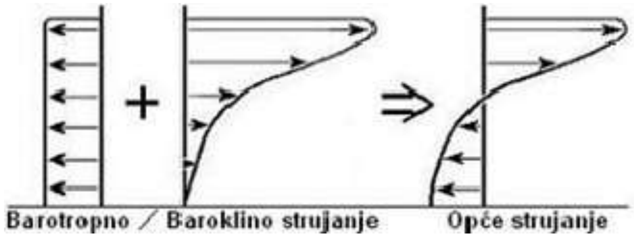


Figure 3.12 Schematic overview of the breakdown of current into its components

	Legend
Barotropno / Baroklino strujanje	Barotropic / Baroclinal current
Opće strujanje	General current

Most often, barotropic and baroclinal currents occur simultaneously. The baroclinal component can be determined using geostrophic approximation, while the barotropic component is determined by measurements or by using specific approximations (Figure 3.12).

3.1.5.2 Wind activity

Wind currents – Ekman currents occur through the action of lasting and strong winds at sea (e.g. wind 8–10 m/s gives a current of ≈ 15 cm/s). They are quite prominent and lasting, and due to the existence of drag reach greater depths (200 m). The current will be strong if the speed of the wind is high and without substantial changes in speed and direction and if it blows long enough over a larger aquatic surface without barriers (islands and coastlines). The current will not flow in the direction the wind blows, instead, due to the Coriolis force, it will deflect 20 to 45° to the right of the wind (northern hemisphere). On the southern hemisphere, the deflection is to the left.

The angle of the deflection depends on the drag of the water on the seabed, particularly in shallow seas. The consequence of the blowing of the wind is the transfer of water to the right of the wind direction (northern hemisphere), where water accumulation occurs and the sea level rises. If the wind is blowing parallel to the coast, i.e. the Scirocco wind on the Adriatic, then the sea level will be increased on the eastern coast of the Adriatic Sea, while it will be reduced along the western coast (Italy). The accumulated surface water along the eastern coast sinks (downwelling), while there is a raising of water from the depths (upwelling) along the western coast where the sea level was in decline, in order to compensate for the “lack” of surface water.

Cyclonal wind currents transport water with the divergence of surface waters as a result of the decrease of the sea level in the middle of the cyclone. Therefore, the shortage of water in the middle of the cyclone is compensated for by a rise of subsurface water (upwelling). In the opposite anticyclone direction, there is convergence, and the sea level rises which leads to a sinking of the excess surface water (*downwelling*).

There wind currents are compression currents, though with the redistribution of the mass field, changes occur to the slope of the sea surface, and these are also slope currents, relative currents. Wind currents can dominant the current field of the coastal seas (such as the Adriatic).

In the flow of a fluid over a surface, the force of drag appears. It is evident that there is a deflection in the flow of water with depth, which is to the right in the northern hemisphere. This deflection increases until the direction of flow takes on the direction opposite to that at the surface (Figure 2.13). This occurs at depths of 50 – 200 m, and is called depth drag D (Table 3.2).

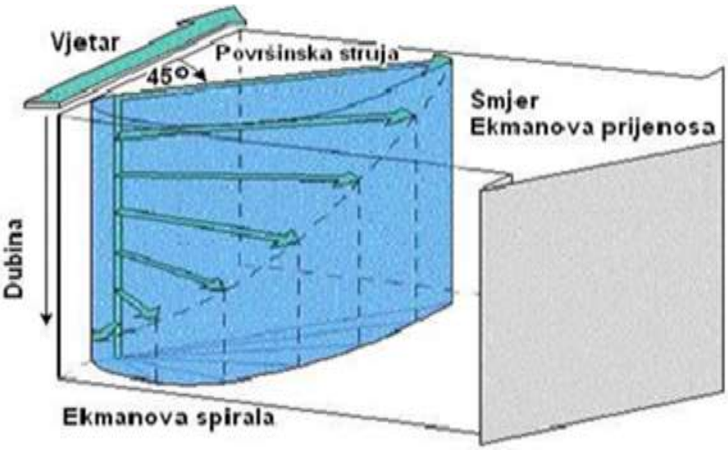


Figure 3.13 Wind currents in the surface layer with depth drag. The flow turns with depth – Ekman spiral and water transfer (Talley et al., 2006)

	Legend
Vjetar	Wind
Dubina	Depth
Površinska struja	Surface current
Smjer Ekmanova prijenosa	Direction of Ekman transfer
Ekmanova spirala	Ekman spiral

Table 3.2 Values of deep drag D, wind velocity V, surface current V_0, coefficient of turbulence drag Az at various latitudes φ (Pond & Pickard, 1983)

Latitude *φ* (º)	10	45	80	
V_0 / V	0.030	0.015	0.013	
Wing velocity V (m/s)	Depth drag D (m)			Az m^2s^{-1}
10	100	50	45	0.014
20	200	100	90	0.055

Depth drag and the angle of deflection depend on the amount of drag. In shallow seas, there is also the drag of the seabed, which impacts the currents above the bed. The angle of current deflection depends on the drag of water on the seabed, which is particularly high in shallow seas, and larger drag gives a lower angle.

The main characteristic of wind currents are (Figure 3.14, Figure 3.15):

- surface currents are deflected by 45° to the right in relation to the direction of the wind, which is valid for the northern hemisphere, while the deflection is to the left in the southern hemisphere,
- the velocity of the current exponentially drops with depth, in which the current vector turns clockwise in the northern hemisphere (counterclockwise in the southern hemisphere). This is called the Ekman spiral.
- the total transfer of the water mass caused by the wind is directed 90° to the right in the northern hemisphere (to the left in the southern hemisphere). When the wind blows along the coast, water will sink along the coast to the right, while water will rise up on the coast to the left, and vice versa when the wind direction is opposite (Figure 3.15). In open waters, Ekman suction occurs which results in the vertical movement of water due to the horizontal changeability of the wind field over a certain area (Figure 3.14).
- in shallow waters, the influence of current deflection is weak, due to the effect of drag from the seabed.

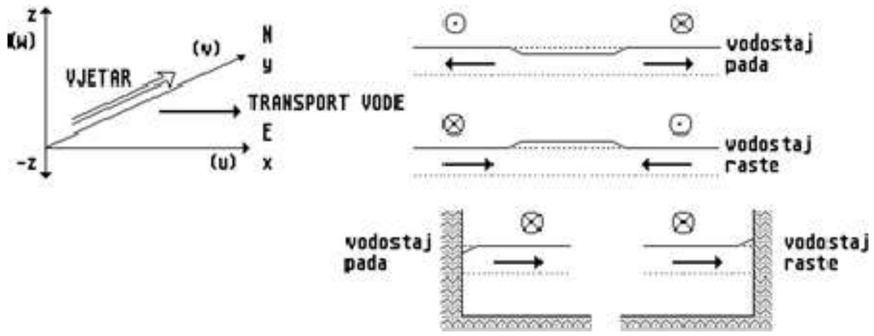


Figure 3.14 Wind action on the transport of water (northern hemisphere)

	Legend
Vjetar	Wind
Transport vode	Water transport

Vodostaj pada	Water level drops
Vodostaj raste	Water level rises

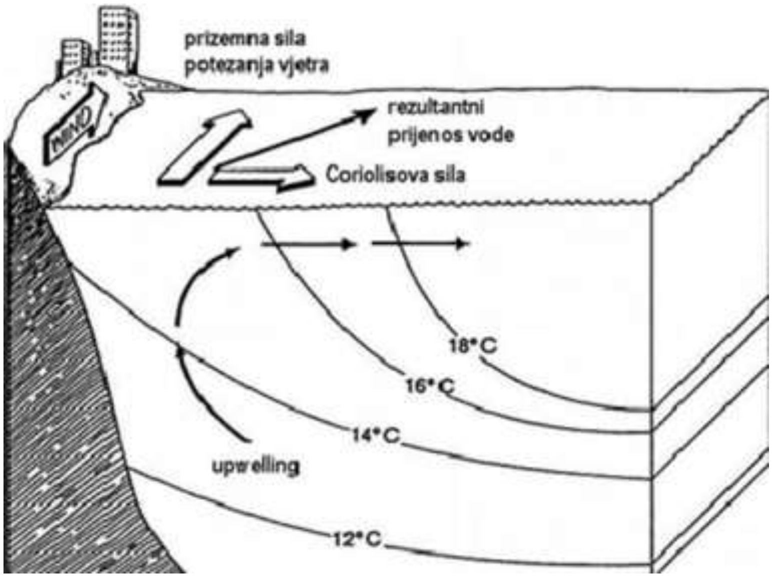
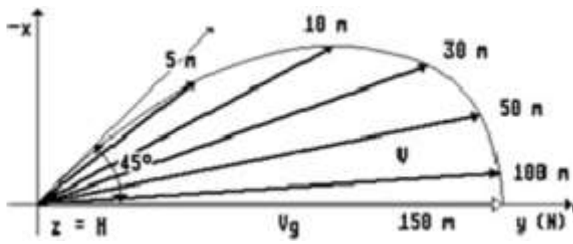


Figure 3.15 Wind action on the transport of water with the upwelling of colder water (northern hemisphere) (Fett, 1979)

	Legend
prizemna sila potezanja vjetra	Surface forces, Wind pull
rezultantni prijenos vode	Resulting water transport
Coriolisova sila	Coriolis force

Smaller marine currents can arise from the eddy of air in the lee of large orographic barriers, where they often flow opposite of the expected direction, and can lead unwary crews and vessels to shipwreck.

Slope currents arise due to the slope of the sea surface (≈ 1:10[6]) and the horizontal changes in pressure. The current is perpendicular to the direction of slope of the sea surface, or parallel to the isobars, and gives the amount for the geostrophic current. This is a relative current, as it is usually unknown as to the exact position of the sea surface in relation to one of the isobar surfaces. Upon approaching the sea bed, the amount of the current drops due to drag, and the direction of the current decreases in the direction of the falling pressure values (Figure 3.16).



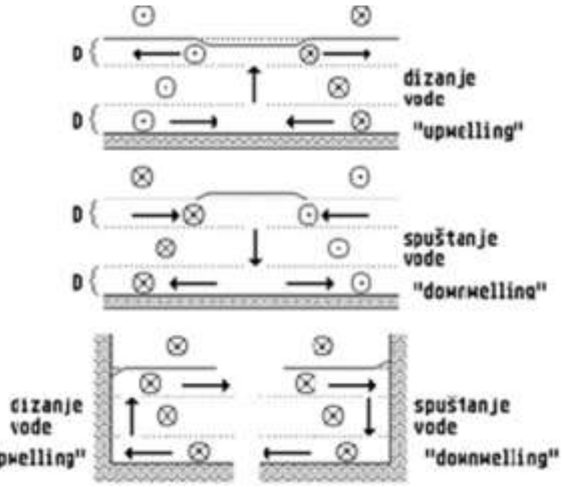


Figure 3.16 Current of water above the seabed

Figure 3.17 Upwelling and downwelling of water

	Legend
dizanje vode	Water rises, upwelling
spuštanje vode	Water sinks, downwelling
dizanje vode	Water rises, upwelling
spuštanje vode	Water sinks, downwelling

The transport of the water mass above D is in the direction of the x-axis, while nearer to the seabed, transport is in the direction of the geostrophic current, and in the direction of the falling pressure values, with the appearance of upwelling and downwelling (Figure 3.16).

At a certain depth, there may be a balance of two columns of seawater of varying properties, when:

Column A (high and less density) = column B (lower and greater density).
At that time, the slope of the isopycnic surface is contrary to the slope of the surface.

This has a significant role in life in the seas, i.e. in marine biology. In areas of upwelling, the living conditions are favourable and there are more plankton and fish. The relative currents are formed due to the slope of the sea surface (≈ 1:10^6) and horizontal pressure changes, though the exact position of the sea level in relation to an isobaric surface is unknown. The current is perpendicular to the direction of the slope of the sea surface, i.e. is parallel with the isobars and gives geostrophic current.

The action of atmospheric pressure on the sea depends on the density in the sea or in the atmosphere. The ratio of atmosphere/sea for density is 1/1000. When the wind speed is 10 m/s, this is an influence on current velocity of 0.01 m/s, therefore, it is evident that atmospheric pressure is not of great significance.

3.1.5.3 Thermohaline currents

Current gradients depend on the distribution of water density, i.e. temperature and/or salinity. Changes in the density of sea water with depth are much greater than the horizontal density changes, and therefore at areas with low water density there is vertical current (upwelling point), though there are also downward currents (downwelling points), which gives rise to thermohaline circulation. This is a circulation of water of the type of a “thermal wind”, i.e. thermal current, and water with lower density (lighter) is found to the right side of the current (northern hemisphere), i.e. that rule of "*light on the right*" applies. There are similarities with thermal winds in meteorology. Thermohaline currents are much weaker than winds. However, the thermohaline circulation dominates the wind current in certain coastal areas and in the deeper layers of the ocean. However, the wind and gradient sea currents can act together, giving rise to lasting sea currents (Figure 3.18).

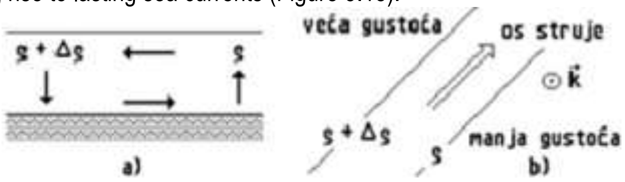


Figure 3.18 Thermohaline currents in the sea

	Legend
veća gustoća	Greater density
os struje	Current axis
manja gustoća	Lower density

As such, the influence of density of sea water on marine currents is seen in the fact that waters with low density rise, creating upwelling, and vice versa, waters with greater density sink, and the relations between these two processes creates thermal currents.

3.1.5.4 Other type of currents

Tidal currents arise due to the action of the Moon and the Sun that move the water masses. These periodically rise and fall (tides – high tide and low tide) and also move in a given direction. The rise (fall) of the water mass is quite large and the velocity of these currents is high, with rates in open waters of ≈ 0.1 m/s, while near coasts they can be very high in some places (Seymour Narrows, western Canada, to 8 m/s; Orkney Islands, Scotland 5–6 m/s). In addition to high velocities, these currents are also marked by a pronounced change in the direction of water movement (by 180°) in line with the tidal periods. The importance of tidal currents is most evident along sea coasts with very high tides (of several metres), when they are seen as a wall of water that approaches at great speed. The changes in the direction of the tidal currents takes place ≈ 3 h after high or low tide is reached, i.e. in the period in between.

Sea currents of two basins. Due to high air temperatures and increased evaporation in the basin, sea water is more saline, denser and heavier and thus it sinks (lowering the sea level) and exits near the floor of the basin into the open waters, while the less saline water of the open waters enters into the basin as a surface current. An example of this is the exchange of water between the Mediterranean and the Atlantic (Figure 3.19). Contrary to this is the inflow of lighter, fresh water into the basin (raising sea level), which then exits the basin as the surface, less dense water into the open waters, while the denser waters of the open seas enter the basin near the floor. An example of this is the exchange of the water between the Baltic Sea and the Atlantic Ocean. This is also the case between the Black Sea and the Mediterranean Sea.

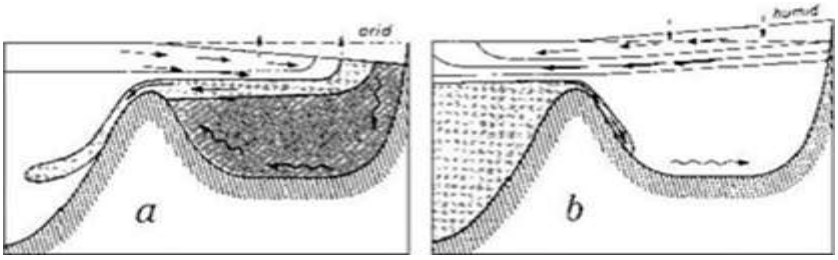


Figure 3.19 Exchange of water between two basins; a) dry, b) wet areas, darkened, denser water, → sea currents, ~~~> gentle expansion (Dietrich, 1978)

In the Adriatic, in relation to the Mediterranean, the entry current dominates in the winter months, while exit currents dominated in the summer. The appearance of the north-easterly Bora wind strengthens radiation and evaporation, and the sea water becomes denser, while the terrestrial waters are of reduced density, such that there is a southeastern current along the eastern coast (rule "light on the right").

A gyre is an approximately circular formation in fluid, whose dimensions in the sea vary from turbulent (centimetre or less) to synoptic (≈ 100 km) scales, and they arise as a consequence of an instability of various wave disturbances in the current field. As such, smaller sea currents can be created by a funnelling of wind in the lee of large orographic barriers, where they flow opposite to the expected direction, and can lead unwary crews and vessels to shipwreck.

Turbulence is the irregular movement of fluid parcels. These are three-dimensional gyres of various dimensions and variable kinetic energies. Turbulence contributes to the transfer of impulses, heat and matter in fluids, and arises due to instabilities.

Inertia current (oscillations) is a horizontal circulation of water parcels in the sea (centrifugal and Coriolis force are at balance). The northern hemisphere has an anticyclonal circulation. In moderate latitudes the period is ≈ 17 h, and the radius of the circle depends on the speed of parcel movement and on latitude (typical radius ≈ 1 km). These oscillations in the sea are caused by wind, while such currents in the atmosphere quickly dissipate. Such movements appear when the wind suddenly stops, but the water continues to move on inertia, turning towards the right.

3.1.5.5 Currents in marginal seas and the Adriatic

In marginal seas (Mediterranean Sea and others), and in lakes, lasting (stationary) circulation is, as a rule, in a cyclonic direction (counterclockwise). The exception is Lake Aral.

Figure 3.20 Scheme of the general circulation of water in the Mediterranean Sea, which includes the fundamental flow of currents in the Adriatic Sea (Tomczak & Godfrey, 2005)

	Legend
Almerijsko-Oranska fronta	Almeria-Oran Front
Alžirska struja	Algerian Current
Mersa Mathru vrtlog	Mersa Matrug Gyre
Shikmonski vrtlog	Shikmon Gyre

The basic circulation in the Mediterranean Sea, which includes the Adriatic and Black Seas, is shown in Figure 3.20. General circulation consists of multiple individual currents, which include multiple larger or smaller gyres. In reality, this circulation is even further divided into many smaller compartments. The entry current from the Atlantic when entering the Mediterranean flows along the African coast towards the east, where it turns and flows towards the west along the coast of Europe, where it sinks and exits the Mediterranean.

The surface circulation in the Adriatic Sea is the consequence of the division of thermohaline characteristics. There is an entry current (NW) along the eastern coast of the Adriatic, which is more prominent in winter, and carries the more saline Levantine waters into the Adriatic Sea, while the less saline waters of the Adriatic flow out along the western coast, which is more prominent in summer. Such seasonal changes are primarily under the influence of gradient currents, and the seasonal changes of the wind. In summer, the north-westerly Maestral wind dominates, which increases the outflow of sea water in the surface layer, while in winter, the south-easterly Scirocco wind affects currents, which increases the inflow of the flow of sea water (Figure 3.22 and Figure 3.23). A depiction of the seasonal changes (summer, winter) of the surface currents on the Adriatic are shown in Figure 3.21.

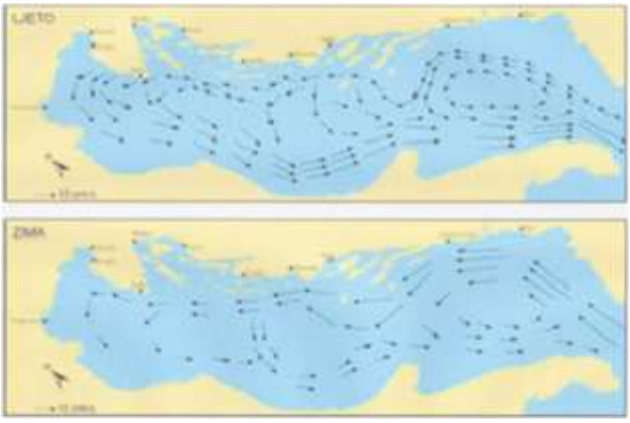


Figure 3.21 Surface currents in the Adriatic, summer/winter (Buljan & Zore-Armanda, 1976)

	Legend
LJETO	Summer
ZIMA	Winter

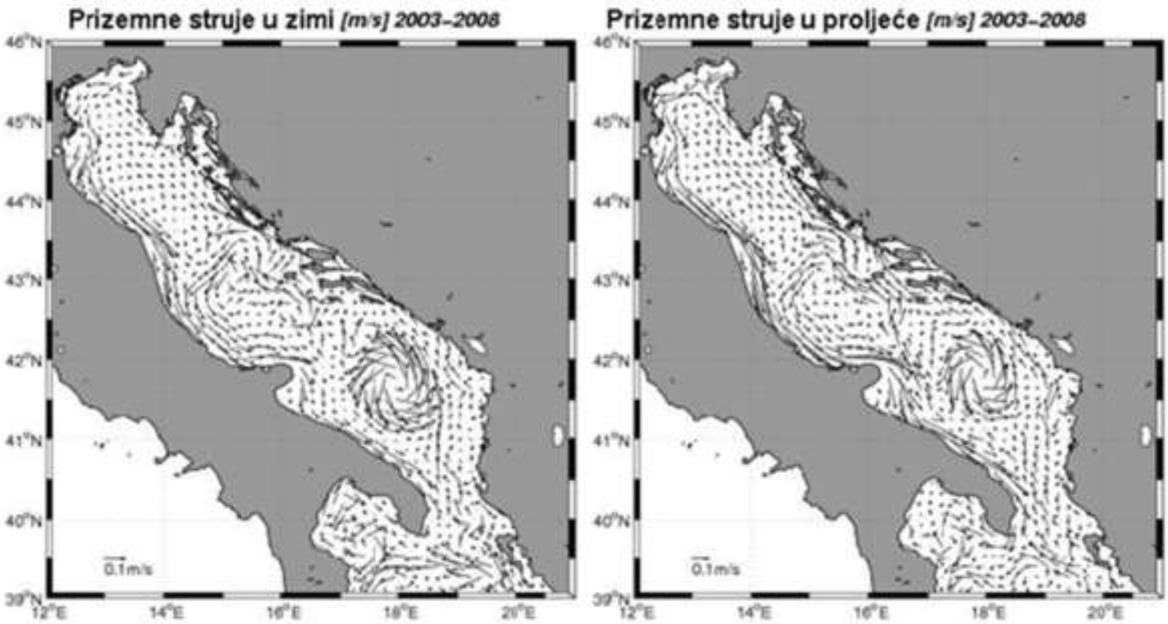


Figure 3.22 Division of surface circulation in the Adriatic, winter – spring (2006)

	Legend
Prizemne struje u zimi [m/s] 2003-2008	Surface currents in winter [m/s] 2003 – 2008
Prizemne struje u proljeće [m/s] 2003-2008	Surface currents in spring [m/s] 2003 – 2008

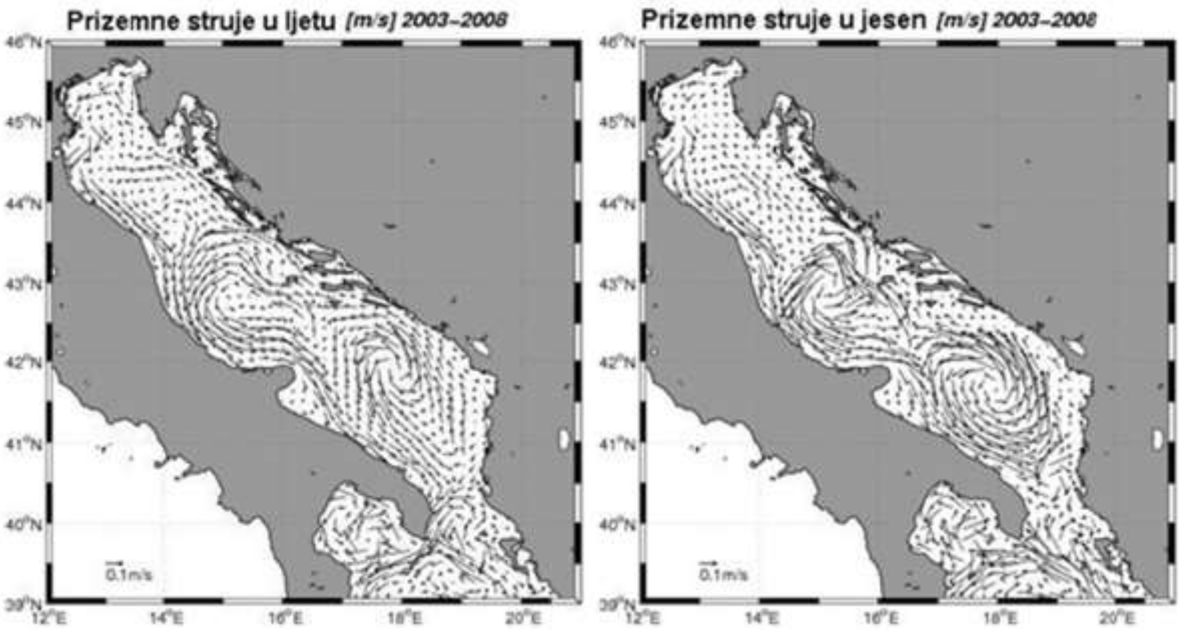


Figure 3.23 Division of surface circulation in the Adriatic, summer – autumn (2006)

	Legend
Prizemne struje u ljetu	Surface currents in summer
Prizemne struje u jesen	Surface currents in autumn

In addition to the general cyclonic circulation, there are other gyre circulation/movements present in the Adriatic, and the most prominent is the Southern Adriatic cyclical gyre. Gyre circulation is present around other topographic forms, such as the Jabuka Pit, and in the northern Adriatic, the north-easterly Bora wind creates cyclonic circulation which creates waters of greater density in the northern Adriatic, while the coastal waters become less dense ("*light on the right*").

In deeper layers of the Adriatic Sea, circulation is under the influence of thermohaline gradients. Along the eastern coast, highly saline Levantine waters enter the Adriatic, while the southern Adriatic waters exist in the layers along the bottom of the Strait of Otrant. The dense northern Adriatic waters flow towards the central and southern Adriatic in the bottom layer, at a rate of up to 20 cm/s, thus altering the thermohaline properties of the central and southern Adriatic.

3.1.6 Waves

Basis – A special form of water movement in the oceans and seas, lakes, rivers and other waters are wave movements. There are multiple types of such movements, with a greater component in the vertical or horizontal plane. Waves always appear at the border between two fluids, when there is mutual (relative) movement. Such a border is also present between air and water, when there is drag between then, while within fluids of various densities, there is the force of cohesion. The wave shows a periodicity of movements whose elements are: wave length - λ ("crest-crest ", "trough-trough"), wave height - h ("crest-trough"), wave amplitude - a (h/2), period - T (time from crest to crest). The direction and speed of the wave, and the general scale of the state of the sea are also taken into account. Sea depth - H has an important role in the properties of waves. Due to the above, there are various types (divisions) of waves, with various properties and causes of emergence.

A body that floats does not move with waves, instead oscillates up and down, and back and forth (an elliptical/orbital path). This means that water particles rise and fall, though one series of particles lags behind another series, and thus it appears as though the particles are moving (oscillating) along the circular path → only the form of the wave is moved (wind and wheat in a field!). On the contrary, the wave spreads in a direction – translocating the movement, in which the direction of oscillation is then perpendicular to the direction of spread. The wave is a disturbance of the stability of the border surface, and the return force is gravity (except for Rossby waves).

According to the forces that cause oscillations of the sea level, there are free waves that arise due to the action of an impulse, e.g. a rock thrown into the water. These are gravity waves and seiches. Force waves arise due to a constant external force, such as wind waves or tides. Acoustic waves appear due to the compressibility of the sea, though they are very small. Capillary waves arise above a calm sea with a light wind due to the surface tension, and have a very small wavelength. Gravity waves are caused by gravity. Short and long waves are the two most common classification of waves. Short waves can be on the surface (surface waves or deep water waves, $\lambda < 2$ H) or in the sea depths (internal waves). Short waves can be called short-period waves (<1 min). Long waves include the deep waves or waves of shallow water, $\lambda > 20$ H (tides and earthquake/tsunami waves), while long waves are long-period waves (≥ 1 min). Progressive waves have various phases, i.e. water parcels in orbit are not in the same phase, and their velocity is C = λ/T, while standing (stationary) waves have the same phases, i.e. the parcels are in the same phase though with varying amplitude (there is a node and antinode to the wave). In inertia oscillations (circulation), the Coriolis force is the return force. Rossby (planetary or long) waves are very large horizontal oscillations of sea water (currents). The tides and accompanying waves arise due to the gravitational pull of the Moon and Sun, with the action of gravity. An analysis of waves validates the linear processes, i.e. waves of small amplitude (h/2) are taken in relation to their wavelength (λ), and this ratio much be $h/\lambda \approx 1/20$ to 1/50 or smaller. That means that a wave with a wavelength of 200 m may have a height of 10 m, which is in any case a large wave. The ratio of the wavelength and sea depth gives the division into surface waves or deep water waves, which are called short waves under the condition → $\lambda < 2H$ (e.g. wind waves, gravity waves, internal waves), and waves by water depth or shallow water waves are called long waves under the condition → $\lambda > 20H$ (e.g. tides and earthquake/tsunami waves). Waves with higher wavelengths have a faster transfer speed and a longer period (Table 3.3.). If waves of varying wavelengths or periods arise in one place, they spread at various speeds. The longest and most periodical waves are the first to leave the site of generation and the first to reach a distant short. At any place, there are not only waves of the same properties, but also waves of varying properties, and waves appear in groups.

Table 3.3 Wavelengths and speed of waves in relation to period

T (s)	1	10	20
λ (m)	1.6	156.1	624.5
C (m s^{-1})	1.6	15.6	31.2

In addition to wavelengths, waves are also classified by periods (long-periodic waves (≥ 1 min). Table 3.4 shows the relationship between wave period and wave length. Therefore, short waves can also be called short-period waves (< 1 min), and long waves are long-period waves (≥ 1 min).

Table 3.4 Classification of waves by periods and wavelength (Pond & Pickard, 1983)

Period	Wavelength	Name
0-0.2 s	cm	capillary waves
0.2-9 s	to 130 m	wind waves
9 – 15 s	hundreds of m	gravity waves, seiches
15 – 30 s	several hundreds of m	long gravity waves
0.5 min – hours	to several thousands of m	long-period waves, tsunami
12.5; 25 hours, etc	thousands of m	tides

The simplest form of wave is the sine wave, which appears as a surface wave in deep water, usually with wind, and has equal wave steepness (symmetrical). The amplitude is reduced with depth. In internal waves that arise at various depths due to changes in water density, the amplitude drops towards the surface and towards the depths.

3.1.6.1 Wind waves and gravity waves

Wind waves or live waves arise due to the action of wind on the water's surface. They are also called surface waves, and due to the action of wind, these are force waves. The properties of the waves depend on the wind (speed, constancy of speed and direction, duration) and on the water mass (vastness of the water, depth, islands). Wind waves can be capillary waves (very small speeds) or heavy, and these are short-period (< 1 min) oscillations of sea level, though their period is most often between 2 and 9 s. Wavelengths are significantly smaller than sea depth (depth > 200 m).

Waves will be stronger (taller) as the wind speed increases (with minimum changes in wind speed and direction) and if the wind blows long enough over a large water area without barriers. The wind sea area is the area of sea over which the wind blows. The wind can generate small waves in just minutes, while for larger waves it requires a sea area of over 2000 km, with multi-day winds at speeds of up to
100 km/h (Table 3.5).

Table 3.5 Dependence of wave height on sea area, during winds of 60 km/h (Gelo, 2000)

Sea area (km)	5	10	20	50	100	500
Wave height (m)	0.9	1.4	2.0	3.1	4.2	6.2

Wind generates the largest waves far out in open waters. On the Adriatic Sea, the north-easterly Bora and south-westerly Scirocco winds can achieve the same speeds, though the Scirocco generates significantly larger waves (5–7 m) than the Bora (1–2 m). Waves are significantly taller in the Mediterranean Sea, and even taller in the Atlantic Ocean. There the water mass may be sufficiently disturbed to create tall and powerful swells.

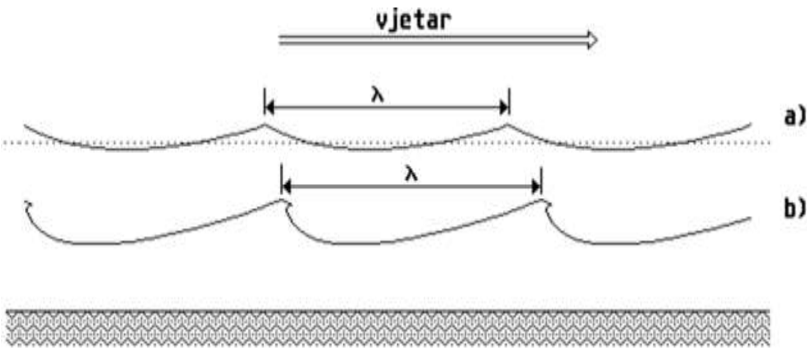


Figure 3.24 Wind wave; a) ordinary, b) breaking wave

Legend

vjetar	wind

Very small waves (when the condition *a/λ* = 1:100 or less is met) tend to be sine waves. However, wind waves do not have a sine shape, but a trochoid shape. A trochoid has a steep and narrow crest, and a shallow and broad trough (≈ 3/4 of the wave is above the baseline) (Figure 3.24 a). The more developed the wave (and slower than the wind), the sharper and more tilted the crest will be in the direction of the wind (Figure 3.24 b)). The wind pushes the wave back and pulls it forward, pushing it down, as there is an swirl of air behind the wave. In wind waves, there is a small horizontal movement of water (wind acts more strongly on the water particles in the crest than in the trough, and causes water movement).

Generally speaking, wave speed is lower than wind speed, except when the wind stops. The ratio of wave height/wave length is 1/7, though in nature due to wave breaking, this is 1/12 or less. Wave height will depend on water depth, as the wave height increases significantly as it enters shallower water.

For deep waters (λ < 2H), the simplified rule is: a wind wave with the period of 5 s will have a speed of 7.8 m s^{-1} and a wave length of 39 m, while a gravity wave will have a period of 15 s and a speed of 23 m s^{-1} and a wave length of 350 m. For shallower water (λ > 20H), the water particles correspond to an ellipse and not a circle, and the following applies: in sea depths to 5 m, long wave have a speed of 7 m s^{-1}, while in sea depths of 20 m, the speed is 14 m s^{-1}, which represents the stopping of the wave in shallow water. For sea depths of 4000 m, wave speed is 200 m s^{-1}. These are earthquake/tsunami waves with a wave length of about 200 km, and a ratio of H/λ = 1/50, meaning these are "shallow water" waves. The period is about 18 minutes.

Gravity waves are caused by gravitation on the sea surface, and they have a relatively long period (10 to 20 s) and wavelength (300 to 600 m, occasionally up to 1100 m).They appear when the wind stops or prior to its start or at a place distant from the site where the wind blows, meaning that these winds exist without the presence of wind. When the wind stops blowing, the water mass continues to be in motion for some time, but since the force of drag affects the water in motion, the wave movements are gradually stifled. Wind waves have various wavelengths, and the wave with a longer wavelength has the fastest speed of advancement. These waves can cross great distances and reach areas where there are no winds, and those are then the gravity waves.[1] Gravity waves are marked by a proper sine wave shape. Wave height can also be large, which depends on the vastness of the sea (Mediterranean up to 5 m, Atlantic up to 12 m).

Wave paths. The speed of approach of waves with larger wavelengths is high, and therefore, they can raise the sea level along the shore by 0.5 m in just minutes.

Wave approaching a steep shore. Waves can deflect off the shore, in which the angle of entry is equal to the angle of reflection, and the entry and deflecting waves meet and can create wave interference. The incoming and reflected waves can create hundreds of waves (locally called *bibavica*), if the waves reach the shore in a perpendicular direction. In more favourable situations, very tall waves with tall crests can form. Though there are also opposite situations, in which very small waves are formed.

Waves of open waters that spread from various areas can come into direct contact, thus creating wave interference. This also occurs when the wind changes direction or course, and new waves are generated, and interfere with the existing waves. If the crests of the two waves mutually interfere, the new wave will be significantly taller, and the crossing of the crest of one wave with the trough of another wave will result in a new wave that is significantly lower. Such waves are very dangerous, as they appear suddenly and can be very tall.

Wave approaching a shallow shore (H = 1/2 λ). In these conditions, there is no wave reflection. Due to the shallowness and drag from the seabed, the period of the wave is not changed, though the speed of spread of the wave is reduced and the wavelength

[1] In the case of a tropical storm, such waves can move up to 3500 km from the site of generation, spreading in all directions round the centre of the storm at speeds of 17 to 21 m s^{-1} (1500-1800 km day^{-1}), and this is one of its first signs.

is reduced (Table 3.6), while the crests of the waves rise up, and the wave breaks. Wave breaking begins when the ratio of wave height and wave length h/λ exceeds the ratio of ≈ 1/12, or even sooner if the water is shallow, i.e. when the ratio between wave length and sea depth h/H ≈ 0.8 or greater.

Table 3.6 Reduction of speed and wave length in shallow waters for a wave with a period of 8 s and a wave length of 100 m in deep water (Pond & Pickard, 1983)

H **(m)**	50	10	5	2
C **(m/s)**	12.5	8.9	6.6	4.3
λ **(m)**	100	71	53	35

Wave approaching the shore at an angle. Waves slow as they approach the show, and wave breaking (refraction) occurs, the line of the wave front bends and the wave pushed forward towards the shore, trying to achieve a parallel relation between the wave front and the shore. Breaking of the wave front occurs. Considering that shorelines are of varying shape, including bays and capes, waves generally reach such shorelines from open waters at an angle. Due to wave breaking, they spread out fan-like in bays, while on capes the waves generally crash on both sides, depending on the direction of approach of the wave (Figure 3.25). In bays the waves expand and so their action is less pronounced, unless the stronger action present on capes.

Groups of waves. Real waves in the oceans and seas do not have a 'purely' wave shape, but instead have various wave lengths, periods and amplitudes. They can also be of varying speed. It can be seen that the outer form of these waves has a wave shape, which can be described from two waves of the same amplitude and have various wave numbers and frequencies. Groups of waves, due to the different speeds of the individual waves, cause interference and foaming of the sea.

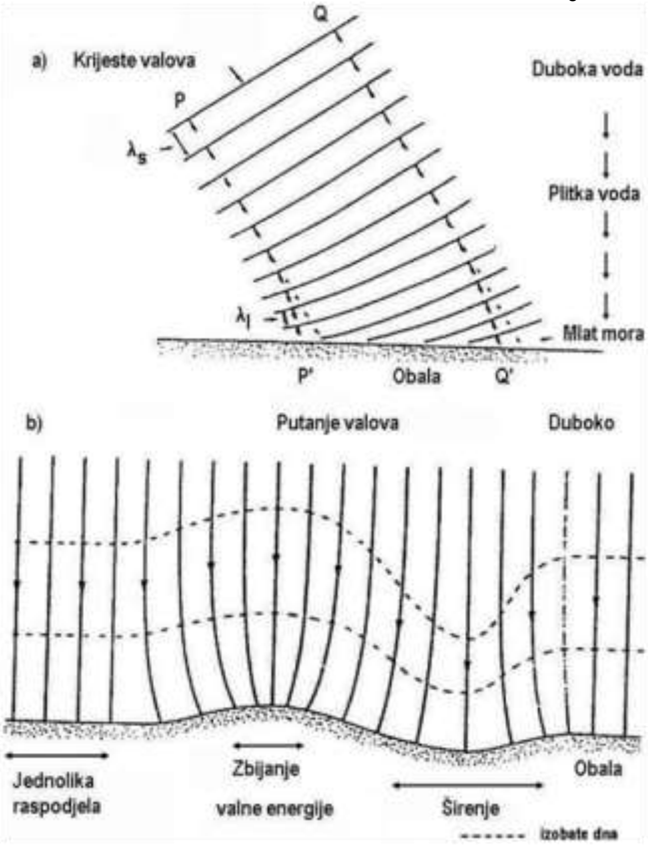


Figure 3.25 Wave approaching the shore at an angle and its breaking (Pond & Pickard, 1983)

	Legend
a) Krijeste valova	a) wave crests
Duboka voda	Deep water
Plitka voda	Shallow water
Mlat mora	Hits shore
Obala	Shore
b) Putanje valova	b) wave path
Duboko	deep
Jednolika raspodjela	uniform distribution
Zbijanje valne energije	compacting of wave energy
Širenje	expansion
Obala	shore

izobate dna	seabed isobaths

3.1.6.2 Surface waves in the Adriatic Sea

The Adriatic Sea is a semi-closed sea, affected by winds of varying direction and speed, usually caused by strong cyclonal processes, especially in winter, which there are also anti-cyclonal surges. The most common surface waves on the Adriatic Sea are caused by the Bora and Scirocco winds, and the Mistral (north-westerly wind) in the summer period.

The properties of surface waves depend on the direction, speed and duration of the prevailing winds, the sea area under the wind, the topography, sea bottom (sea depth) and the shape of islands and the coastline with the accompanying orography. Therefore, in the Adriatic Sea, the Scirocco wind generates much taller waves than the Bora wind, at the same speed and duration of wind.

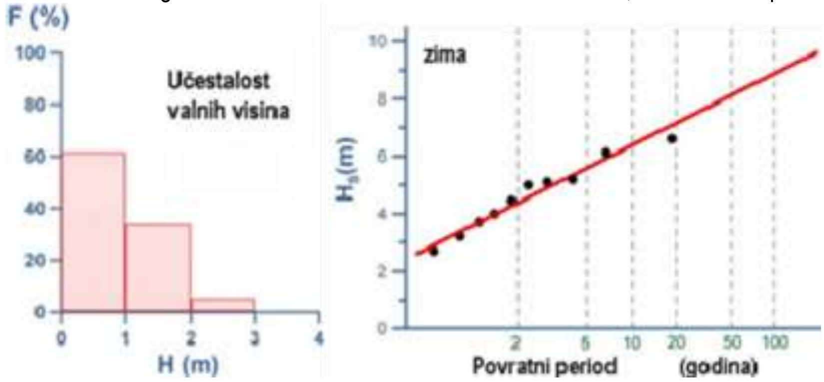


Figure 3.26 Frequency of wave heights in the southern Adriatic in winter, ship measurements (left). The restoring period of significant wave heights in the northern Adriatic based on ten-year measurements (right) (2004).

	Legend
Učestalost valnih visina	Frequency of wave heights
zima	Winter
Povratni period	Return period
(godina)	(years)

The tallest wave heights in the area of the open waters of the northern Adriatic, on the marine platforms, was recorded during a long-blowing gale force Scirocco wind and was h_{max} = 10.8 m. In addition to this wave height, other wave properties have been measured in certain situations, such as the mean size of 1/3 or 1/10 of the tallest waves (significant wave height $h_{1/3}$ = 6.0 m), mean period T_{sr} = 8.5 s, mean wave length λ_{sr} = 112 m). During the Bora wind, the tallest recorded wave in the northern Adriatic was h_{max}= 7.2 m (significant wave height $h_{1/3}$ = 3.9 m), mean period T_{sr} = 5.7 s, mean wave length λ_{sr} = 51 m). The data measured on the open waters of the Adriatic give the hundred-year restoring period of the tallest wave, height 13.5 m (Figure 3.26). In the coastal regions, waves are smaller, depending on the topographic properties and the openness of the waters towards the prevailing winds.

3.1.6.3 Internal waves

Internal waves (weight, gravitational) arise in seas of variable depth due to changes in the density of sea water, and they represent a barocline of water oscillations. The amplitude of these waves can be very high, which decline towards the surface and towards the seabed. These movements are most often not observed on the sea surface, but when the upper layer of the sea is shallow and inhomogeneous (e.g. in estuaries) or when the generating force is strong (e.g. a tide creating force), then internal waves are seen on the sea surface.

Differences in density of marine layers arise with the inflow of freshwater from land, while in the depths, the sea water is of normal salinity. This creates internal waves at a certain depth, which spread towards the surface and can, as a consequence, lead to the rocking of boats, even though the surface is calm. An internal wave can significantly affect sea currents. The period of an internal wave varies between several minutes and the period of inertial oscillations (at this latitude $T_i \approx$ 17 h), and can occasionally be even higher.

Due to the layer of water lying above the later where there is a prominent change in the density of sea water, i.e. where the internal wave has been formed, the restoring force is the product of gravity and the relative lift of the sea. Therefore, internal waves have much larger amplitudes and periods than the corresponding surface waves. The amplitude of internal waves can be several tens of metres (Figure 3.27), and the period several hours, days or weeks, which is different from barotropic weight waves, which have a period of several seconds to a maximum of one day.

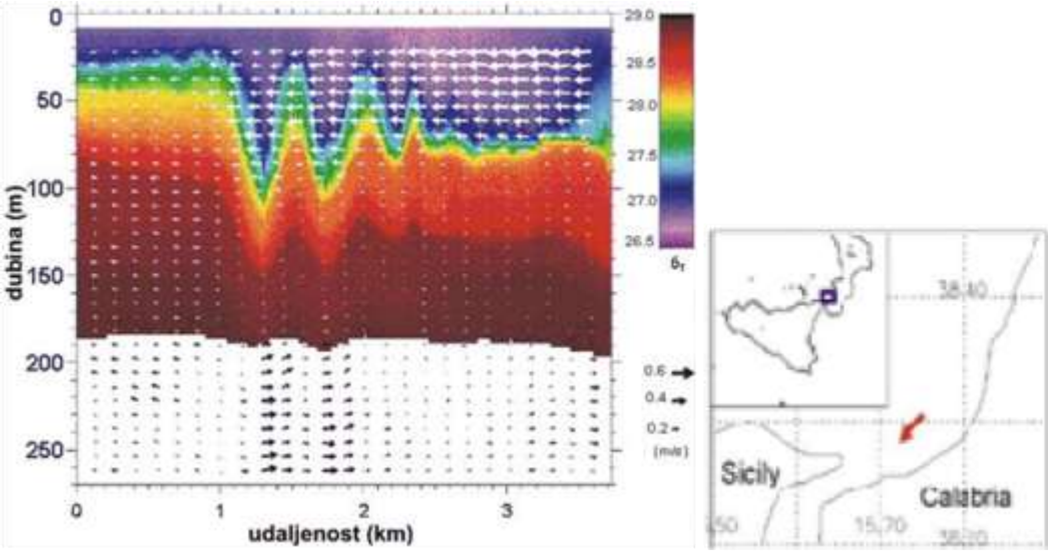


Figure 3.27 Internal waves in the Strait of Messina, with the division of the density σt and water circulation [m/s], 25.10.1995 (from Alpers et al., 2002)

	Legend
dubina (m)	depth (m)
udaljenost (km)	distance (km)

The property of internal waves in the deep sea, where the surface layer is shallower than the bottom layer, is that the speeds in the surface layer are faster and in the opposite direction than the bottom layer. In a two-layer approximation, due to the conservation of mass, the ratios of speed are inversely proportionate to the ratio of the depths of the layers. Therefore, the corresponding currents can be very strong, and in the Adriatic, have been recorded to be twice as strong as the barotropic tidal currents.

3.1.6.4 Long waves

Long waves appear over the entire water mass (water depth), with the condition → $\lambda > 20H$, and due to the exceptionally large wave length in relation to depth, and so these are shallow water waves. The water particles describe an ellipse, a small ellipse axis does not depend on depth, while a large ellipse axis does (at the seabed, the large axis = 0). These waves do not dissipate, and their speed depends only on the water depth. These are hydrostatic waves, with a constant amplitude.

A seiche is a standing gravitational wave arising from resonance, i.e. the oscillation of the sea level in the “basin”. The term “basin” refers to a channel, bay and lake, in which a channel is open on both sides, a bay on one side, while a lake is completely closed. A stimulus from the atmosphere or open waters is important, and can be associated with interference. It can occasionally appear as a strong current. The external impulse forces the water out of hydrostatic balance, and a return to this state of balance causes the swaying of water back and forth, creating waves. The period depends on the dimensions of the basin, and the standing wave is generated when the wave length is equal to two lengths of the basin, and depending on whether it is an open or closed basin, the water depth is also importance. In a seiche in a closed basin (lake), the oscillation period is greater than the length of the basin, and is inversely proportionate to the depth of the basin.

The periods of seiches range from minutes to hours to all day. The value of the period of seiches in a closed basin of various lengths and depths is shown in the table below (Table 3.7). These closed basins, in a way, represent harbours, where the influence of a seiche can occasionally be very significant, if with the given physical dimensions of the basin a disturbance also appears which could significantly disturb the marine surface causing material damages. In open basins, such as bays, the period of the seiche is larger, and for some period (e.g. 12.4 h) there is a connection between the depth and length of the basin (bay) (Table 3.8).

Table 3.7 Basic period T for various lengths ℓ and depths H of a closed basin (according to Pond & Pickard, 1983)

ℓ **(km)**	**10**	**100**	**500**	**1000**
H **(m)**	***T*** **(min)**	***T*** **(h)**		
50	15.0	2.5	12.6	25.1
100	10.8	1.8	8.9	17.7
200	7.8	1.3	6.3	12.6
500	4.8	0.8	4.0	7.9
1000	3.6	0.6	2.8	5.6

Table 3.8 Depth H and length ℓ of an open basin during a period of 12.4 h (Pond & Pickard, 1983)

H (m)	50	100	200	500	1000
ℓ (km)	247	350	495	782	1110

In the Adriatic Sea, seiches can appear in the entire Adriatic or its parts, including the smallest areas, such as harbours, bays and channels. Such a seiche represents a bay seiche with node line at the Strait of Otrant. The period of a seiche is from 21 to 23 h (same as tides, and interference may arise), and the amplitude increases from the southern to the northern part of the Adriatic. In the northern Adriatic, due to the topographic characteristics (shallow and closed shelf), the amplitude of the Adriatic seiche can be more than 50 cm. Therefore, with pronounced tidal oscillations and slowing, particularly if they arise simultaneously, this seiche contributes to the flooding of the coastal regions of the northern Adriatic. The most well known is the flooding of Venice, Italy. This flooding is most common after a long duration of the Scirocco wind, which forces the sea towards the closed end of the Adriatic. With the appearance of interference of several types of oscillations, this can lead to very tall waves.

If the Scirocco wind blows over the entire Adriatic or just over its part, in addition to the basic Adriatic seiche, the first next form appears as a free oscillation with a node line at the Palagruža threshold and the Strait of Otrant, with an oscillation period of ≈11 h.

Due to the topography of the seabed of the Adriatic, seiches appear in its northern and central parts, with periods of 8.2 and 6 h. They also appear in smaller semi-closed basins, such as the waters of the central Dalmatia islands (period 4 h), Gulf of Kvarner (period 2 h), Bay of Kaštel (period 1 h), and in smaller bays and harbours (Port of Ploče – 30 min, Vela Luka Bay - 15 min, Split Harbour - 7 min, Zadar Harbour - 4 min). The amplitude of individual seiches can be several dozen centimetres tall (Bay of Kaštel, amplitude 20 cm), and can cause flooding of smaller areas and marine currents that can hinder the navigation of ships and vessels while sailing into and out of harbours and ports (Figure 3.28).

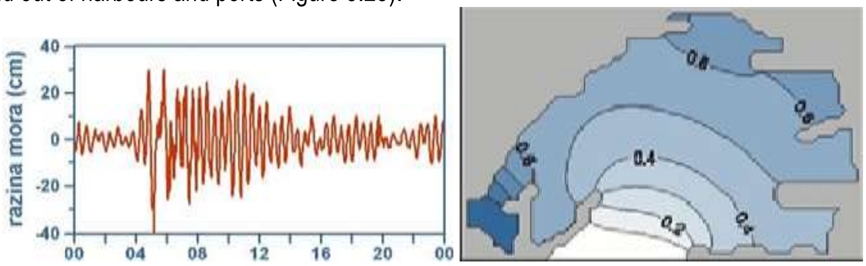


Figure 3.28 The appearance of seiches, Port of Ploče, 27 June 2003, period 30 min (left), relative amplitude of the base seiche of the Split Harbour, period ≈ 7 min., obtained by numerical modelling (right)

	Legend
razina mora (cm)	sea level (cm)

3.1.6.5 Other types of waves

<u>Kelvin (coastal) waves</u> are undispersed waves that move parallel to the coast at the speed of gravity waves. In the northern hemisphere, the shoreline is to the right, on the southern hemisphere, the shoreline is to the left. They arise due to the action of wind on the sea surface (Figure 3.29). The Kelvin wave is a gravity wave that runs along the coast, with geostrophic approximation perpendicular to the coast. The strength of the wave drops greatly with increasing distance from the shore (there are also equator Kelvin waves).

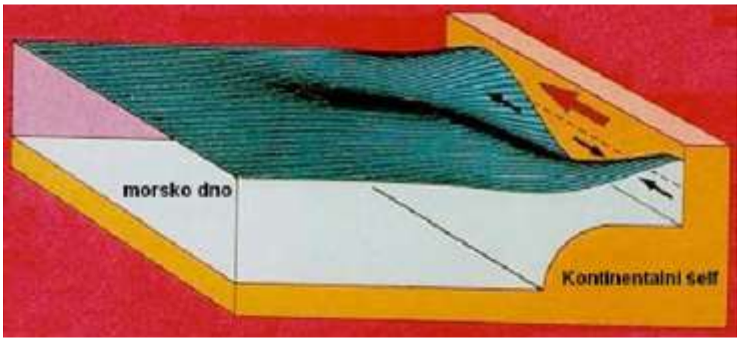


Figure 3.29 Overview of the spread of a coastal Kelvin wave in the northern hemisphere (according to Emery, Talley & Pickard, 2006)

	Legend
morsko dno	sea bed
Kontinentalni šelf	continental shelf

Topographic waves are a group of waves that arise due to the shape of the coast and the seabed, island groups, and other bordering areas in the sea. Due to the action of wind on the sea surface, and upwelling and downwelling of water in the coastal areas, the parcels along the sea surface are shifted from or towards the coast, and the disturbance spreads along the body. They are occasionally called topographic Rossby waves.

Earthquake or seismic waves and tsunamis are long, progressive, gravity waves in the sea, that arise as a consequence of tectonic disturbances usually due to a submarine tremor, volcanic eruption, landslide or falling of a glacier or iceberg into the sea. They are common in the Pacific Ocean (≈ 80% tsunamis). They are generated by a strong impulse or multiple impulses, the waves spread concentrically on all sides. The entire water mass is in motion (from the surface to the bottom), and the number of waves depends on the number of impulses.[2]

The wave properties depend on the strength of the impulse, its distance, sea depth, form of the coast and other elements. In open waters (outside the hypocentre), earthquake waves are often not felt, i.e. on a boat, though the height can be from 1-2 to 10 m, though the wave length is very large and so the sea appears to be a flat surface. Problems arise along the shore, where the sea level is significantly increased (5–10 m) with possible catastrophic consequences. Though the wave quickly loses speed in shallow water, the wave length is shortened and it gains in height, up to 30 m. Occasionally, prior to the arrival of the wave, the sea can significantly retract and become silent, which can last from several minutes to 2 h, and the return of the water is gradual or often forceful. Therefore, for ships, it is more favourable to be out in the open and deep sea.

Earthquake waves can have a large wave length (to 200 km), significantly larger than the sea depth, and these are typical long waves. The period is 5–6 min or 10–30 min, occasionally to 1 h, and the rate of movement depends on the sea depth. A tsunami moves at a great velocity of 70–250 m s^{-1} (250 to 900 km/h). For water about 5 km deep, the wave velocity is 0.2 km s^{-1}, so they are slower than seismic waves, which have a velocity of 5 to 10 km s^{-1}, and therefore seismic waves can serve as a warming for an oncoming tsunami.

Material damages cannot be directly avoided, only through construction and activities outside possible threatened areas. The tsunami warning system is based on a network of mutually connected seismological and oceanography stations and services. With the appearance of an earthquake of significant magnitude, centre underground or near the sea, seismologists warn the oceanography services near the epicentre. If a wave is observed at sea, notification is sent to the threatened area for the necessary protection measures. However, unusual behaviour has been noted in some animals, including restlessness and flight.

Earthquake waves on the Adriatic Sea: the question arises as to whether earthquake waves are possible on the Adriatic Sea, which lies on a single, small tectonic plate and is surrounded by multiple earthquake hotspots.

Earthquakes occur more frequently and are stronger in the southern Adriatic. The Albanian coast is somewhat more pronounced. An earthquake in Montenegro (1979) generated a large earthquake wave (Figure 3.30), which quickly moved in the open waters of the southern Adriatic (greater depths) with a lag in the coastal areas. The wave height was small, from 20–25 cm in Bar, and only a few centimetres in Dubrovnik (Orlić, 1984). The earthquake in Dubrovnik (1667) created a significant earthquake wave. Records state that the water from the Dubrovnik Harbour "retracted three times, such that boats fell and hit the bottom, and each time, the water returned with some force as to roll the boats over". It can be concluded that tsunamis indeed occur.

[2] An eruption of the volcano Krakatao in Indonesia (in 1883) created a hypocentric wave more than 35 m in height, the waves destroyed 1000 settlements and some 36,000 people were killed, and the wave disturbance circled the globe twice. In 1896 a tsunami in Japan destroyed 13,000 houses and 270,000 people were killled. An earthquake in the Aleutian Islands (1946) created a tsunami with a velocity of 870 km h^{-1}, which reached Hawaii after 4.6 h with a wave height of 10–15 m, and after 18.1 h, the waves reached Valparaiso, Chile with a height of 1 m. In 1960, an earthquake in Chile created waves that killed about 1000 people, and after 23 h, the waves reached Japan with a height of 1 m and killed another 100 people. An earthquake and resulting tsunami on the island of Sumatra, Indonesia in 2004 caused the deaths of 250,000 – 300,000 people along the shores of the Indian Ocean.

Figure 3.30 Motion of an earthquake wave in the Adriatic Sea. 1979 earthquake in the seas of the Montenegrin coast. Time calculation of the arrival of the wave front, in minutes (Orlić, 1984)

Tides are quasi-periodical movements of water in the oceans and seas due to the gravitational pull of the Moon and Sun, together with the action of centrifugal forces relating to the spin of the Earth and Moon. This includes the spin of the Earth and Moon around a common centre point. Considering the proximity of the Moon, though it is much smaller, its action is about 2.17 stronger than that of the Sun. Topographic properties of the sea (coastline, water depth), drag and other forces are also important, which requires highly complete calculations for forecasting the tides. Similar to the sea tides, there are atmospheric tides. However, there are also Earth tides, which can be up to dozens of centimetres. There are a number of concepts that define the condition connected with the appearance of the sea tides.

When the Sun, Moon and Earth in their motion line up (during a new moon or full moon), due to the stronger gravitational force, the effect of the tides is largest, and this period is called the *syzygy*, and when they are perpendicular to the Earth (first or third quarter), the effect is the smallest and the period is called the *quadratura* (Figure 3.31).

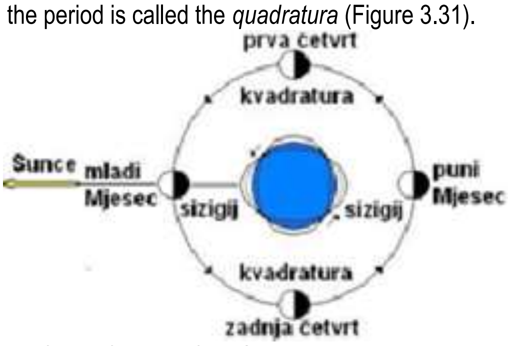


Figure 3.31 Scheme of the influence of the Sun and Moon on the strength of marine tides

	Legend *(clockwise from top)*
prva četvrt	First quarter
kvadratura	quadratura
puni mjesec	Full moon
sizigij	syzygy
zadnja četvrt	Third quarter
mladi mjesec	New moon
Sunce	Sun

The tides are seen in the oscillations of sea level (raising and lowering) and the strong change in the direction of the sea currents. They cause high and low waters, called high tide and low tide. Each tidal component is a given point is determined by its amplitude and wave phase, with the note that there is a very long period measurable in days or months (e.g. 13.7, 27.6, 182.6 days). Table 3.9 below shows the wave amplitude in relative ratios.

Table 3.9 Some basic tidal components and their relative amplitudes (Werner, 1992)

Tide	Component	Symbol	Period (h)	Amplitude
Principal lunar	semi-diurnal	M_2	12.42	100.0
Principal solar	semi-diurnal	S_2	12.00	46.6
Larger lunar elliptic	semi-diurnal	N_2	12.66	19.2
Luni-solar	semi-diurnal	K_2	11.97	12.7
Luni-solar declinational	diurnal	K_1	23.93	58.4

Principal lunar declinational	diurnal	O_1	25.82	41.5
Principal solar declinational	diurnal	P_1	24.07	19.4
Larger lunar elliptic	diurnal	Q_1	26.87	8.0

The water motions have semi-diurnal (12.42, 12.00, 12.66 and 11.97 h) and daily periods (23.3, 25.82, 24.07 and 26.87 h) which correspond to the lunar day. The period of the Moon's revolution around the Earth does not coincide with the Earth day. The average duration is 12 h and 25 min, and it lags ≈ 50 min at the highest position (culmination) of the Moon. At certain places on the Earth's surface, the tides appear primarily in semi-diurnal periods, while in other place they appear in diurnal periods, though there are also mixed cases.

These periods and many others determine the overall tides. However, there are at least three basic types of tides: *semi-diurnal*, *diurnal* and *combined* (Figure 3.32) and there are four categories of tides depending on the size of the ratio of the form:

- F → 0 – 0.25 semi-diurnal
- F → 0.25 – 1.5 combined, primarily semi-diurnal
- F → 1.5 – 3 combined, primarily diurnal
- F → > 3 diurnal

Figure 3.32 Examples of diurnal tides. Zadar (2004)

	Legend
Zadar, Hrvatska	Zadar, Croatia
dnevna morska mijena	Diurnal tides
dan	Day

The tides are not uniform everywhere. They are smallest in the central parts of the oceans and increase towards the sea coasts, particularly in shallow and closed seas, where the fluctuations in sea level can exceed 10 m (i.e. coast of Great Britain and Japan, Bay of Fundy in Canada where they reach 15 m). In the Adriatic, they range from 0.3 to 0.8 m.

Due to the raising (lowering) of the water mass, there are horizontal shifts. These are tidal currents, which can have speeds in open seas of ≈ 0.1 m s^{-1}, while they can be very fast near the coast, up to 8 m s^{-1}. These currents are marked by large changes in the direction of water movement in line with the periods of the tides. Changes in the direction of the tidal current appear about 3 h after high or low tide. As a consequence of the sudden changes in water circulation, tidal waves appear, and are short, steep and pointed. Such a tidal wave approaches the shore, slows due to drag from the sea bottom and gains in height, to 15 m. Usually it takes less time for the wave to grow than to subside (growth ≈ 2 h, subside ≈ 10 h). Tidal wrinkles are rapidly growing high tides at the mouths of shallow rivers (water growth ≈ 1 m in 10 s and 2 m in the next 20 mins, with growth up to 8 m). The effects of tidal waves usually increase with the appearance of resonance → seiche. Rip waves are a specific type of tidal wave that form when wind waves meet a tidal wave.

In the seas, there are nodes and amphidromic points of zero amplitude (no high or low tides) and the crests of tidal waves circle around these points, i.e. the wave phases change suddenly. Tidal waves circumvent such a point in the northern hemisphere in a cyclonic direction (counter clockwise) and in an anticyclonic direction (clockwise) in the southern hemisphere. In these points, there are strong tidal currents. Usually, the largest tidal oscillations are along the coasts. Therefore, there are amplitude lines that connect all the points of the same tidal range and create a concentric circle around the amphidromic points. Approximately perpendicular to the amplitudal lines are the tidal lines, which connect all the points of the same degree of the tidal cycle and spread out from the amphidromic point, i.e. have the highest amplitude, and the phase changes little.

Tides in the Adriatic Sea

A closed sea poorly exchanges water masses with the oceans, and so the tides are weaker. The Mediterranean Sea exchanges water masses with the Atlantic through the narrow Strait of Gibraltar, and so tidal oscillations are small (less than 0.5 m) (Figure 3.33), except in shallow regions of Tunisia and in the northern Adriatic, where the tidal range can exceed 1 m.

The range of tides in the Adriatic Sea is from ≈ 30 cm in the southern part of the Adriatic to ≈ 120 cm in the Gulf of Trieste, while the mean daily amplitude is 22 cm in Dubrovnik, 23 cm in Split, 25 cm in Zadar, 30 cm in Bakar and 47 cm in Rovinj. The tides in the Adriatic Sea are primarily of the combined type, except in the area near Zadar, where diurnal oscillations prevail, due to the proximity of an amphidromic point of semi-diurnal components (Figure 3.34). These are very small semi-diurnal amplitudes and there is circling of water. In moving away from this point, the amplitude increases, particularly towards the north. The diurnal component expands from the Croatian towards the Italian coast, and their amplitude increases from the southern towards the northern Adriatic.

In the Adriatic, there are seven tidal constituents, four semi-diurnal (M_2, S_2, K_2 and N_2) and three diurnal (K_1, O_1 and P_1). Their amplitude and phases are shown in Table 3.10 for specific ports on the Croatian coast of the Adriatic, and they enable the charting of tide tables for future periods.

The energy of the tides is exceptionally high and very important in maritime and inland navigation, particularly for sailing into and out of ports. On the other hand, the exceptionally large amplitude of sea levels is very suitable for the production of electricity in tidal power plants.

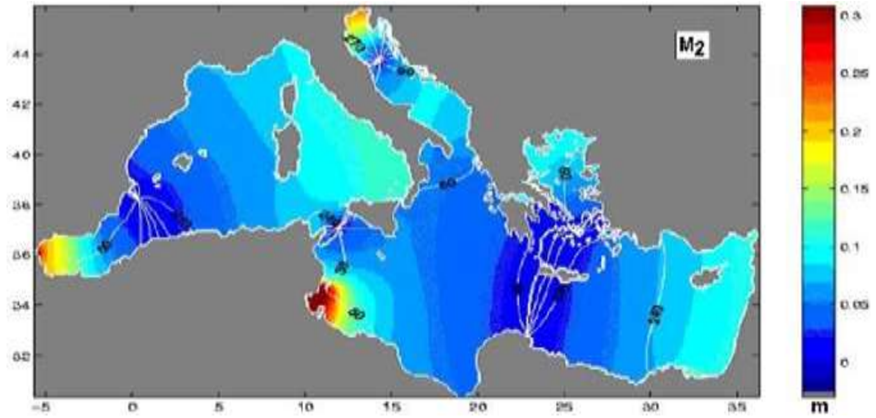


Figure 3.33 Amplitude and phases of the semi-diurnal constituent M_2 in the Mediterranean Sea (Egbert, Bennett & Foreman, 1994)

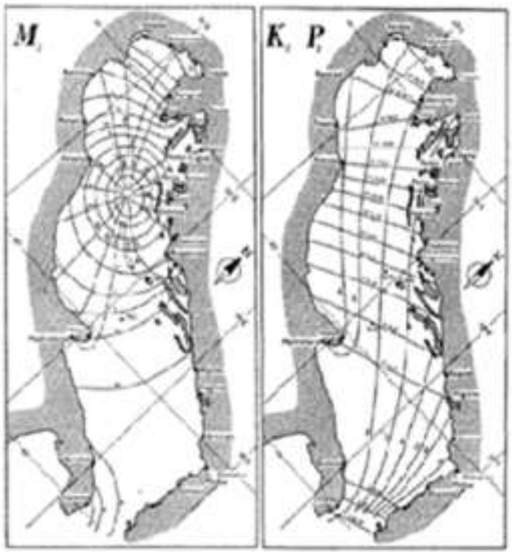


Figure 3.34 Properties of the main semi-diurnal M_2 and daily K_1 tidal constituents (Polli, 1960)

Table 3.10 Amplitude (a) and phase (fv) of significant tidal constituents for some ports (Hydrographic Institute, 1973)

Port		M_2	S_2	N_2	K_2	K_1	O_1	P_1
Rovinj	***a*** (cm)	19.30	10.78	2.99	3.08	16.35	5.04	5.25
	f_v (°)	271.5	280.2	263.8	269.9	71.8	57.9	68.4
Bakar	***a*** (cm)	10.57	5.47	1.98	1.53	13.77	4.07	4.64
	f_v (°)	263.7	241.6	246.9	231.7	64.5	49.1	61.5
Mali Lošinj	***a*** (cm)	7.86	4.52	1.30	1.41	13.2	4.48	4.36
	f_v (°)	239.9	244.8	243.9	231.7	64.5	49.1	61.5
Zadar	***a*** (cm)	6.11	3.23	0.98	0.83	13.44	4.15	4.44
	f_v (°)	229.7	226.4	241.7	219.5	62.7	55.7	52.5
Split	***a*** (cm)	7.95	5.58	1.38	1.64	8.82	2.69	2.90
	f_v (°)	129.0	130.8	125.6	124.1	55.9	47.5	51.8
Vis	***a*** (cm)	7.35	5.16	1.30	1.23	7.89	2.38	2.73
	f_v (°)	107.0	110.89	103.6	112.9	56.4	42.3	49.2
Dubrovnik	***a*** (cm)	9.28	5.76	1.68	1.65	5.19	1.9	1.69
	f_v (°)	115.1	120.4	110.6	115.7	62.4	47.3	60.2

3.2 Chemical features

3.2.1 Spatial and temporal distribution of pH value, dissolved oxygen, nutrients and organic matter in the water column

3.2.1.1 pH value and dissolved oxygen

The pH of seawater is in the slightly basic range due to the excess of dissolved anions, which consists mainly of bicarbonate and carbonate ions. The largest effect on pH in the sea is exerted by processes of production and degradation of organic matter in which CO_2 is removed (photosynthesis) or produced (respiration) in the marine ecosystem. The usual pH value for the eastern Adriatic coast is 8.2 ± 0.1, while the influence of photosynthesis on the shift of seawater pH value is up to 0.2 pH units towards the basic range, and intensive decomposition of organic matter can reduce the bottom layer pH to below the value of pH = 8. In addition to the aforementioned natural processes, pH may be affected by the flows of waste and industrial water, as well as freshwater inflows, but their effect is locally restricted due to the carbonate buffering system of seawater.

Spatial and temporal distribution of seawater pH value, as well as of other parameters measured in the water column, will be displayed for investigated stations OC1 - OC19a located along the Croatian coastline and in the open sea area of southern, central and northern Adriatic for the period from 1994 to 2010 (Table 3.11).

Table 3.11 List of the investigated stations along the Croatian coast with locations, depths and area. Source: Initial assessment of the state and load of the marine environment on the Croatian part of the Adriatic (Institute of Oceanography and Fisheries, 2012)

Station	Location	Depth	Area
OC1	Dubrovnik	100	Coastal open sea of the southern Adriatic
OC1d	Slano	40	Coastal area of the southern Adriatic
OC1h	South - Adriatic Pit	1180	Open sea of the southern Adriatic
OC3	Port of Ploče	35	Coastal area of the southern Adriatic
OC5	Split Gates	50	Coastal area of the central Adriatic
OC5a	Stončica, island of Vis	100	Open sea of the central Adriatic
OC5d	Island of Palagruža	170	Open sea of the central Adriatic
OC5f	Monte Gargano	110	Open sea of the central Adriatic
OC6	Kaštela Bay	37	Coastal area of the central Adriatic
OC7	Vranjic - Kaštela Bay	18	Coastal area of the central Adriatic
OC8c	Jabuka Pit	260	Open sea of the central Adriatic
OC9	Port of Šibenik	35	Coastal area of the central Adriatic
OC12	Zadar	30	Coastal area of the central Adriatic
OC16	Rijeka	65	Coastal area of the northern Adriatic
OC17	Eastern coast of Istria	50	Coastal area of the northern Adriatic
OC18	Western coast of Istria	30	Coastal area of the northern Adriatic
OC19	North Adriatic	32	Open sea of the northern Adriatic

The figure below, Figure 3.35, shows the box-whisker plots of pH values in the water column of investigated stations for a period of longtime measurements ranging from 1994 to 2010.

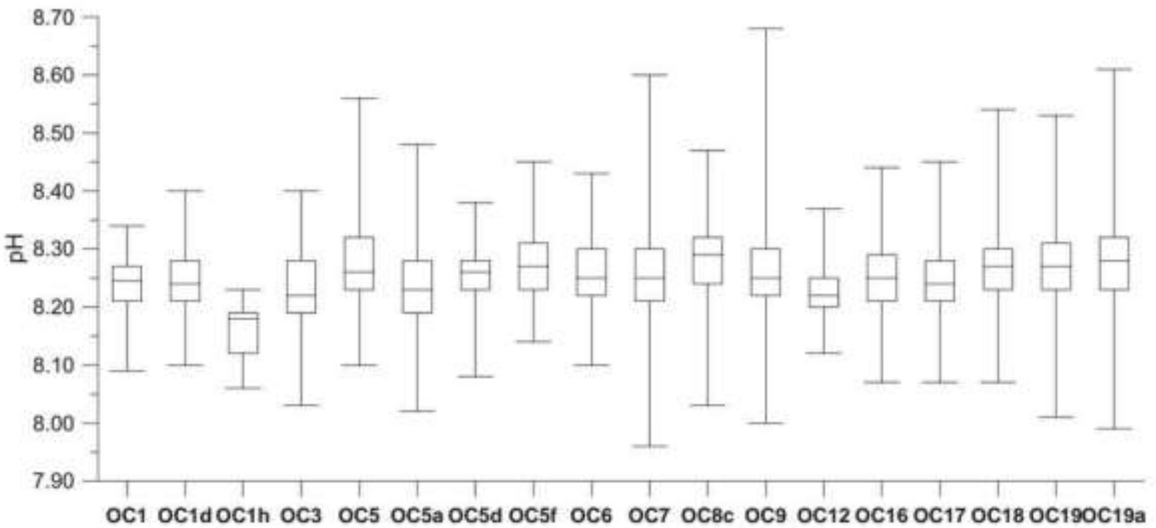


Figure 3.35 Box-whisker plots of pH value in the water column of investigated stations for the period 1994-2010 (bottom line - minimum value, rectangle - area from 25th to 75th percentile, upper line - maximum value, central line - median).

The medians of pH value are in the range from 8.18 (OC1h station in the South-Adriatic Pit) to 8.29 (OC5 station in the Split Gates). Dispersion of 50% of all data is uniform for the majority of stations, except for the OC1h station with a depth of 1180 m, where the majority of pH value is lower than the median. The absolute range of pH value in the water column of all stations was 7.96 to 8.65, measured at stations OC7 and OC9 in the coastal area under anthropogenic influence (Vranjic and Port of Šibenik). In addition to these stations, a relatively large range was found at the OC19a station in the open sea of the northern Adriatic.

At the majority of stations a standard distribution of the pH value was determined, and more significant deviations with larger ranges of values were found at the OC7 and OC9 coastal stations (Vranjic and Port of Šibenik) in the central Adriatic, and at the OC19a station in the open sea of the northern Adriatic. Analysis of data spanning many years for this parameter indicates a trend of pH value reduction at investigated stations.

Oxygen, like other atmospheric gases, dissolves in natural waters according to Henry's law, and in a state of equilibrium its concentration is proportional to the partial pressure in the atmosphere. The solubility of oxygen, apart from pressure, also depends on temperature (T) and salinity (S), and, including dependence on these parameters, it can be expressed as a percentage of saturation (O_2 %) with 100% saturation corresponding to the equilibrium state.

As different chemical and biological processes that take place in the sea constantly disturb the equilibrium of oxygen, oversaturation (> 100%) or undersaturation (< 100%) are common appearances. The main processes that disturb the establishment of equilibrium of oxygen are primary production of organic matter (photosynthesis), whereby the oxygen content increases, as well as respiration and heterotrophic degradation (oxidation) of dead organic matter, resulting in a decrease in oxygen content. Oxygen is therefore the most sensitive indicator of the intensity of biochemical processes and, alongside T and S, the most frequently determined chemical parameter.

The figure below, Figure 3.36, shows the box-whisker plots of oxygen saturation in the water column of the OC1-OC19a investigated stations in the period from 1994 to 2010.

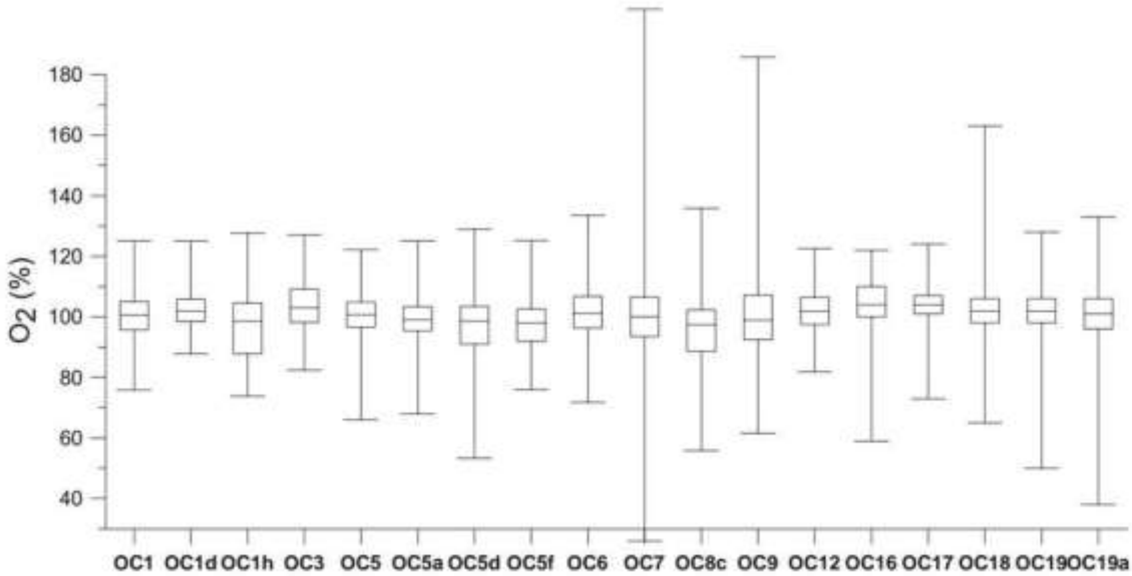


Figure 3.36 Box-whisker plots of oxygen saturation in the water column of investigated stations for the period 1994-2010 (bottom line - minimum value, rectangle - area from 25th to 75th percentile, upper line - maximum value, central line - median)

The medians of oxygen saturation for specific stations ranged from 97.4 to 104%, whereby medians higher than the balanced saturation (> 100%) were determined at stations in the coastal areas of southern and central Adriatic (OC1, OC1d, OC3, OC5, OC6, OC7, OC12) and at all stations in the northern Adriatic (OC16-19a), which points to a prevailing impact of the photosynthesis process on the balance of oxygen in the water column of mentioned stations. Medians of oxygen saturation <100% (prevailing respiration) were found mainly in the water column of stations in the open sea (OC1h, OC5a, OC5d, OC5f and OC8c), on which the compensation of oxygen is made difficult due to a bigger depth, but also on the relatively shallow coastal station of OC9 in the Šibenik Bay (z = 38 m) where degradation processes of organic matter prevail over the process of photosynthesis. Dispersion between the 25th and 75th percentiles (50%) of all data on saturation of the water column with oxygen was uniform for most stations, except for the deepest stations of the open sea (OC1h station in the South-Adriatic Pit and OC8c station in Jabuka Pit), where such distribution was expected due to difficult ventilation of the deeper layers. Minor deviations in data dispersion around the median are also visible on the OC9 coastal station in the Šibenik Bay. The established distribution of data was expected because this statistical element is significantly impacted by station depth (shallower stations have relatively uniform saturation values) and freshwater inflows of nutrient salts (they increase the primary production and level of dissolved oxygen).

The absolute range of seawater saturation with oxygen in the investigated period was 25.9 to 201.6%, and it was found in the water column of the OC7 station in the Vranjic Basin during August 1997. At this station in the 1980s and 1990s, due to the input of municipal and industrial wastewater, small depth and poor circulation of water, there were frequent occurrences of red phytoplankton bloom, so-called "*red tides*", accompanied by hypoxic and anoxic conditions in the bottom layer and with a massive dying of fish and benthic sessile organisms.

Somewhat higher saturation of dissolved oxygen was found in the coastal waters of the Central Adriatic in relation to the area of the open sea, while in the northern Adriatic these differences were less evident. The largest saturation ranges were found at stations in the Vranjic Basin and Port of Šibenik. Analysis of the oxygen concentration in the bottom layer of coastal and open areas in the Adriatic showed that the situation in both areas can be assessed as very good because no critically low values were found (2 - 3 mg l^{-1}) that could have a negative impact on the life of organisms in the marine environment. Data processing found that no significant saturation trend was present at the majority of stations, except at stations OC6 in the Kaštela Bay and OC18 near Rovinj, where a positive, i.e. negative saturation trend was found.

3.2.1.2 Concentrations of nutrients in the water column

Dissolved nitrogen and phosphorus salts (nutrient salts) are, together with sunlight, trace elements and carbon dioxide, a prerequisite for the process of photosynthesis in the marine environment. This process converts the said elements into amino acids, proteins and nucleic acids, which following the death of organisms, sedimentation and heterotrophic degradation remineralize and return to the water column as dissolved inorganic salts (nitrates, nitrites, ammonium salts and orthophosphates). Some phytoplankton organisms (diatoms, silicoflagellates), in addition to nitrogen and phosphorus, use dissolved silica as building material for their shells, and the regeneration of this element is done through the chemical dissolution of deposited biogenic opal. These processes do not constitute entire biogeochemical cycles of these elements; one part of the elements is lost forever from the cycle (through filling in the sediment, adsorption to the mineral phase, conversion to the gaseous state), but is also compensated through the inflow of rivers, groundwater or atmospheric yield, which finally brings balance to marine ecosystems.

Dissolved inorganic salts of nitrogen appear in the oxidized (nitrate, nitrite), as well as in reduced form (ammonium salt) in natural waters. Because of the relatively rapid processes of oxidation and reduction of these compounds, their sum is presented here, i.e. dissolved inorganic nitrogen, TIN.

The figure below, Figure 3.37, shows the box-whisker plots of the concentration of total inorganic nitrogen in the water column of investigated stations OC1-OC19a for the period from 1994 to 2010.

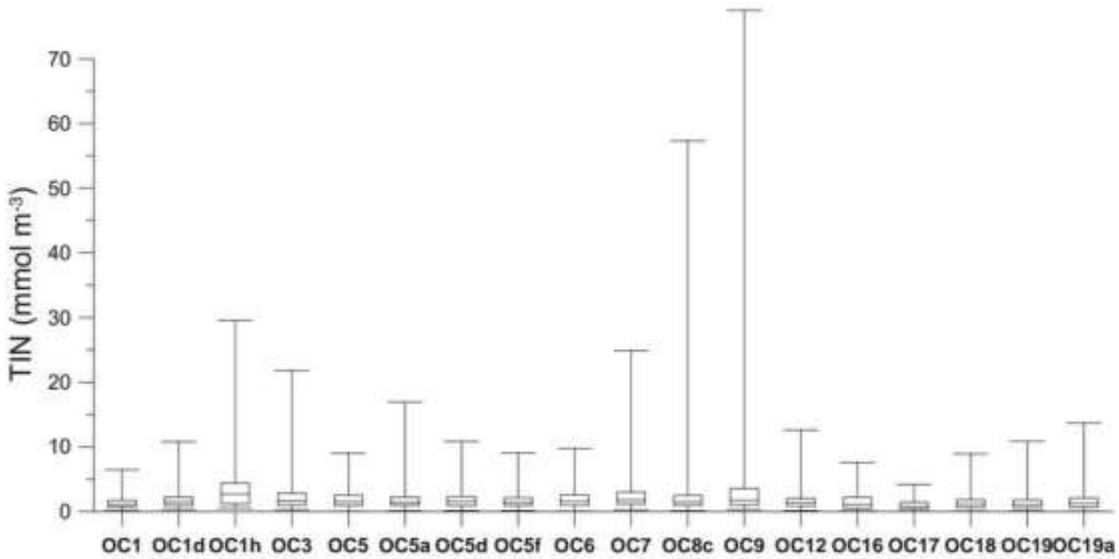


Figure 3.37 Box-whisker plots of the concentration of total inorganic nitrogen in the water column of investigated stations for the period 1994-2010 (bottom line - minimum value, rectangle area - 25th to 75th percentile, upper line - maximum value, central line - median). Data sources: IOR-Split, CIM-Rovinj

Medians of TIN concentrations for the research period between 1994 and 2010 (Figure 3.37) are in the range from 0.77 (OC17 stations in Kvarner) to 2.68 mmol m^{-3} (OC1h station in the southern Adriatic). Dispersion of 50% of the data (from the 25th to 75th percentile) is relatively uniform for most stations (from 0.8 to 2.4 mmol m^{-3}), except at the deepest station in the open sea (OC1h) and OC9 station at the Port of Šibenik (larger area of dispersion), and at stations OC17, OC18 and OC19 in the northern Adriatic (smaller area of data dispersion). The absolute range of the dissolved inorganic nitrogen concentration is from 0.02 to 77.48 mmol m^{-3}, with the minimum value established at the OC19a station in the open sea area of the northern Adriatic, and the maximum value at the OC9 station in the Šibenik Bay.

The relatively large ranges of TIN concentration were, similarly to oxygen saturation, found at the deep stations OC1h, OC5a and OC8c and at stations in the estuaries of the rivers Krka and Neretva (OC3 and OC09 stations), as well as in the Vranjic Basin at the OC7 station. Medians of orthophosphate concentrations (HPO_4^{2-}) in the investigated area ranged from 0,010 (stations OC16, OC17 and OC19 in the northern Adriatic) to 0.072 mmol m^{-3} (OC9 station at the Port of Šibenik) (Figure 3.38).

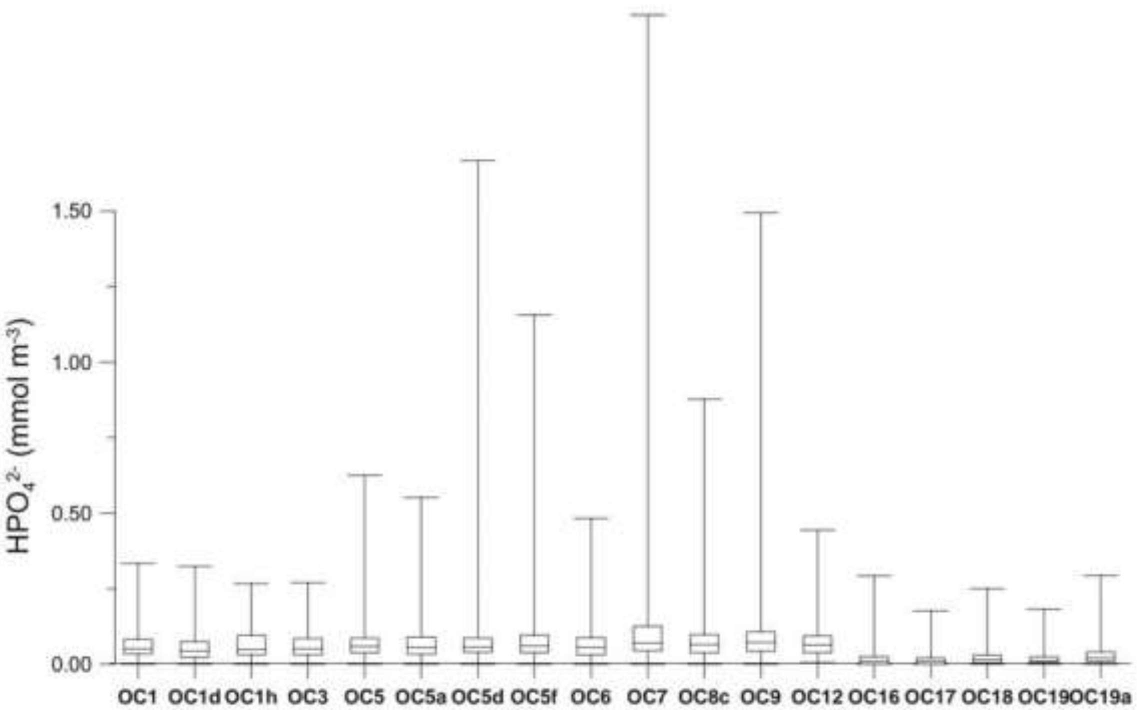


Figure 3.38 Box-whisker plots of the orthophosphate concentration in the water column of investigated stations for the period 1994-2010 (bottom line - minimum value, rectangle area - 25th to 75th percentile, upper line - maximum value, central line - median). Data sources: IOR-Split, CIM-Rovinj

Dispersion of 50% of all data at the stations in eastern and central Adriatic was relatively uniform from 0.03 to 0.09 mmol $m^{-3,}$ and more significant deviations were recorded at stations OC7 and OC9 in the Vranjic Basin and Port of Šibenik, which were the result of an anthropogenic input of orthophosphate. Unlike the area of southern and central Adriatic, the concentration range in northern Adriatic from 25th to 75th percentile was somewhat narrower (0.005 to 0.03 mmol m^{-3}). The above data confirms that concentrations of orthophosphate in the northern Adriatic are lower than those in central and southern Adriatic, and are at the detection limit. Since the "Initial assessment of the state and load of the marine environment on the Croatian part of the Adriatic" report describes chemical parameters sampled and analyzed in the laboratories of two Institutes (IOR-Split and CIM-Rovinj), it is important to note that during 2010 both institutes successfully took part in an international intercalibration to determine the concentrations of nutrient salts.

The absolute range of orthophosphate concentrations during the investigated period was from 0 (recorded at several stations) to 2.15 mmol m^{-3} (OC7 station). High concentration ranges at individual stations were also established, in addition to the OC7 station in the Vranjic Basin, for the group of deep open sea stations in the Palagruža Shelf and Jabuka Pit (OC5d, OC5f and OC8c) and at the OC9 station in Šibenik Bay.

Since freshwater flows into the sea and orthosilicate flow rates from sediment are the main ways they enter the marine environment, medians, but also concentration ranges within which 50% of all values occur, are a good representation for evaluating the impact of these processes on individual stations. The established medians of orthosilicate concentrations during the period 1994-2010 (Figure 3.39) ranged from 0.96 (OC5d station near Palagruža) up to 2.66 mmol m^{-3} (OC19a station in the open sea of the northern Adriatic), which clearly indicates a completely opposite effect of inflows or flows on the open sea area of the central Adriatic in relation to the northern part. Distribution of 50% of all data was relatively uniform for the majority of stations in the area of southern and central Adriatic, except for the stations in the mouths of the rivers Neretva, Krka and Jadra (OC3, OC9 and OC7) where most of the data is above the median due to increased concentrations in the surface layer. As regards stations in the northern Adriatic, the OC19a station stands out with an increased concentration range between the 25th and 75th percentiles, and an uneven distribution around the median. The reason for this is not, as in the case of central Adriatic, the freshwater inflow of orthosilicate, but a pronounced flow from the sediment. The absolute concentration range was from 0 (OC1d station near Slano in the southern Adriatic and OC19a station in the open sea of the northern Adriatic) to 67.18 mmol m^{-3} (OC9 station at the Port of Šibenik). A relatively high range was established, in addition to the OC9 station, at the OC5a station (Stončica, open sea of the central Adriatic) due to the remineralization of orthosilicate in the sediment.

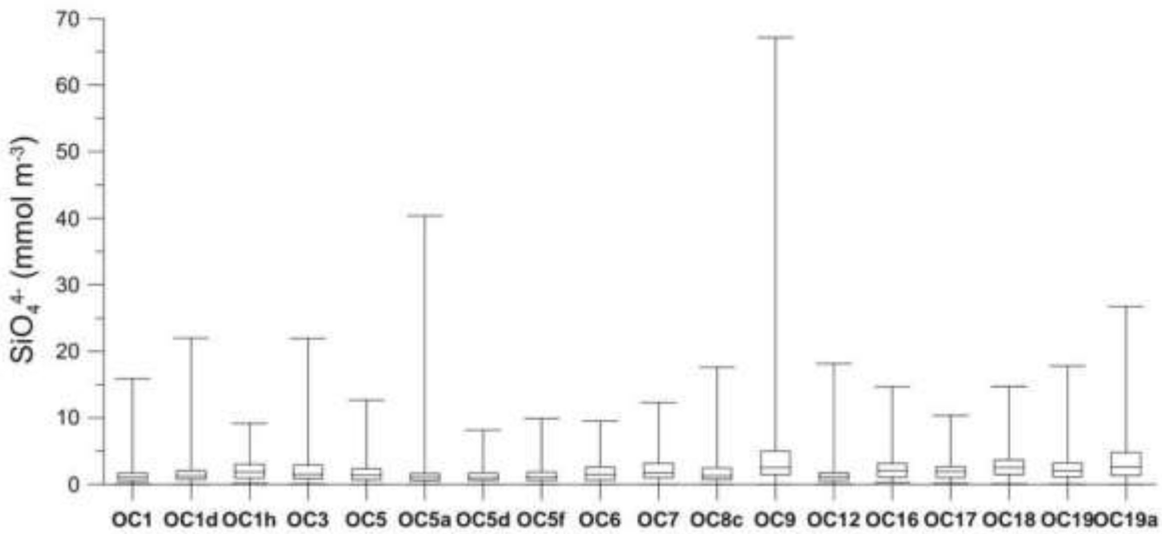


Figure 3.39 Box-whisker plots of the orthosilicate concentration in the water column of investigated stations for the period 1994-2010 (bottom line - minimum value, rectangle area - 25th to 75th percentile, upper line - maximum value, central line - median). Data sources: IOR-Split, CIM-Rovinj

Based on multi-annual data, notable seasonal variability of nutrient salts concentrations was established (total dissolved inorganic nitrogen and orthosilicate), whereas changes in orthophosphate were somewhat less notable. The highest concentrations of nutrient salts were established, similar to pH values and dissolved oxygen, at stations under direct anthropogenic influence (the Vranjic Basin and the Port of Šibenik) but also at the deeper stations in the open sea of southern and central Adriatic, where concentrations in the bottom layer (due to the natural process of decomposition of sedimented organic matter) can increase significantly. Elevated concentrations of nutrient salts were also recorded in the open sea area of the northern Adriatic (OC19a), where the impact of the Po River is crucial, in addition to the remineralization processes in the sediment core. According to the calculated N/P ratios, it can be stated that orthophosphate is a critical nutrient salt for the primary production of organic matter in the entire coastal region of the Republic of Croatia, as well as in open waters. Analysis of multi-annual changes in nutrient salt concentrations showed different trends at individual stations for inorganic nitrogen and orthosilicate, while orthophosphate showed a trend of decreasing concentration.

3.2.1.3 Organic matter in the Adriatic, an indicator of ecosystem status and change

Organic matter in the sea is one of the largest bioactive carbon reservoirs on Earth (662 Pg C), a source of food and an energy foundation for micro and macro organisms, a vital component of the biogeochemical system and a barometer of climate change. Organic matter enters the sea from different sources, including plant and animal excretion, bacterial degradation, autolysis of dead organisms, through rivers, wastewater and from the atmosphere. Organic matter is made up of different molecules that react with each other, with trace metals and with living organisms and inanimate dispersed particles in a wide spatial and temporal continuum, and today it is tested as a dynamic component of the global carbon cycle.

Dissolved organic matter (DOC), which makes up about 90% of the total organic matter in the sea, is an extremely complex and diluted mixture of compounds, of which only about 20% have been well defined so far. The proportion of particulate organic matter (POC) as present in the total organic matter (TOC=DOC+POC) is generally less than 10%. It consists of living and non-living phyto and zooplankton, bacteria, their excretion and degradation products, as well as of macroscopic aggregates. Recently, there has been intensive research on the vertical flow of POC, which has a significant impact on sediment composition and the sea layer above the sediment, and is the main food source for benthic organisms, as well as a precursor in the process of fossil fuel creation. The largest part of organic matter (> 70%) has the property of surface activity (surfactants or surface-active matter: PAT), and is concentrated through adsorption processes on natural interfaces of the sea with the atmosphere, sediment and living and nonliving dispersed substances, where it participates in the processes of mass and energy transfer.

One of the most important pieces of information about organic matter in the sea is obtained by examining the total carbon content in a mixture of organic compounds (TOC) distributed in a dissolved (DOC) and particulate (POC) fraction. Examination of a reactive component of organic matter, total surface-active organic matter (PAT NF) and dissolved organic matter (PAT F), enables determining representative characteristics, and in addition, a better understanding of the organic matter cycle in the sea.

This area is characterized by the appearance of pronounced seasonal and long-term fluctuations in oceanographic and biological conditions, mainly due to the impact of eutrophic freshwater from the Po River, with seasonal and annual variations caused by meteorological factors, advection of oligotrophic seawater from the central part of the Adriatic along the eastern coast, and by a very variable and complex circulation. These fluctuations also affect the content, distribution and properties of organic matter in the investigated area.

In the past two decades excessive algal bloom and the creation of large mucilage have been especially frequent in the northern Adriatic. These phenomena of varying intensity marked 1988, 1989, 1991, 1997 and the period from 2000 to 2004, while from

2005 to 2010 there was no occurrence of excessive algal blooms. Many hypotheses about the phenomena of excessive algal bloom are explained with the accumulation of organic matter primarily along zones with different salinity in the stratification period.
Seasonal and spatial fluctuations in average monthly values of the concentrations of DOC, PAT NF and PAT F for a period of 13 years (1998-2010) are characteristic for the northern Adriatic area. In the spring months, organic matter in the sea is accumulated, high values are retained during the summer and early fall, and from late fall to winter, in the period of decline in ecosystem stability, stratification and temperature, there is depletion of organic matter. Variations are most pronounced in the surface, illuminated layer of the sea, and less pronounced in the sea column and the bottom layer of the sea.
Analysis of fluctuations in average concentrations of DOC, PAT NF on a long time scale (1998-2010) showed that the intensity of fluctuations in certain years is very different and can be an indicator of global changes in the northern Adriatic ecosystem. Seasonal variations in DOC and PAT NF throughout the test period clearly show that in the years characterized by the occurrence of excessive algal blooms there is significant accumulation of organic matter (DOC and PAT NF) accompanied by phenomena of mucilage. Maximum values were established in 1998, while in subsequent years a declining trend in content of organic matter was recorded, with the lowest values recorded in 2006.
Analysis of the collected data on the concentrations of organic matter in the northern Adriatic during the period 1998 - 2010 shows pronounced seasonal and spatial variations of DOC and PAT NF of different intensity, which are characteristic for the area of northern Adriatic, and are most pronounced in the productive euphotic zone. Multi-annual tests of DOC and PAT detected a visible trend of changes in the content, properties and fluctuations of organic matter. Significant reduction in the content of DOC and PAT from 1998 to 2006 points to an important process of oligotrophication in the northern Adriatic, confirmed by other comparative research in the same ecosystem. The increase in content of DOC and PAT from 2007 to 2010 is likely the result of a new cycle of organic matter accumulation, which can, along with other favorable conditions, lead to the repetition of the harmful phenomena from the period 1998 – 2004. Results of the PAT (NPA) reactivity testing enabled the assessment of the presence of a specific type of organic material, which very likely plays a dominant role in the creation of mucilage organic matter and, together with characteristic measurement signals gained through PAT testing, which directly point to possible development of mucilage, can be used for early warning of harmful phenomena such as excessive algal blooms with mucilage occurrences. Future testing and constant monitoring of the dynamic in changes of organic matter in dissolved (DOC) and particulate (POC) form, as well as PAT, will allow for a better understanding of natural changes in the marine ecosystem, as well as of those caused by anthropogenic activities, and in combination with the results of complementary research they will serve as a basis for sustainable use, management and development of this area.

3.2.2 Descriptors of good environmental status

According to the Commission Decision 2010/477/EU, the proposed fifth descriptor of good environmental status is eutrophication, and good environmental status for this descriptor is described as: **Human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algal blooms and oxygen deficiency in bottom waters.**
According to the Initial assessment, eutrophication in the Croatian part of the Adriatic Sea has an impact that is mainly manifested at the local level. The environmental condition of this part of the Adriatic is in its largest portion good, i.e. of highest quality. The Initial assessment agrees with the condition which was found during the implementation of the Water Framework Directive (2000/60/EC).
Each disorder in the marine ecosystem balance is primarily reflected on the first trophic step, so by monitoring phytoplankton biomass it is possible to gain a very good insight into the complete state of the marine ecosystem. The increase in phytoplankton biomass is most often conditioned by increased availability of nutrient salts, and up to a certain extent this process has a positive effect on secondary production and on the entire ecosystem. From this aspect, the area of northern Adriatic demands special attention, as it is one of the most productive parts of the Mediterranean Sea, and is under the direct influence of the Po River, the third-ranked river by flow (1540 m^3/s) in the Mediterranean. If we assume that, for the Croatian part of northern Adriatic, the data collected over more than 40 years at the SJ107 station (13 Nm from Rovinj) can describe well what happens in its open part, we can see that the chlorophyll concentrations are characteristic for noneutrophic coastal seas and that there is significant annual variability present. The said variability can also be attributed to the natural as well as to the antrophogenic component of eutrophication load. An important assumption that results from the analysis of all available data on eutrophication of the Adriatic is that the regional perspective of the problem is significant compared to the majority of its Croatian part.
Good environmental status for the indicator of nutrients concentration in the water column is achieved if the mean annual values (geometric mean) for certain nutrient salts do not exceed: total phosphorus (TP) 1.4 µmol/L; total inorganic nitrogen (TIN) 2.4 µmol/L; orthophosphate (PO4) 0.15 µmol/L.

Good environmental status for dissolved oxygen is described in the following manner: **The concentration of oxygen in the bottom layer must be sufficient for the survival of marine fauna.** Due to the anthropogenic effect, episodes of oxygen concentration decrease (hypoxia) must be temporally and spatially limited so as not to cause the massive dying of organisms. The appearance of complete disappearance of oxygen in the bottom layer (anoxia) must not occur. The indicators are the concentration of dissolved oxygen in the bottom layer, spatial extent of anoxia or hypoxia as well as their duration. DSO is preserved if the oxygen concentration is not less than 2 mg/L, as a limit value between anoxia and hypoxia.

3.3 Climatic features

3.3.1 The impact of individual meteorological elements

For the major part of the year, the wider area of the Adriatic Sea is located in a circulation area (cyclones) of moderate width with changes of weather, except during the summer when the Azores anticyclone prevents incursions of cold air into the Adriatic. Then this area comes under the influence of the subtropical belt. Apart from the cyclogenetic effect of the northern Adriatic, weather in the Adriatic is also influenced by the Dinarides orography. Cyclonic activity typical for colder periods is significant for the cloud and precipitation regime of the coast and hinterland, with the cyclones generally never crossing from the Adriatic to the mainland in the coldest part of the year. **In the summer** the Adriatic has prolonged clear weather with a balanced air pressure with about 1015 hPa. In accordance with the general baric gradient in the Mediterranean and the position of the Adriatic Sea, at that time there is a northwestern wind (Etesian wind) on the open sea, light wind in the northern Adriatic, moderate wind in the central Adriatic, and occasionally strong wind closer to Otranto. At the same time local daily periodical air circulation occurs at the majority of islands and the coast, due to non-uniform heating and cooling of the land and sea and the mountains and adjacent lowlands. This is diurnal wind from the sea to the mainland and nocturnal wind from the mainland and down the slope towards the sea, which allows for the exchange of air properties, and thus the establishment of uniform spatial distribution of meteorological parameters and mitigation of extremes. In the colder part of the year and at night during calm weather, turbulence is small and local conditions are more pronounced, so the differences in values, variations and spatial distribution of meteorological parameters of mutually closer stations are large. Winds that stand out in terms of force are bura (bora) and jugo.

Sea level as a dividing surface between the atmosphere and the sea is very dependent on conditions in the atmosphere and the sea. Atmospheric pressure acts on the sea. Higher pressure lowers its level, and lower pressure enables it to rise. These changes are about 1 cm for 1 hPa pressure change. The complex effects of the atmosphere on the sea are associated with air currents - winds, which create waves or sea currents. What can be added to this are sea level changes related to water evaporation, precipitation, flow of rivers and groundwater, creation / melting of ice, which is less pronounced, except in some places.

Temperature

The atmosphere lets through a lot of the Sun's radiation to the Earth's surface, which means that the atmosphere is heated very slightly by radiation. Therefore, the atmosphere (troposphere) is heated indirectly, below from the base, the land and sea, which have different thermal properties. As the heating of the atmosphere (troposphere) is connected to the heating of the base, the troposphere is warmest at the bottom and temperature decreases with altitude. Water surfaces get heated / cooled differently than land. The transfer of thermal energy in water takes place through processes of radiation, conduction and transfer (convection). Water lets through radiation energy of small wavelengths into the deeper layers, and it strongly absorbs radiation in the long-wave area, which results in surface heating (a water layer of 10 cm absorbs half the total energy radiated by the Sun). Heat conduction is inconsiderable. The most important way of heating / cooling of water masses is transfer - convection. As the specific heat of water is larger than that of land, water will be less warm than land from the same amount of received heat, with part of the energy being lost in water evaporation. Large water masses change their temperature slowly, because they heat and cool slightly due to their high specific heat. Changes in sea surface temperature are small, which applies to annual changes as well, although the highest ones are up to 8 °C at moderate geographical latitudes. More pronounced changes are in closed seas, near the coast and in shallow water. Different conditions are present above the sea. As changes in temperature of the sea surface are small, the air temperature ranges just above the sea surface are also small. This mitigating effect of the sea on air temperature decreases with increasing altitude. At a few hundred meters above the sea, temperature changes during the day do not depend only on the temperature of the surface, but also on the absorption and radiance of radiation in those air layers, and the air temperature ranges at an altitude are higher than near the sea itself. During the day the air is warmer, and at night it is cooler than the sea surface. These temperature differences are smaller than over land. As air is cooled more at an altitude during the night, and temperature near the sea surface is relatively constant, there is instability and rising of warm air. Therefore, convection, and with it the thunder over the sea, is more frequent at night than during the day.

Air temperature is one of the indicators of the state of life and work of people, but also of its impact on the processes in the atmosphere and the sea. Mean annual air temperatures in the areas closer to the Adriatic are shown in the figure below, Figure 3.40, and refer to the period 1961-1990 as a normal climatological series. The problem is that these are air temperatures recorded at land meteorological stations (many of them close to the sea), but are not direct data of measurements over the open sea (at 2 m height as a standard). However, it can be observed that the mean air temperatures closer to the coast are generally about 14 to 15 °C or 15 to 16 °C towards the southern parts of the Adriatic. The calculated (predicted) maximum air temperature values over the next 50 years are expect to be about 35 to 40 °C, while the minimum values are within the limits of -15° C to -10 °C, then from -10 to -5 °C, and in some places in the south from -5 °C to 0 °C.

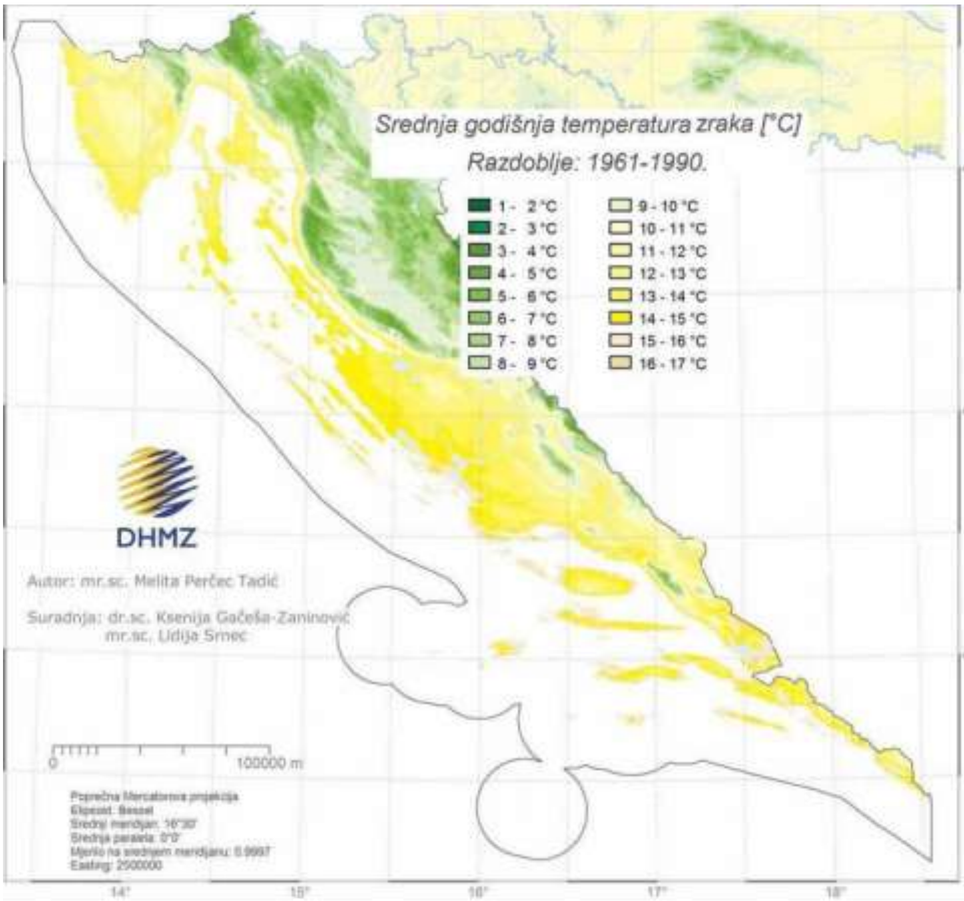


Figure 3:40 Mean annual air temperatures in areas closer to the Adriatic, in the period of 1961 – 1990. (MHS)

<u>Wind</u>

Basic forces acting on air in movement are the gradient force (due to pressure difference), Coriolis force, centrifugal force and friction force. In the northern hemisphere the wind usually turns towards low pressure or left, and on the right hemisphere to the right. Initially, wind increases with altitude through friction reduction and it changes direction. There are numerous types of winds, and starting winds are those between land and sea, i.e. coastal winds during nice and stable weather. During the day, wind blows from sea to land (sea breeze) with a speed of 3-8 m/s, and during the night the other way around, i.e. from land to sea (land breeze). Sometimes in the night, if the land is cold and the sea relatively warm, land breeze can be quite strong in some places (> 15 m/s). There are also other types of wind, and bora and jugo are prominent in the Adriatic. There are also burin and maestral.

<u>Bora</u> blows on the shores of the sea where mountain ranges divide warmer air over the sea from colder air over the land. Bora is a strong, cold and mainly dry wind that blows from the northeast quadrant and in gusts.[3] Bora reaches speeds of 15 m/s, sometimes exceeding 30 m/s, while gusts of wind assume values of 50 m/s. Due to its pronounced changes of direction and speed in very short periods, bora creates a very strong turbulence, which leads to significant problems in all human activities. Going from the east coast towards the open sea, bora gets weaker and is rarely stormy (speed greater than 17.2 m/s ≡ 8 Bf) on the west coast. Bora blows for several hours to several days, and it occurs throughout the year even though its frequency is different in some years. At the eastern coast of the Adriatic, the frequency of bora decreases from the north-western to the south-eastern section. In the winter it can last up to two weeks with breaks. Winter wind is on average stronger then summer wind. Stormy, severe bora lasts for a maximum of two days. In the summer, it usually does not last longer than a day, and sometimes for just a few hours. Bora marks the typical weather condition in the Adriatic.

At sea, bora causes short, but not high waves (1 to 3 m extremely). Moving away from the eastern coast, wave height initially increases and then decreases. The tops of waves are dispersed into foam by the bora, which carries it as dust (sea smoke) and this significantly reduces visibility.

The emergence of bora is influenced by atmospheric pressure over central Europe and the Adriatic, i.e. the Mediterranean. Here, the current direction in the lower troposphere is important, determined by the cyclone position in the Mediterranean or by strengthening of the ridge of high air pressure over central or eastern Europe towards our region. Therefore, there is a difference between cyclonic and anticyclonic bora (Figure 3.41).

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3 The beginning of bora is linked to ***hydraulic flow*** (hydraulic jump) over the mountains. It is connected to breaches of cold air from the north and should be observed in the ***lee*** as well as in the ***windward side*** of the hill with respect to temperature inversion.

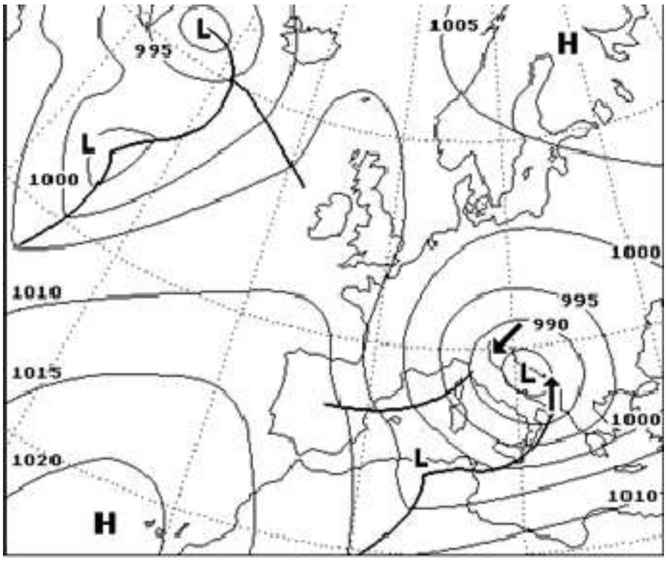


Figure 3.41 Bora in the north and sirocco in the south Adriatic (MHS)

The onset of bora is not connected to any particular moment during the day, and when it starts, this is different for various places on the coast. An additional feature of bora is that is starts suddenly. Characteristic signs for the occurrence of bora depend on its type. There are some signs for cyclonic bora, like the creation of clouds on mountain tops, "cloud cap". On the lee side towards the sea a so-called foehn wall appears, clouds that look as if they lay down by the mountain. When individual small clouds detach and peter out carried by wind, and the tops of hills and mountains are covered by the cloud cap, a rush of bora is to be expected on the open sea at any moment, while along the coast it is already blowing. If the cap is growing, this means that bora is also gathering strength. If bora starts to blow during cloudy weather, its weakening or cessation can be expected only after clear weather starts from the northeast. After a strong bora, cold weather usually ensues, with weak or moderate winds. During the day a northwest wind then tends to blow for a few hours, and at night a moderate wind from the mainland. There are no particular warning signs for anticyclonic bora.

Bora forms a multiplicity of vortices of various sizes formed when it blows down the mountain. These vortices are caused by irregular air flows over the mountain ridge and at numerous protrusions and depressions on mountain slopes, as well as by the state of the atmosphere when a stable wave flow type turns into a vortical one. Strengthening of the wind (gusts) ensues when the flow directions of two contiguous (adjacent) vortices coincide, and weakening of the wind (standstill) occurs when two contiguous vortices are in opposition. In addition to changes in speed, there are short-term, but distinct changes of bora direction in a circle of as much as 360°, vortices.

The shape of the land has an almost decisive influence on the direction and speed of bora, so it can blow from N to ENE. These are usually areas of notches and glens at mountain ranges. The places where bora blows are: Gulf of Trieste (Trieste, Savudrija), Kvarner and Kvarnerić, Rijeka Bay (Martinšćica, Bakar Bay), Velebit Channel (between the island of Krk, Prvić, Rab, Pag and the coast, Senj, Senj Gate, Karlobag), the area of Šibenik and Split (Kaštela Bay, Solin "kliška bura"), Vrulje Bay (between Omiš and Makarska), Dubrovnik, Bar and Drim Bay. Somewhat lighter bora blows around the mouth of the Krka River, then in Žuljan Bay (Pelješac), at the mouth of the Neretva River and Bay of Kotor, and it blows relatively lightly on the west coast of Istria, in the Zadar Channel, in the lee of Dugi Otok, Kornati and Mljet and on the coast between Cavtat and Oštri rt. In other countries there is also wind that has the features of bora.

It was mentioned that bora can reach speeds of up to 50 m/s (180 km/h), and its highest speed was measured at the Maslenica Bridge near Zadar - 69.0 m/s (248 km/h - 21 December 1998). Bora is also very strong in other places along the coast of the Adriatic; at the Krčki Bridge its speed was measured at 54.5 m/s (196 km/h - 3 December 1983), in Senj 48.0 m/s (173 km/h - 9 January 1985) and in Split - Marjan 45.0 m/s (162 km/h - 31 January 1983). The largest average hourly values of wind speed were measured in Split - Marjan 29.2 m/s (105 km/h - 15 March 1962) and in Senj 28.9 m/s (12 December 1967).

Burin usually blows in the summer, during the night as wind from the land towards the sea. On the east coast it blows from the northeast, and on the west coast from the southwest. The direction of burin in our region is NNE to ENE, towards the eastern shores of the Adriatic it is mostly eastern, and on the west coast of the Adriatic it blows southwest. Its speed is up to 12 m/s and can reach up to 30 km of open sea. Burin is actually a combination of wind from the land (land breeze) and wind blowing from the mountain to the valley (upslope wind).

Jugo is the wind of the Adriatic Sea, conditioned by the general southern current arising from the Mediterranean cyclone (Genoa) or in the Adriatic, and it only sometimes blows in the broader expanse of the Mediterranean as part of the sirocco wind circulation. Sirocco can sometimes turn into jugo, but never the other way around. Over the open sea, in the Adriatic, jugo usually blows from the southern quadrant, and it turns towards the south-eastern quadrant closer to the coast, due to the influence of orography and friction. It is a warm and humid wind, accompanied by cloudy and rainy weather. It blows for several days at a steady speed of about 10 m/s, and as a gale it reaches as much as 30 m/s. It is stronger on the open sea, while it diminishes in strength towards land. It is more frequent in the southern Adriatic and during the cold part of the year, when it is stronger than in the summer. In the southern Adriatic it is most common from fall to late winter, and in the northern Adriatic from late winter to early summer. In the winter it lasts for a week, and up to three weeks with breaks. In the summer it lasts up to three days.

Jugo is strong on the open sea or where the wind blows along a channel. Such areas are: Gulf of Trieste, Kvarner and Kvarnerić, external channels between islands in northern Dalmatia, Lastovo and Mljet channels and the open sea south of Dubrovnik.
The occurrence of jugo is linked to the decrease in atmospheric pressure, increase in temperature and air moisture, and with calm, or weak wind and a cloudy horizon. The sky is blanketed with clouds massed around mountain tops (on the islands and the mainland). Visibility is poor. Rain is moderate, severe or includes showers, with heavy rainfall on the coast. Thunder also appears. Jugo develops after one to two days of blowing, and does not come suddenly. It usually turns into gale (> 17.2 m/s ≡ 8 Bf) during the third day of blowing. The sea starts to rise, and is often preceded by "dead" waves from the southeast. Jugo creates high waves, much higher than bora, although their speed may be equal. Wave height normally reaches 3-5 m or even more (10.8 m), causing difficulties in maritime affairs and coastal areas. Jugo is accompanied by intensified sea currents (1 m/s) and rising sea level in the eastern part of the Adriatic (> 50 cm).

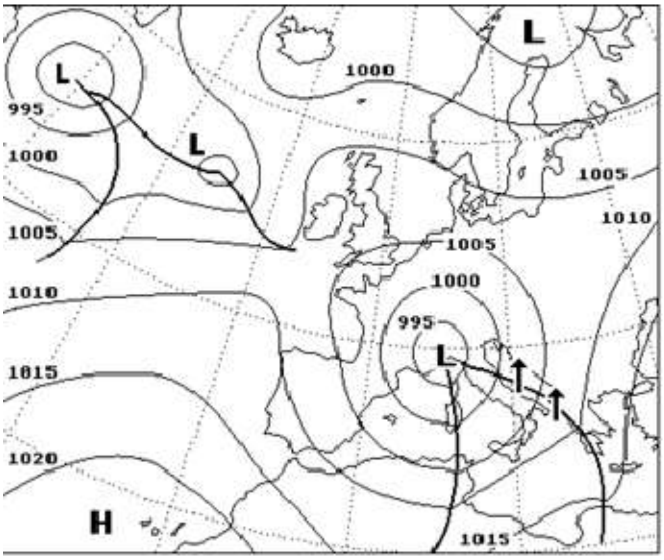


Figure 3.42 Jugo (general weather conditions) (MHS)

Jugo depends on the position and movement of the center and the propagation area of cyclone and anticyclone, so there is cyclonic and anticyclonic jugo, although it is mostly of cyclone origin. In case of anticyclonic jugo (high atmospheric pressure over eastern Mediterranean) cloudiness is less developed, and there is almost no rainfall.

Maestral **-** in summer, because of the Azores anticyclone and decreased pressure over southwest Asia, there is high northwestern airflow over the wider area of the Adriatic; this is ***Etesian*** wind. The Etesian wind impacts the lower layers and even the sea breeze, which gathers strengths; this is maestral. Maestral (not to be mistaken with the mistral wind in France) occurs in the summer during the day on the east coast of the Adriatic. It blows towards land from west to northwest, slowly turning with the Sun, with a speed of 5-8 m/s, and towards the south Adriatic at over 15 m/s. Maestral weakens or is absent a day or two prior to jugo or rainy weather. The sea breeze blows from the southwest on the banks of Albania. Eastern or southeastern wind blows from the sea during the day on the west coast of the Adriatic.
Winds of the Mediterranean Sea - what is evident from the aforementioned is the existence of winds in the area of the Adriatic Sea, as part of the Mediterranean Sea. These winds are just some of the more significant ones. It is sometimes said that each bay or cape has "its" own wind, which is not far from the truth. Basic winds over the Mediterranean Sea are shown in the figure below, Figure 3.43. The largest expanses are taken by sirocco, as a wind that blows from Africa across the Mediterranean Sea. Apart from these winds, the Etesian upper level wind is also included, which together with ground-level winds produces certain types of winds, for example, maestral in our region.

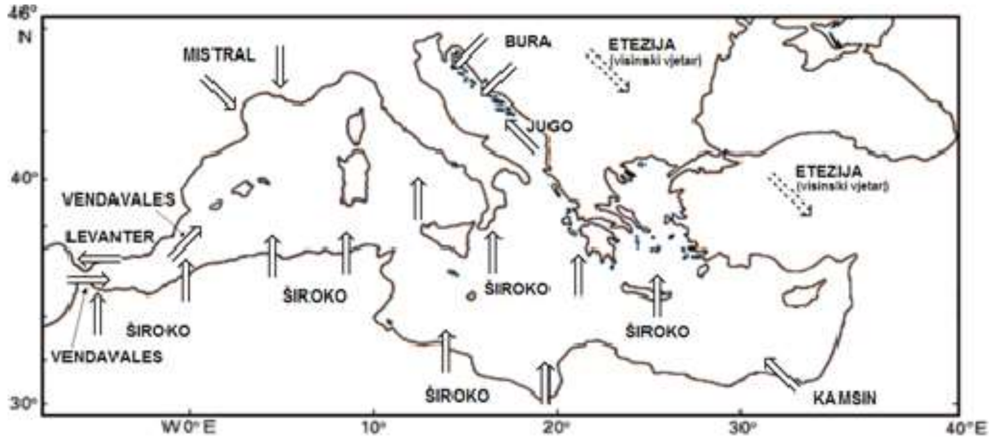


Figure 3.43 Winds of the Mediterranean Sea (MHS)

Mean annual wind speeds in areas closer to the Adriatic are shown in the figure below, Figure 3.44, and refer to the period of 1992 - 2001 as one short climatological series. Wind was measured at the standard height of 10 m. However, it can be observed that the mean wind speeds closer to the coast are higher, especially in some places. As the mean value sometimes hides the true value of a certain element, (forecasted) calculated core values of the highest 10-minute wind speed for the next 50 years are shown (Figure 3.45). Speeds of around 30-35 m/s, and in some places 40 m/s can be expected, and in the Senj Channel close to 50 m/s. Of course, these speeds can cause bigger waves, as well as stronger sea currents.

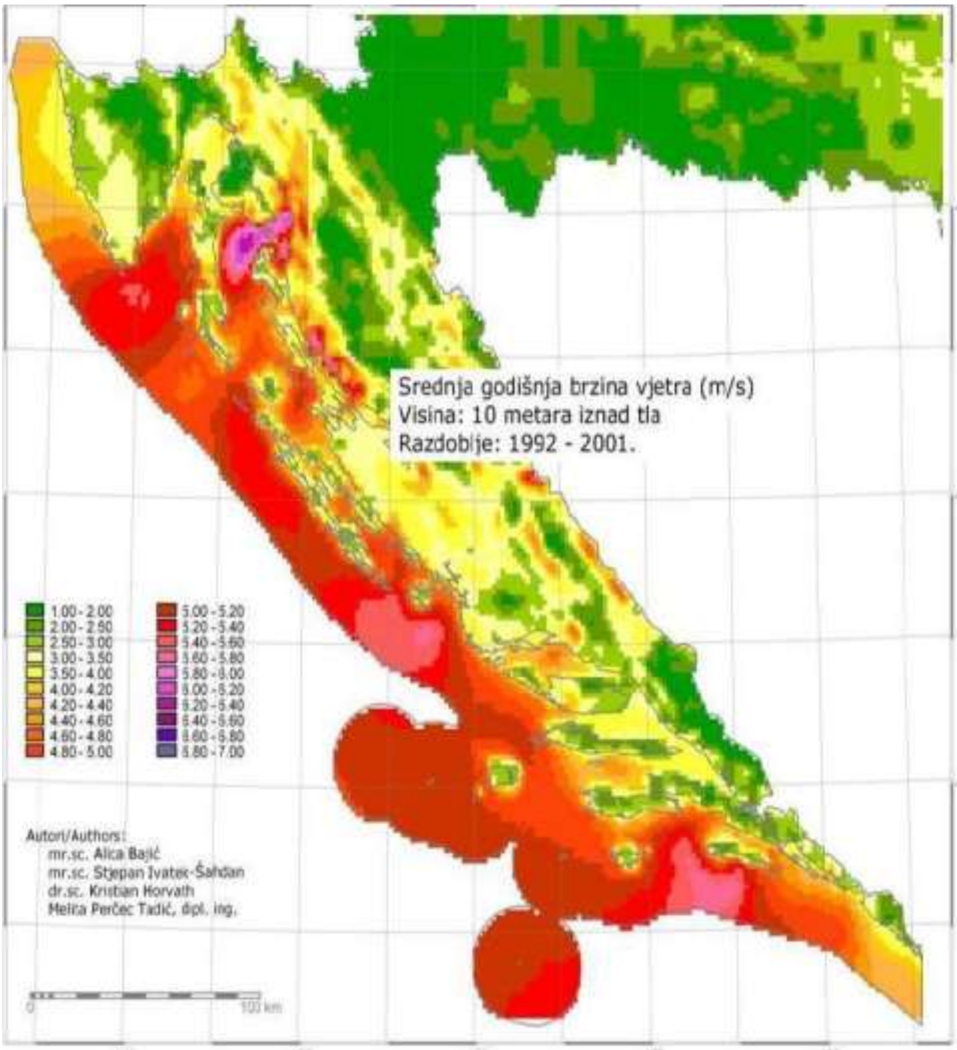


Figure 3.44 Mean annual air speeds in areas closer to the Adriatic, in the period of 1992 – 2001. Source: MHS)

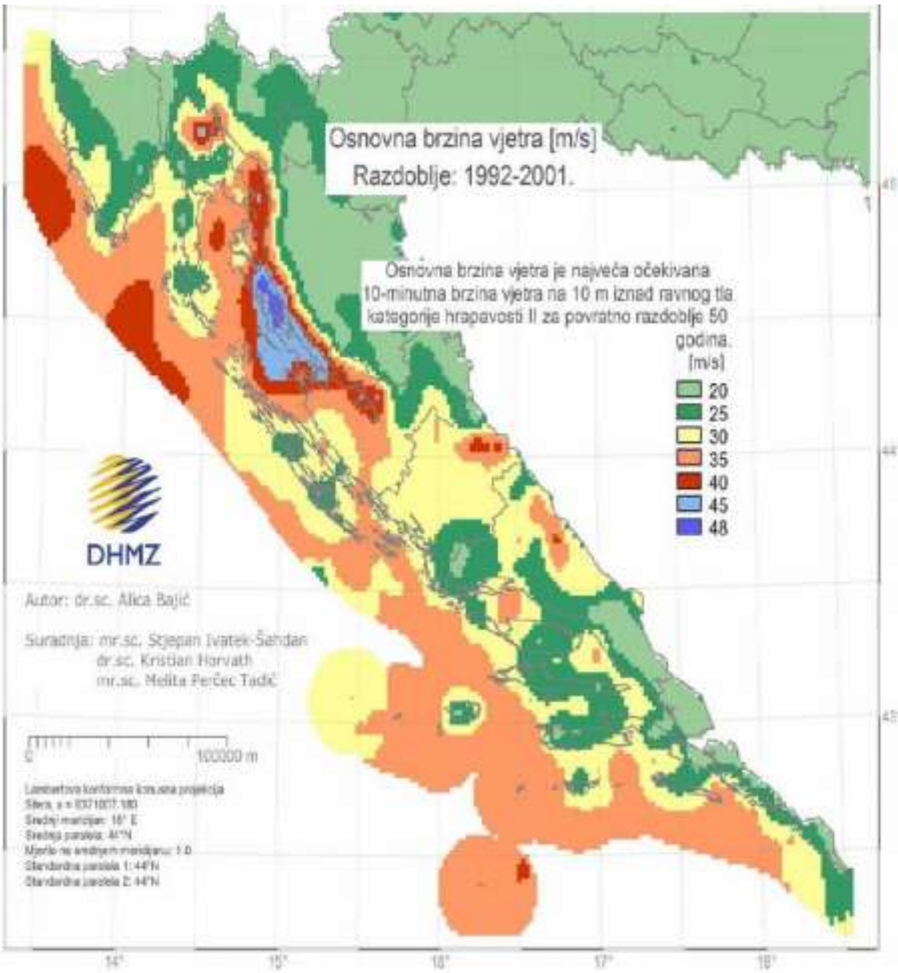


Figure 3.45 Basic air speeds in areas closer to the Adriatic, in the period 1992 -2001, for a return period of 50 years (source: MHS)

Process modeling - Measured wind data is more difficult to obtain over sea surfaces that are distant from land. They are mostly obtained during research or during journeys of ships that have appropriate measurement instruments. The said applies to all meteorological and oceanological elements. The number of ships taking measurements (Atlantic, ship A or B or C ...) who are stationed at one particular place in the oceans is diminishing due to the high cost of system maintenance. Admittedly, satellites can play a big role, but for certain measurements there are problems with the appearance of a heavier cloud system, and difficult or impossible measurements. Then, numerical modeling plays an important role, giving increasingly better research results, as a complement to measurements. An example is the modeling of a ground-level wind over the Adriatic during the day, i.e. night (Figure 3.46).

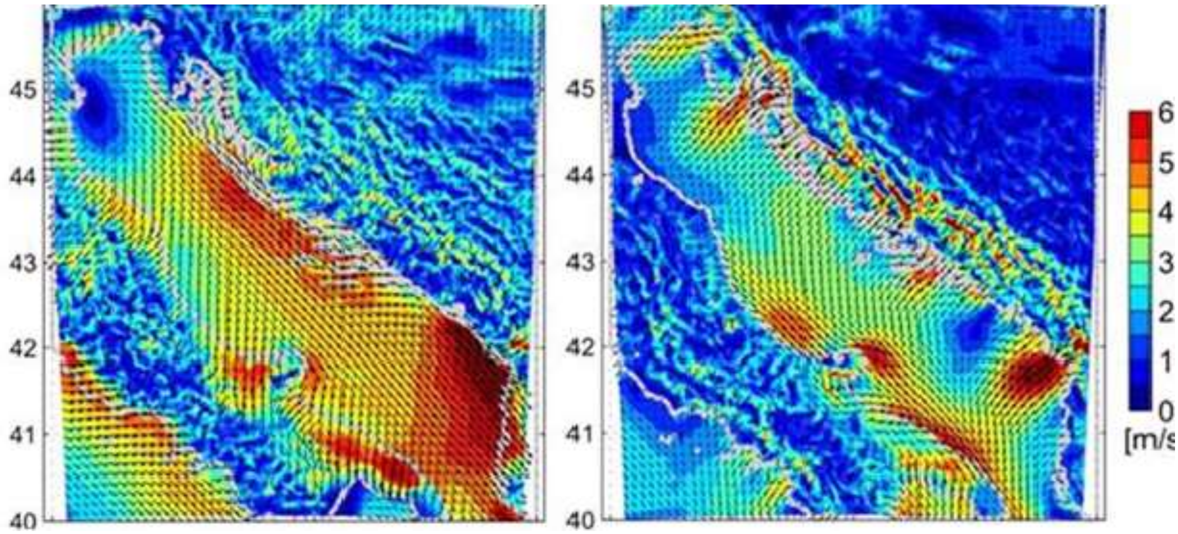


Figure 3.46 Modeled mean ground-level wind over the Adriatic during the day (left) and at night (right) during summer days undisturbed by Etesian wind and coastal circulation Bencetić Klaić, Pasarić, Tudor, 2009).

By applying the appropriate numerical models "Aladin" and "SWAN" with a resolution of 2 km, results are obtained that show the state of the weather or sea (bora analysis, 14 November 2004 at 18 UTC). The following shows the field of a ground-level wind (direction and speed), and the field of waves (height and direction of movement) (Figure 3.47) in the Adriatic, created by a strong bora (13 -18 November 2004, speed of 240 km/h). The largest wave heights of 5.5 m were found in the central Adriatic closer to Italy, while in the Kvarner region they were about 3 m, despite a strong wind of over 30 m/s. The obvious reason is a small fetch. It should be noted that the modeling results are in close agreement with the measurements.

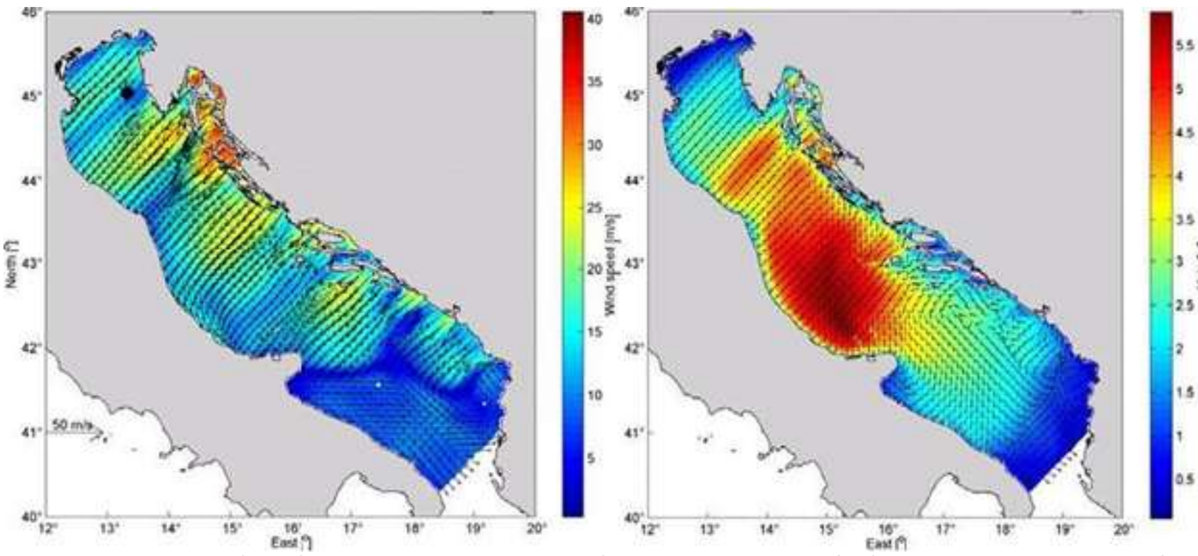


Figure 3.47 Predicted field of ground-level wind at a height of 10 m above sea level (m/s), for 14 November 2004 at 18 UTC. (Janeković and Tudor, 2005) - left photo, and Predicted field of wave height (m), for 14 November 2004 at 18 UTC. (Janeković and Tudor, 2005) - right photo

3.4 Geological and petroleum geological features of the underground

The Adriatic area, as well as the Apennines on one side and the Dinaric Alps on the other, nest on the lithospheric microplate Adria (or Apulian). The geological history, i.e. paleogeographic and geo-tectonic development of this Peri-Adriatic area may be followed from the oldest discovered or drilled rocks in the Adriatic underground and coast, and these are the Hercynian consolidated Upper Palaeozoic layers of the Velebit and South-eastern Lika. In the Middle Carboniferous period (Moscovian), about 310 million years ago (MA), this area was located in the epeiric platform on the northern edge of Gondwana located at a latitude of 10° south. Due to the movement of the large lithosphere plates of Gondwana to the south and Laurasia to the north, with a dominant direction of movement towards the northeast and north, to the present day position at a latitude of 40° to 46° north, this area has travelled a path of about 6000 km (Dercourt and others, 2000; Scotese, 2002, Vlahović and others, 2005 with reference older literature Vlahović and others, 2005).

During this time period, from the Moscovian to the Holocene, with continually changing tectonic dynamics that was reflected through the formation of various sedimentary environments, from deep sea through to shallow sea and land, the Hercynian substrate is covered at places with over 15,000 m of various clastic and carbonate deposits. According to the most significant palaeographic and tectonic events that caused these dynamics, four petroleum geological units (PGU) particularly stand out. (Image 3.48)

The rock substrate of the Adriatic Carbonate Platform (AdCP) from the Middle Carboniferous period to the Early Toarcian:

- rock of the AdCP from the Toarcian to the end of the Cretaceous;
- rock from the Palaeocene and Miocene;
- deposits from the Pliocene and Quaternary.

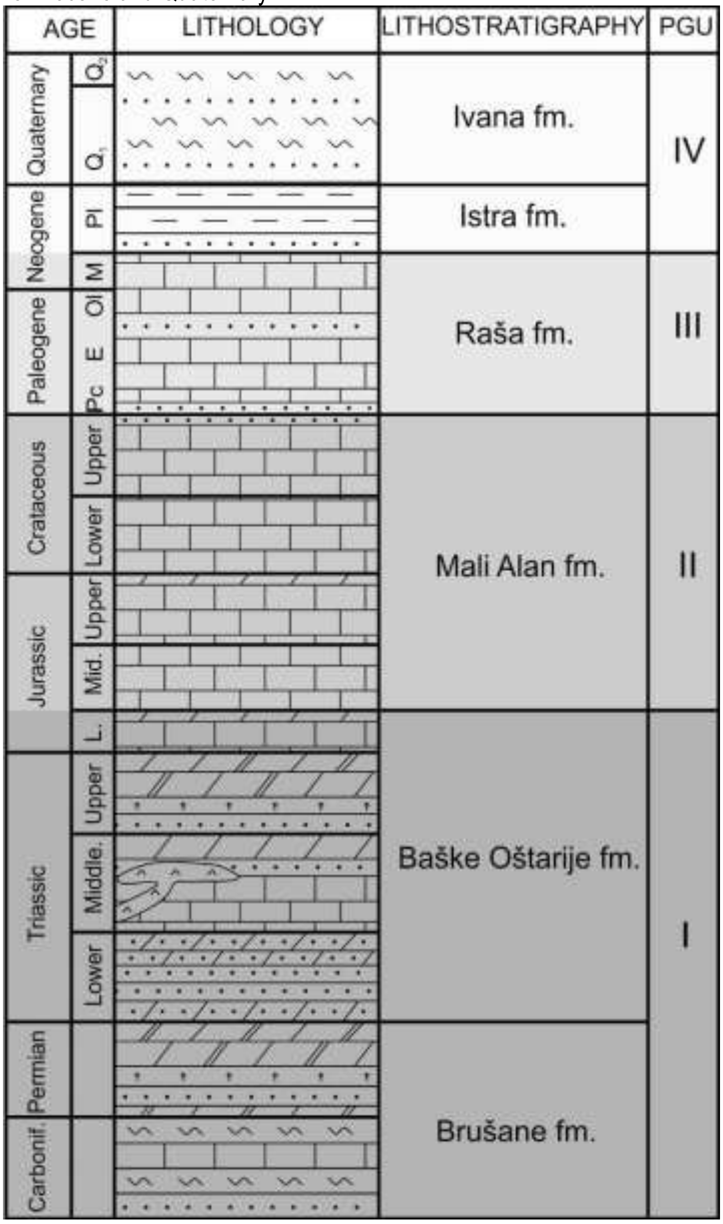


Image 3.48 Schematic geological column with indicated formations and petroleum geological units (Source: Jüttner Preradović, 2005)

3.4.1 Substrate of the Adriatic Carbonate Platform (AdCP), Middle Carboniferous – Early Toarcian; first petroleum geological unit

The oldest deposits in the substrate of AdCP are clastics of the Middle and Lower Carboniferous period (Velić and others, 2000). They were discovered in Lika and at the base of the Velebit Mountain in Lika near Bruvno and from Štikada to Brušani.

During the Middle and Lower Carboniferous, and at the beginning of the Permian, in relatively shallow surrounding river deltas and estuaries, primarily sludge and sandy detritus were deposited, which were brought here by terrestrial watercourses. Clastic deposits and rocks – shale and sandstone were created from these. They contain marine macro fauna like trilobites, brachiopods, bivalvia, gastropods and crinoids. Of land plants, Equisetum and ferns were found.

In even shallower parts of the deposit environment, outside the range of the terrigeneus mixtures, carbonates were also deposited - Fusulinid limestone. They are located within the form of kilometre lenses within the mentioned and prevailing clastics. They are rich with microfossils - foraminifera, primarily fusulinids and calcareous algae.

In the Middle Late Permian, a land period ensued as a consequence of heaving and with it also an intensive erosion of previously deposited carbonate and Early Permian deposits. Red terrestrial deposits were sedimented – Brušani sandstone and siltstones with lenses of Košna conglomerates. At the end of the Late Permian, with gradual ingression, the depositing of shallow marine carbonates began which, with occasional interruptions, lasted until the Middle Eocene. In conclusion, the described carbonate and Permian clastic deposits also represent a substrate for the carbonate rocks of the karst Dinaric Alps.

With gradual flooding of land surfaces, from the end of the Late Permian to the end of the Permian, shallow, primarily tidal environments with sedimentation of carbonate deposits prevailed, mostly early diagenetic dolomites (EDD) known under the name Mizzia dolomites (in the broader sense). Some of this dolomite was also late diagenetic dolomite (LDD), so often a change in grey calcareous EDD and light grey crystal LDD are noticed. Given the indentedness of the paleo relief, tens of metres to a maximum 1100 m of these deposits have been sedimented. At places, in subtidal environments and/or lagoons under almost anoxic conditions, there are deposits of layered bio-clastic packstone/grainstone alternating with laminated to micaceous black mudstones enriched with organic substances. As of recently they are too ripe, but once they were real source rocks. On the Velebit from Brušani towards Baške Oštarije, this limestone, at three levels inside the Mizzia dolomite, is well known, while in Velika Paklenica it has been discovered at one level. Owing to the rich fossil content (brachiopods, Foraminifera, calcareous algae), the age of these carbonates is determined in a range from the Early Kungurian to the end of the Permian. Towards the end of the Permian there was also local gradual thawing with depositing of Greden deposits – red siltstone and sandstone. Laterally in relation to Lika and the Velebit in the area of present day Gorski Kotar, mostly clastic deposits, sandstone and shale were deposited in places with flysch-like features. On the other hand, southeast from present day eastern Lika (Butišnica and Una valley), then in northern and central Dalmatia (Knin, Drniš, Vrlika, Sinj), evaporites were created in sabkha environments.

From a paleogeographic point of view, during the Middle and Late Permian, sedimentation took place on an epeiric carbonate platform. Data about Permian deposits in the Adriatic underground originate from the well in Rovinj and Amanda-1 bis, the deepest Adriatic well (7305 m) in which in Trogkofel deposits specific fusulinid foraminifera have been confirmed.
Continuous transition from the Permian into the Triassic was marked by strong terrigenous influence that bear witness to the immediate vicinity and erosion of land surfaces. They are also reflected in the shallow water Lower Triassic sedimentation, while the end result are Werfenian deposits built from sandy dolomites and micas sandstone. Lower Triassic deposits have been found in Palagruža and in the well Susak More 1 AL.
On the Lower Triassic deposits, in continuity, follow Diplopora limestone and late diagenetic dolomites of the Middle Triassic. They are deposited in shallow sea environments of increased energy, in favourable conditions for the development of benthic organisms – various molluscs, calcareous algae, foraminifera, etc. During the Ladinian, as a consequence of extensional tectonics, alongside deep faults in the, to then, deposited carbonate sequences small basins emerged, but also partial gradual thawing out so that in the basins next to submarine volcanism, shale, sandstone, pool limestone and pyroclastic rocks, tuffs and tuffites appeared. On land these rocks and deposits are most developed on the slopes of the Velebit in Donje Pazarište.
The Middle Triassic magmatism in the Adriatic and coastal parts of Croatia is known in two series: (1) land from the Fužinski Benkovac to Senjska draga, Donje Pazarište, Knin and Drniš to Sinj, and (2) in the offshore parts of Adriatic on the islands of Jabuka, Brusnik and Vis (Komiža). On the Adriatic carbonate-clastic deposits from the Ladinian period can be found in Komiža, while on Palagruža clay deposits with gypsum can be found. The Middle Triassic was also confirmed in the well Vlasta-1.

The mentioned extensional shifts in the Peri-Mediterranean area culminated in the Early Ladinian separation of the microplate Adria from the northern edge of Gondwana. This marked the end of the existence of the epeiric platform and emergence of the large isolated South tethyan megaplatform that encompassed the present day karst Dinaric Alps, southern Apennines, Apulian, Albanides and Helenides. The Peri-Adriatic area for the most part thawed out at the end of the Middle Triassic, so that from the Late Ladinian to the Late Norian, in paleo-karst coves and sinkholes in the Middle Triassic on Diplopora limestone there are deposits of red land Raibl clastic deposits, primarily siltstone, fine and coarse grained sandstone and breccia and conglomerates. At places, even during the Carnian, there was marine sedimentation, so in the narrow Adriatic region from this period the Carnian limestone and evaporite deposits in Komiža originated. The biggest part of the Island of Palagruža is made from fine grained, Upper Triassic, late diagenetic dolomites.

Similar to the Middle Pernian, so too in the Early Norian through gradual ingression, the sea flooded the karst Diplopora limestone and clastic Raibl deposits, so until the end of the Triassic, the Main dolomite of the Upper Triassic was sedimented. Its basic lithological feature is the replacement of grey early diagenetic with brown late diagenetic dolomites. At places, in the first layers of the Main dolomite, there are interbeds of tuffite-like dolomite. These arose from volcanic ash during eruptions of basalt lava like, for example, in Baške Oštarije on the Velebit. The Main dolomite, closest to the Adriatic Sea, aside from the Velebit, is near Ploče and southeast from Slivno Ravno across to the Dubrovnik coast and Župa to Konavle. Upper Triassic deposits have also been confirmed in the wells Vlatka-1 and Vlasta-1.

The transition from the Triassic to the Jurassic was continuous, while the border was set in the floor of the first limestone layer in the Main dolomite. In the Lower Jurassic, three stratigraphic units most commonly stand out: (1) Mali Alan limestone and dolomites of the Hettangian and Sinemurian with exchange of algea (Paleo- dasycladus) and foraminiferal (orbitopsele and other lithuolid) limestone and late diagenetic dolomites, (2) Lithiotic limestone from the Pliensbachian and Early Toarcian (lithiotid bivalvia and lithoulid) and (3) Blotchy limestone from the Toarcian. Mali Alan and lithiotic limestone relatively close to the sea can be found in Gornje Jelenje, in Senjska draga, Baške Oštarije and the National Park Paklenica, while they are closest and almost on the coast between Gradac and Ploče.

More recent research have shown that the upper part of the Lithiotic limestone is of Early Toarcian age (SABATINO and others, 2013). The crossover from Lithiotic limestone to Blotchy limestone in the Early Toarcian also denotes the end of the first petroleum geological unit or border with the AdCP, i.e. with the second petroleum geological unit.
The Lower Jurassic deposits have not been confirmed in Adriatic wells. In the deepest intervals of the well Jadran 02, there is mention of the Mesozoic, while in the wells Vlatka-1 and Vlasta-1 the Jurassic in general.

3.4.2 Rocks of the Adriatic Carbonate Platform, Late Toarcian – end of the Cretaceous; second petroleum geological unit

The Peri-Mediterranean region during the Toarcian period was affected by significant tectonic and paleo-geographic changes, particularly important for the Adriatic region. So it is through Toarcian extensional shifts that the large South tethyan platform was broken into three smaller platforms – the Apennines, Apulia and Adriatic that are mutually separated by deep-sea pools. The two southern most platforms, the Apennines and Apulia platforms, were divided by the Lagonero pool, while between the Apulia and Adriatic platform, the Adriatic basin was formed that connected the Ionian pool in the southeast, Umbria-Marche pool to the west and Belunno basin to the northwest. In this way, the newly formed Adriatic basin, already in the Early Jurassic, represented the beginning of the present day Adriatic Sea. This fact prompted some Croatian geologists to name the newly formed individualized tethyan carbonate platform, bordered by the Adriatic, Umbria-Marche and Belunno pools on the southwest and west, the Slovenian and Bosnian basin to the north and northeast, and Cukali-Budva basin in the east and southeast, the Adriatic carbonate platform (AdCP; Vlahović and others, 2005, with reference literature). It formed between the Lower and Middle Jurassic and remained up until the Late Cretaceous emersion when the majority of it thawed out.

Deep-sea sedimentation also began with the formation of the Adriatic basin. The Toarcian and Late Middle and Upper Jurassic pool/pelagic sediments have been drilled in wells in the Italian part of the Adriatic. There were no interruptions in sedimentation on the AdCP regardless of the extensional shifts. On the contrary, interior parts of the platform were deepened, so during a greater part of the Toarcian, Blotchy limestone was deposited. Other than this, during the Toarcian the first oceanic anoxic event took place (OAE – **O**ceanic **A**noxic **E**vent).
Toarcian Blotchy limestone is dark grey with brown and yellowish blotches, with well expressed thin to medium thick layers. Mostly it is a case of mudstone, skeletal floatstone and ooidal packstone/grainstone. The blotchy appearance originates from unequal dolomitisation and bioturbation. The appearance of Blotchy limestone at the surface, closest to the Adriatic coast is located south and southwest of Gornje Jelenje, on the coastal slopes of Velika Kapela, along the extension of the entire Velebit from Senjska draga to Mali Alan. In the Nature Park Paklenica, above Starigrad Paklenica and in Konavle, they are closest to the sea.

Normally and in continuity, Middle Jurassic limestone with lenses and interbeds of late diagenetic dolomite is followed by Blotchy limestone. These are thickly layered mostly dark grey mudstone deposited in protected environments of spacious lagoons. They can be found in the central and northwest parts of the AdCP. The first two thirds of these deposits are very weakly fossiliferous. Significant fossils, mostly conductive foraminifera, can be found in the top third, in the limestone of the Bathonian stage. In the south-eastern region of the AdCP, in central and southern Dalmatia, on Biokovo, the Neretva valley, Dubrovnik coast, Župa and Konavle, Middle Jurassic limestone are also thickly layered, however with significantly different lithological features: primarily they are grained, in lower levels and ooidal and expressly fossiliferous (Gastropods, bivalvia, corals, algea, foraminifer). Middle Jurassic carbonates closest to the sea are located in western Istria on the coast itself (estuary of the Lim channel, Monsena) where they are located in the heart of the western Istrian anticline, then between Gornje Jelenje and Grobnik, along the coastal slopes of Velika Kapela and Velebit, particularly in the Nature Park Paklenica, on the coastal steep slope of Biokovo and Rilića and further southeast across Neretva towards Dubrovnik to Konavle.

In continuity, the Middle Jurassic is followed by Upper Jurassic shallow sea carbonates. They consist of various types of layered limestone and late diagenetic dolomites. They are located along the coast from the Kvarner Bay to Konavle. In the narrow Adriatic area, they have been discovered in western Istria and the island of Lastovo and surrounding islands next to Susak and Mljet. Lithologically they are different types of very fossiliferous limestone (algae and foraminifera) and significant sequences of late diagenetic dolomites. There are also frequent finds of Upper Jurassic limestone and dolomites in Adriatic wells, such as, for example Jadran – 15/1, Jadran 15/6, Jadran – 18/5, Istra More – 1 and Amanda – 1bis, while deep sea pools of calpionellid limestone in Maiolica formations in Amanda – 1bis. Detailed data about the aforementioned wells, with reference literature was processed by Veseli (1999).
In the Middle Upper Jurassic, in the Peri-Adriatic region during the Kimmeridgian stage, a significant compression of tectonics was confirmed that was reflected in the central parts of the AdCP through the emergence of two shallower basins with hemipelagic sedimentation. The local basin, without a direct connection with deep sea oceanic areas, formed in present day Gorski Kotar, in Velika Kapela with sedimentation of dark grey layered and panelled limestone with cherts and tuffs and rare finds of ammonite. A larger basin with direct connection to the open Tethys extended from the north-eastern edge of the AdCP in present day Bihać, eastern Lika, across Poštak and Svilaja to Sinj. Also sedimented were Lemeš deposits, dark layered and

panelled limestone with tuffs, cherts and a rich ammonite community. Anoxic sedimentation conditions, as well as a significant percentage of organic matter in limestone have been confirmed in both basins. On the other hand, the south-western edge area of the AdCP, during the Kimmeridgian was partially in emersion as, for example, in Istria and Biokovo. During the Tithonian, the mentioned basins were filled with calciferous deposits, so shallow sea sedimentation continually progressed to the Aptian during which significant paleogeographical changes occurred. The Upper Jurassic deposits have been confirmed in the wells Lastovo Onshore and Vis – 1.

Lower Cretaceous deposits in the Adriatic region are located in the areas of Istria, Krk, Cres, Lošinj, Dugi otok, Vis, Hvar, Pelješac, Korčula, Lastovo, Lastovci, Mljet and Elafiti. Drilling has been carried out in multiple land and offshore wells Dugi otok, Amanda - 1bis, Istra More - 1, Jadran - 02, Jadran - 7/3, Patricija - 1, Perina - 1, Palagruža – 1, Vis - 1, Vlatka - 1. All the abovementioned locations are in the area of the AdCP, and this means that it is a case of exclusively shallow sea carbonates, primarily limestone, sporadically also late diagenetic dolomite. Locally in Istria there are early diagenetic dolomites in Berriasian. Regionally widespread, short-term emersions in the Hauterivian and Barremian are also common.

During the Aptian, two significant events were determined on the surface profiles of Adriatic islands and coast so it may be assumed that they have also impacted Aptian deposits in the Adriatic underground. The first is connected with the Lower Aptian, lower orbitolinic limestone in which a pelagic influence was determined. This was a consequence of a small increase in sea levels, as well as a reflection of the global anoxic event OAE-1a. The second is Upper Aptian on the AdCP regional emersion of varied duration, the longest in Istria during the Early Aptian and Late Albian.

The transition to the Upper Cretaceous is partially continued in limestone development, such as, for example in southern Istria. However in the largest part of the Adriatic region, and probably also in its underground, there are significant occurrences of late diagenetic dolomite and dolomite breccia. They are most widespread in Istria, on Krk, Cres, Dugi otok, Rava and Pašman. They are normally followed by Rudist limestone of the Upper Cretaceous.

Already in the Late and Middle Cenomanian, due to synsedimenation tectonics, the determined lateral changes to sediment environments and facies intimated later significant events. So with the global increase in sea level in the Early Cenomanian, the entire AdCP was flooded, and this lasted throughout the Late Turonian. This was also the time of the new anoxic event, OAE-2, when there was sedimentation of offshore, so called, calcareous limestone with pelagic/plankton micro fauna, and in places sedimentation of ammonites. In somewhat shallower environments, in protected lagoons, panelled limestone was deposited in which fossil remains of fish were preserved. These and Early Upper Cretaceous events and the consequences were explored and described in detail by Gušić and Jelaska (1990) on Brač, and later confirmed in multiple works in the area of the entire AdCP.

Due to Cenomanian tectonics, individual parts of the AdCP in the Adriatic coast were raised so high (e.g. western Istria) that until the end of the Cretaceous the marine sedimentation was not renewed on them. From the Early Turonian to the end of the Cretaceous, the AdCP thawed out increasingly, while the shallow sea environments gradually reduced so that in the Maastrichtian they were reduced to a local phenomenon, like for example on Brač and in Konavle. A similar situation is to be expected in the Adriatic underground.

In deeper parts of the Adriatic continuing on from pool Upper Jurassic calpionellid limestone, deep-sea sedimentation was continued throughout the Lower and Upper Cretaceous. There is little data for the pool Lower Cretaceous in the Croatian part of the Adriatic underground. Veseli (1999), in the wells Istra More – 1, mentions pelagic limestone up to the Lower Aptian, debris breccia with fragments of shallow sea carbonates and turbidites from the Upper Aptian to the Lower Campanian and pelagic globotruncana limestone with carbonite turbidites up to Maastrichtian. Pelagic limestone in Maiolic formation to the Aptian have been confirmed in the well Amanda-1bis, and on them carbonite debris with clastic platform limestone of Aptian – Albian state and to the end of the Cretaceous deep sea limestone with pelagic fauna. In other Adriatic wells, Upper Cretaceous has been confirmed in the wells Inga-1, Irma-2α, Istra More-5, Jadran-02, Jadran-05, Jadran-08 1, Jadran-13 and Dubravka More-1, while Cretaceous in general for the wells Istra More-3, Istra More-4, Jadran-09, Jadran-22.

On the surface, hemipelagic facies already in the Early and Middle Cenomian have been identified on Cres and Lošinj, while on Premuda, Dugi otok, Brač and Hvar during the Early Santonian and Campanian (Dol formation).

The thawing of the AdCP also denoted the end of the second petroleum geological unit. Karstification of Upper Cretaceous carbonate rocks ensued which lasted to the paleogenic transgression into the Palaeocene and Eocene. In the central parts of the AdCP this karstification has lasted to the present day.

3.4.3 Rocks of the Palaeogene and Miocene; the third petroleum geological unit

Due to the Upper Cretaceous compression tectonics, the central and north-eastern parts of the former AdCP were raised so that through Paleogenic transgression, the sea covered flattened and relief lower areas in the present day Adriatic and along it. Sedimentation of foraminifera limestone occurred in which the biostratigraphic sequence can also be followed from the miliolid through to alveolina and nummulite to discocyclina and globigerina. However, sedimentation of these biofacies depended primarily on sedimentation environments, so shallow sea platforms are favourable for miliolids and alveolina, platform slopes and ramps for nummulites and discocyclina, while pool environments are favourable for globigerina. This way it was confirmed that in some places in the Early Eocene, miliolids, alveolina and nummulites sedimented simultaneously, and possibly discocyclina limestone sedimentation as well. The age of foraminifera limestone is Palaeocene and Eocene.

Geographically, foraminifera limestone extends along the coast from the Dragonja River to Konavle. It can also be found on the majority of islands (of the larger ones, it is not present on Dugi otok, Šolta, Lastovo and Mljet) which shows that it is also present in the Adriatic underground. Lithologically these are varieties of skeletal and bio-clastic limestone, wackstone-packstone-grainstone miliolids and alveolina from environments of shallow sea shallows to nummulites and discocyclina from submarine slopes and ramps. The genesis of carbonate ramps indicates the deepening of the sediment area due to the activity of Eocene tangential tectonics, a consequence of which was the formation of longitudinal basins of Dinaric extension (NW-SE) with pool, clastic and pelagic sedimentation and thawing of shallow sea areas between the basins. Depending on the paleo-relief of the sea floor, foraminifera limestone of varied thickness were deposited. The thickest in Konavle and in northern Istria, over 300 m, while in other areas from a few tens of metres to a maximum of 200 m.

Globigerina marl and clay wackstone are known as transition deposits from foraminifera limestone into flysch. They were discovered on the islands and coast, and were also confirmed in wells from Istra More – 1 to Istra More – 5 and Amandi-1bis. They were deposited in deeper and pool environments. The thickness of these deposits ranges between 5 m to 50 odd metres.

With the continuation of heaving and increasingly greater thawing, intensive erosion followed and great quantities of eroded materials were carried into the basins with the waters from the land. Sedimentation of clastic deposits with turbidite features ensued, of which basic lithological features are changes of marl and sandstone, in the literature most often called Eocene flysch. There are viewpoints that, for example, a part of the Eocene flysch deposits of the Pazin pool was sedimented even in batial environments. The age of the flysch is not unambiguous: going from Istria where it is Middle to Upper Eocene towards the southeast, the flysch is ever younger, and in Konavle there are sediments of the Early Oligocene to the Middle Miocene.
It is widespread on the coast from Istria to Konavle and on the islands of Krk, Cres, Rab, Pag, Vir, Hvar and the Pelješac peninsula. The thickness of the flysch varies, it is often difficult to determine due to tectonics (folding, reverse faults). The estimate of the thickest flysch deposits range from 350 m in Istria, 680 m in Konavle to 900 in the Zadar hinterland. There is also no doubt in the existence of flysch in the Adriatic underground, where it is probably covered with younger deposits.
Miocene deposits in the Adriatic region, other than the mentioned Miocene age of flysch in Konavle, were discovered superficially only on the Island of Palagruža. On the Island of Pag (Crnika) Miocene lake deposits have been identified. However, the greatest number of deep offshore wells has drilled Miocene deposits. Such is the case in the aquatorium of Palagruža, that Miocene marl deposits in interbeds of sandy and clay limestone and evaporite deposits of Messinian age have been confirmed, and the case is similar with central and northern Adriatic wells.

3.4.4 Deposits of the Pliocene, Pleistocene and Holocene; the fourth petroleum geological unit

Pliocene deposits in the narrow Adriatic area have not been discovered on the surface. They have been established in almost all exploration wells. They consist of changes to marl, marl clay, clay marl and silt. Their thickness is up to 400 m.

Pleistocene clastic deposits in the area of the northern Adriatic contain hydrocarbon of a bacterial, biogenic origin, resulting from accumulation of organic substances from land. It is the gas – methane – that, other than 98 % methane, also contains nitrogen (about 1 %) and carbon dioxide (less than 1 %). The conversion of organic clusters into gas occurred at temperatures from 0 °C to 75.0 °C at depths of 600 m to 1,300 m (Barić & Tari, 2001). In Italy 80 % of all gas fields belong to the type of biogenic or diagenetic origin (Mattavelli and others, 1993). The majority of these fields are located in the northern Adriatic underground. Source rocks are silts with medium content of hydrogen from organic compounds of 0.44 %. Kerogen is type III and IV. Generation and accumulation of biogenic gas is carried out *in situ*. Bed deposits are weakly connected sand and silts with a porosity of 20 % to 35 %. The covering and insulating deposits are made from sea sludge and clay of pyroclastic origin. According to Levorsen (1956), the beds are structural (anticline), stratigraphic (buried hill) and combined. Particularly frequent are traps originating from differential compaction and those created by un-wedging collector rocks. The thickness of the Pleistocene sediment complex amounts to 900 m in the southwest, while in the direction northeast, due to un-wedging, this has been reduced to 200 m (Marić, Đureković, 2011).

In the area of the central and southern Adriatic, according to contemporary exploration (Vaniček, 2013) there is only one depression, with one formation, the formation Melita, within one mineralogical provenance and two depocentres. The reference formation consists of homogenous fine-grained sediments with progradation features. The maximum thickness of formations is 1000 m, and probably even more as we move to the south Croatian underground, which is in accordance with bathymetric references. In principle, thickness increases from the coast towards the west, towards the demarcation line, and from the north towards the south. Detritus originated from the Dinaric Alps and from the volcano of central and southern Italy. Part of the detritus was brought by rivers and sea currents, and part (volcanic ash) of it arrived with air currents. The thickness of sedimentation, its originating area and relatively well expressed variations of usual fine-grained compositions provide the basis for the conclusion of a good probability for finding gas in the beds originating from differential compaction and circumstances of diaprism and volcanism.

3.4.5 Tectonic overview

There is much literature and a fund of data about the tectonics of the Adriatic underground and it is impossible to show its immense size in this overview, primarily because they are inaccessible for public use. In the multitude of articles and studies there are no synthesized works that would encompass the entire underground.

In general, three types of tectonic structures dominate in the Adriatic underground and surrounding areas: (1) tangential, with a series of reverse faults that comprise a flaky structure, (2) normal faults and (3) diapiric intrusion of Early Palaeozoic, Triassic and Miocene evaporate and salts. In the underground itself, these structures have encompassed rocks older than the Holocene and are covered with recent sediments.

Tangential structures, folds, reverse faults and flaky structures, originated in the Early Paleogenic and Neogenic tectonic shifts. They are located in the Croatian and Italian coasts and the Adriatic; however, they are convergent, i.e. with direction of movement of the overlying limbs of reverse faults towards the central part of the Adriatic (e.g. in Menichetti and others, 2006). These faults are located in nearly the entire Croatian part of the Adriatic, right up to the border with the one time AdCP or Karst Dinaric Alps. Moving along the Croatian coast towards the central Adriatic, individual islands or series of islands represent individual flakes between which in the underground are reverse faults of primarily Dinaric, however also Hvar extension. The overlying limbs are most often made from Cretaceous carbonate rocks (anticline parts of folds, i.e. islands), they are reversely shifted to the southwest and south and elevated on Palaeogene deposits, most commonly on flysch (synclinal parts of the fold, i.e. channels between islands). The most well known of such faults extend from the SW slopes of Ćićarija and Učka west from Cres and Lošinj, SW from Dugi otok, Kornati, Šolta and Brač.

Drawing a conclusion from the established normal faults on the islands and the coast, it is certain that they also exist in the Adriatic underground. Faults with horizontal shifts, like the fault Vincezna-Schio-Palagruža, also belong to this category. Intrusions of evaporites and salt are connected to such faults, as is the case with the terrestrial part near Sinj, Vrlika, Drniš, Knin and Lička Kaldrma. Diapiric structures of evaporate are confirmed near the Island of Jabuka, near Komiža on Vis and near Palagruža. They are also present in other parts of the Adriatic Underground, and they are clearly outlined on seismic profiles (Image 3.49).

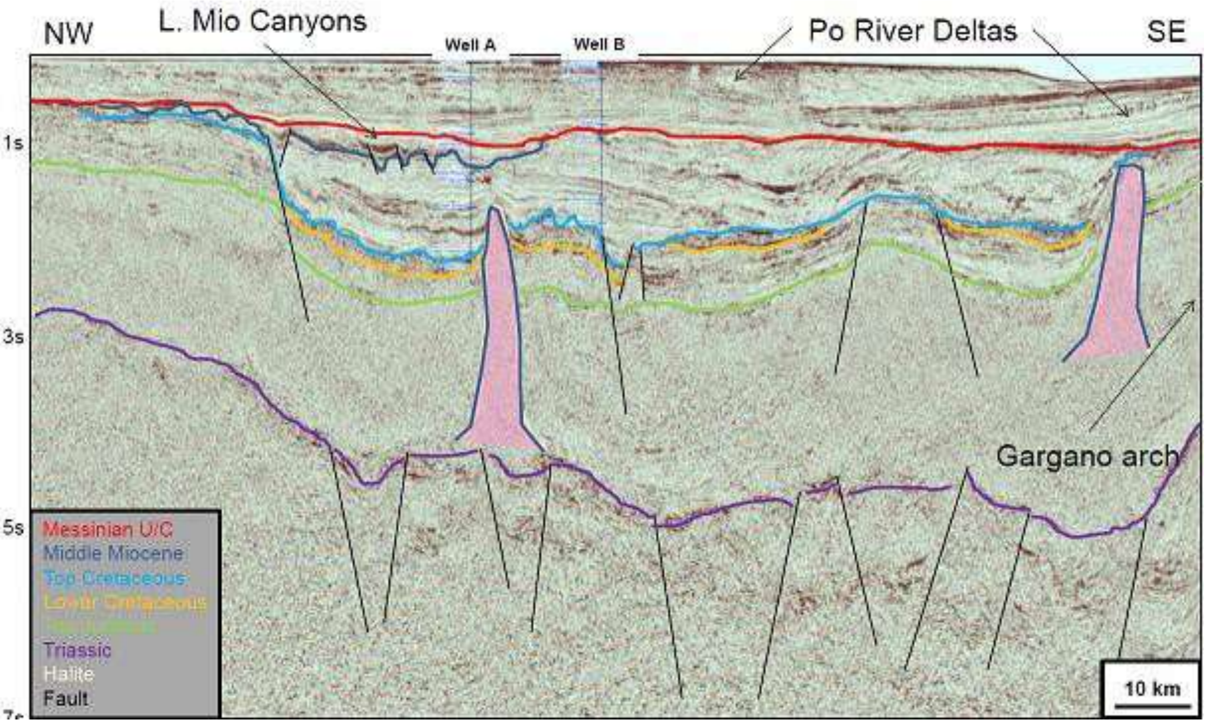


Image 3.49 Overview of diaper in the area of the central Adriatic (Source: AZU)

3.4.6 Basics about petroleum geological features

The basic condition according to which an area may be deemed petroleum geologically prospective is the presence of source rocks, of course, also with certain defined collector and insulating rocks, and favourable structures. Data about **source rocks** described here refer to both samples from the surface but also samples from wells (Barić & Velić, 2001). From the description of geological features of the underground it is evident that through an entire column of rock from the Palaeozoic to the Pleistocene there are rocks with primary and secondary types of porosity and rocks with good insulation characteristics. Presented here are details about source rocks and their geochemical features.

Surface samples of **Permian** age contain a low concentration of organic matter (C_{org} 0.2 – 0.3 %), which is most probably a consequence of atmospheric activity, wherein the organic matter is decomposed and undergoes oxidative changes. Tests were also conducted on samples of mudstone from the exploration wells Bruvno – 1 (interval 495 – 3186 m). The content of organic matter in these deposits varies between 0.30 and 0.65 %, while maturation parameters show an extremely high level of thermal changes. It is possible to assume that these sediments were active source rocks in the past; however, intensive thermal activity and generation of hydrocarbons caused a reduction of the content of organic substances and the formation of “dead” kerogen. Today these deposits represent inactive source rocks.
The samples of sediments of **Triassic** age are represented with dark grey to black limestone and clastics (shale). The content of organic matter in surface samples varies in the range from 0.02 to 3.62 %. Pyrolythic analyses did not confirm their generating potential, given that the organic matter is highly thermally altered. Generation of hydrocarbon took place in an earlier period, which was then followed by overheating, thermal changes.
From the deposits of **Jurassic age**, the “Lemeš formations” sediments stand out. Their defining feature is a high concentration of organic matter that in individual samples reaches values of C_{org} of 31 %. Pyrolythic analyses have confirmed great petroleum potential and the deposits “Lemeš-formations” represent very good to excellent source rocks.
Samples of **Albian** limestone indicate immature petroleum source rocks. Dark grey to black, panelled, laminated limestone of **Cenomian age** contains high concentrations of organic matter which reaches values of C_{org} of 8,34 %. Organic facies of tested samples are hydrogen rich lipid matter. The evaluated level of thermal conversion of organic matter corresponds to the diagenetic, immature stage. The sediments represent excellent petroleum – source rocks, with a large quantity of soluble organic matter, bitumen.
Limestone of **Campanian** age is in places high in concentration of organic matter (C_{org} 5.29 %) which means that it is a very good source rock. Pyrolythic and optical tests have shown the presence of thermally immature type I kerogen, with very good petroleum potential. Samples of limestone of **Maastrichtian** age showed a concentration of 18 % C_{org}. Sediments are a good petroleum source rock, even though they are in the stage of low thermal conversion.

3.4.7 Earthquakes, liquefaction and slumping of loose sediments

Croatia is on the list of countries that have express maps of earthquake activities and dangers, drafted according to the highest standards of the seismic profession valid in the work of seismology, and this act has enabled the implementation of European standards for anti-earthquake construction. New maps (Image 3.50, Image 3.51) replace old maps from the 80’s of the previous century in which earthquake dangers were shown with the aid of zones of intensity in degrees of the Mercalli-Cancani-Sieberg (MCS) scale.

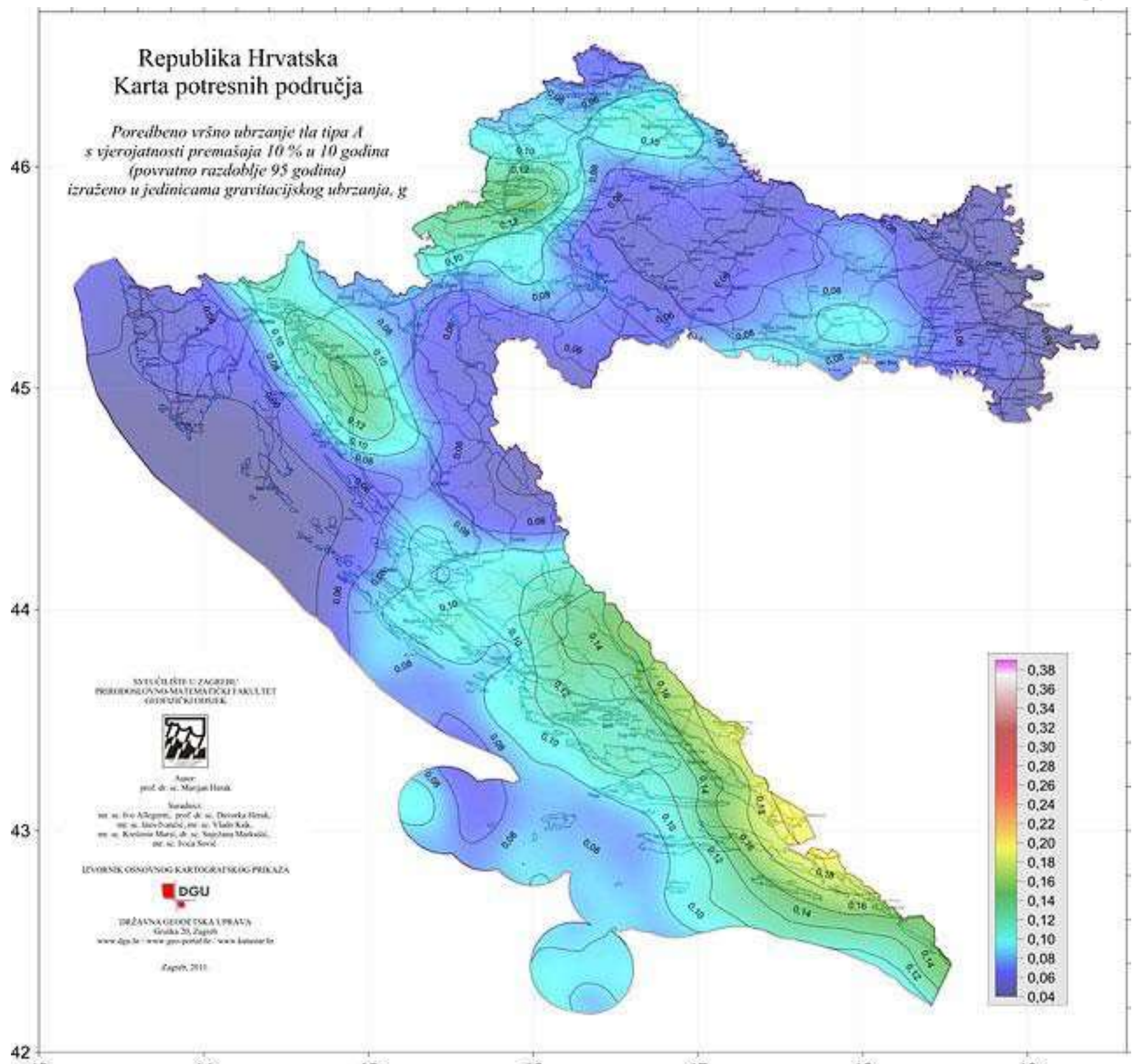


Image 3.50 Map of Croatia with earthquake areas. The map of comparative peak acceleration of soil type A with probability of surpassing 10 % in 10 years (return period of 95 years) expressed in units of gravitational acceleration (Source: DGU)

It is a known fact that Croatia is one of the seismically more active areas in the so-called Mediterranean-Trans-Asian belt, in which, along with the Circum-Pacific belt, 90 % of all of the earthquakes on Earth occur. The inhabitants of southern Dalmatia are particularly sensitive even at the mention of earthquake, as well as the wider Dubrovnik area, which is marked on the map of Croatia as one of the seismically most threatened, both by activity and potential, that is, strength of a possible earthquake.

The wider Dubrovnik area is followed by the northwestern part of Croatia and the wider Zagreb area, however in these parts earthquakes are of weaker intensity.

A large part of geophysical exploration has been dedicated to the seismic activity in Croatia. In the period 1996 – 2005, two strong earthquakes occurred on the territory of Croatia – in 1996 near Ston (M = 6.0) and in 2003 near the island of Jabuka (M = 5.5). A detailed analysis of the earthquake near Ston was carried out by Markušić and others (1998), and Herak M. and others (2001). Through an analysis of earthquakes in the area of the central Adriatic (near Jabuka) (Herak D. and others, 2005), active epicentral areas inside the Adriatic microplate, unknown to date, have been identified. Herak M., Herak D. and Markušić S. (1996) drafted a revision of the catalogue of earthquakes for the territory of Croatia to improve the homogeneity and data. The catalogue is continually being adjusted and supplemented with new data so that for the period from B.C. to the end of 2011, it contains some 55, 000 earthquakes. Seismic zoning of Croatia was the subject of research in the work of Markušić and others (1997), Markušić and M. Herak (1998) and Markušić and others (2000).

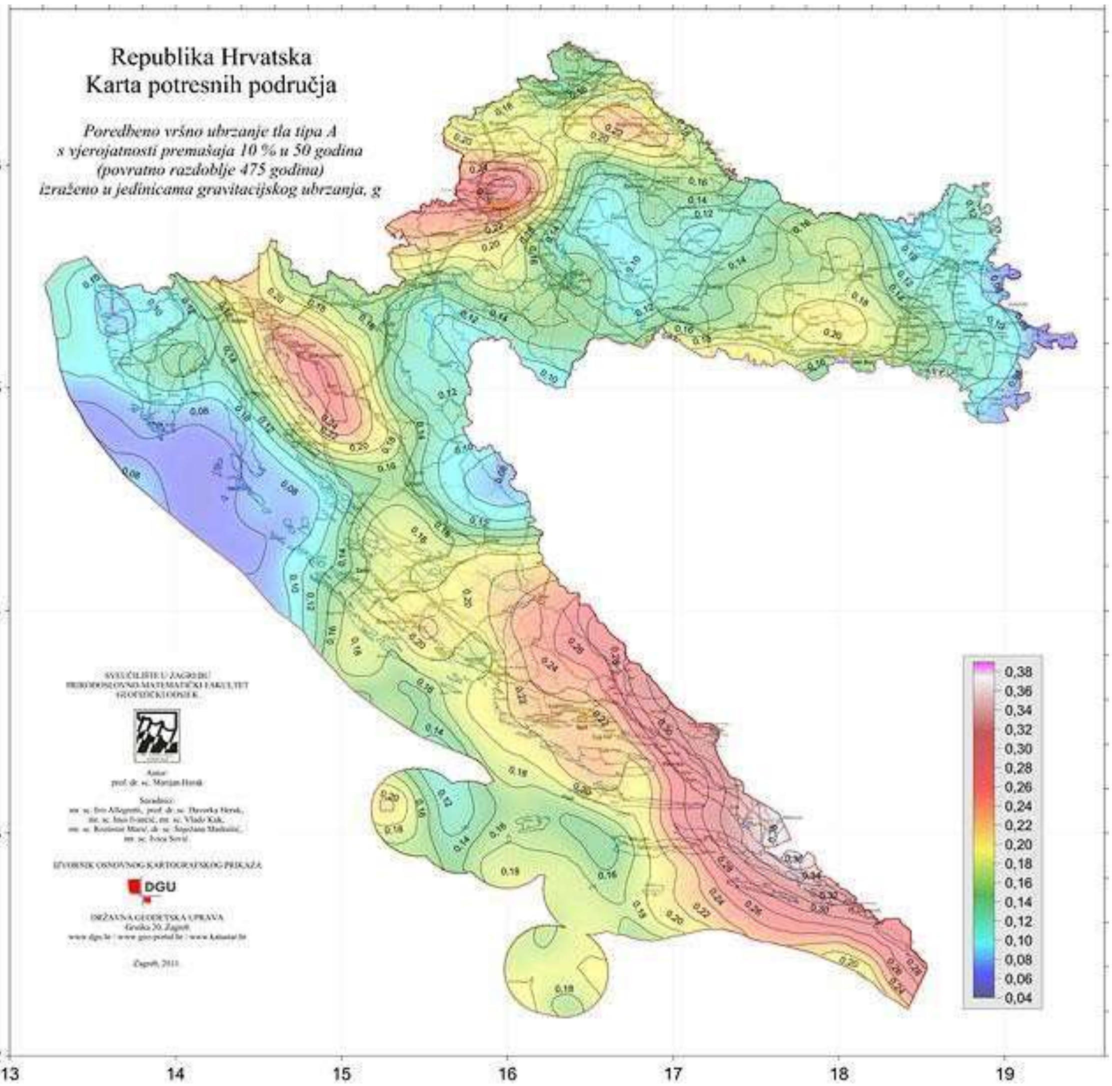


Image 3.51 Map of Croatia with earthquake areas. The map of comparative peak acceleration of soil type A with probability of surpassing 10 % in 50 years (return period of 475 years) expressed in units of gravitational acceleration (Source: DGU)

Since the beginning of 2013, Croatia **has been hit by ten earthquakes**, of which eight had an epicentre within the borders of Croatia, while earth tremors of the other two were also felt in Croatia. Of the eight, the strongest occurred in the vicinity of Split – on 17 January an earthquake occurred with an epicentre 20 km from Split of magnitude 4.1 on the Richter scale, and on 4 February an earthquake occurred with an epicentre 16 km from Split of the same magnitude (4.1 on the Richter scale). The latest recorded earthquake in the Republic of Croatia occurred on 24 February with an epicentre 6 km from Dubrovnik, and it was of magnitude 2.5 according to Richter.

It is estimated that in the southern part of Croatia, the maximum possible magnitude of an earthquake is of 7.5 degrees according to Richter, while in the north-western part of Croatia it is estimated at 6.5 degrees according to Richter. The southern part of Croatia is under greater threat because of the fact that the Adriatic microplate is moving under the Dinaric Alps, and the geodynamic process is stronger and more expressed than those occurring and “hitting” the rest of the country. Regarding the Adriatic region it can be generally ascertained that a significant increase in earthquake intensity is predicted and this from 6 degrees according to Richter (southeast from Istria) right up to 9 degrees according to Richter (wider area surrounding Dubrovnik). The largest part of the aquatorium is in the region with 8 degrees according to Richter.

Using new seismic zoning and using various methods (Monte Carlo, methods of modal summation and calculation of synthetic seismograms) new probability and determinist research of seismic hazards for individual areas of Croatia were made (Markušić and others, 1998; 2002; Lokmer and others, 2002; Herak, M., 2002; Panza G. and others, 2002; Herak, M. and others, 2001, 2003). The hazard is expressed with maximum or project acceleration, and maximum expected intensity of the earthquake for various return periods. The greatest seismic hazard was determined in the wider Dubrovnik area, while the Zagreb region is highlighted as the most at risk area for earthquakes in the interior.

Maps of earthquake regions are maps of seismic hazards or earthquake dangers that are estimated on the basis of observed seismic activity over a period as long as possible. For Croatia, the basic database is contained in the Croatian catalogue of earthquakes (Herak and others, 1996) maintained by the Geophysical department of the Faculty of Science in Zagreb. Currently, it contains data on more than 40,000 earthquakes that occurred on the territory of the Republic of Croatia and neighbouring regions, and it is regularly supplemented by data on new earthquakes. The present day network of seismographs in Croatia enables annual average location and inclusion in the catalogue of more than 3, 500 earthquakes. The map of earthquake epicentres is shown in Image 3.52. Magnitudes of earthquakes in the catalogue are local magnitudes (ML), for which in a number of works it was shown that for Croatia moment magnitudes (MW) closely correspond.

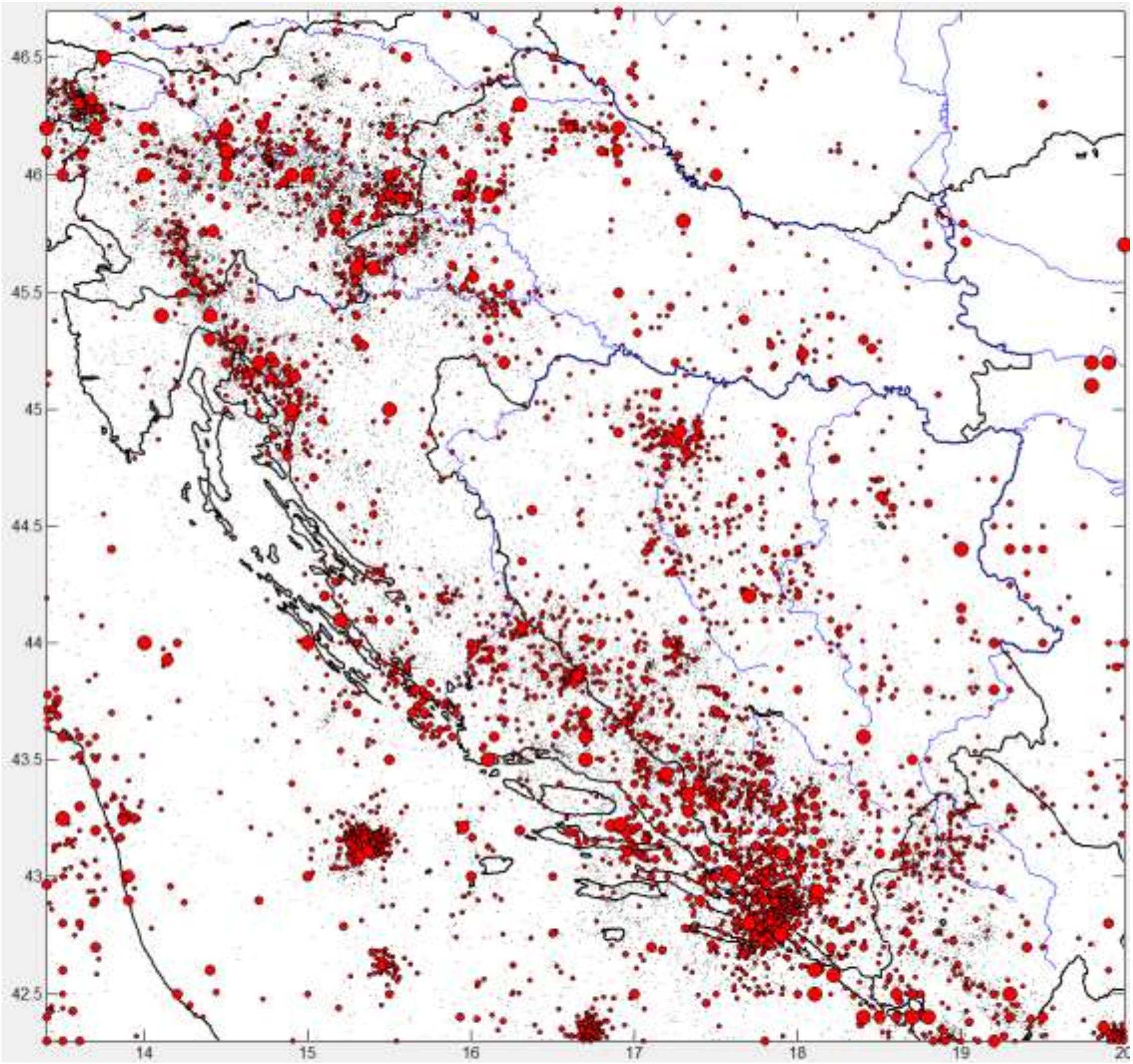


Image 3.52 Earthquakes epicentres from the Croatian earthquake catalogue (Source: Geophysical department of the Faculty of Science, 2011)

Also presented here is some seismic data for the southern Adriatic which emerged due to a continued increase in the number of seismic stations in Croatia, particularly along the coast and on the islands, and exchange of data with Italian seismic centres on the western side of the Adriatic, for example the Island of Palagruža (KUK, K., http://astrogeo.geoinfo.geof.hr/pelagosa_arhipelag).

Just like the entire region of the southern Adriatic, the epicentral region of Palagruža and its surrounding area is seismically permanently active, more and more strongly than the region of the northern Adriatic, and again somewhat weaker, in terms of the strength of earthquakes and the frequency of earthquakes of great magnitude, than in the coastal area of southern Croatia. Here the earthquakes, like in the majority of regions in Croatia, occur mostly with hypocentral depths (focal depths) between 10 and 15 km. The average focal depth of all noted earthquakes amounts to 12.4 km. The deepest earthquakes in the Palagruža epicentral region were noted at a depth of 30 km and belong to a group of earthquakes from the last few years (the first occurred on 17 August 2010, then the following two occurred in the short period of ten days, the first on 28 January, and the second on 10 February 2012). The strongest recorded earthquake in the epicentral region of Palagruža was of magnitude 5.3 according to Richter, and occurred on 26 April 1988, 30 km east-southeast from Palagruža. At the same time it was the only earthquake in the near epicentral distance (up to 50 km from the exploration location Palagruža) of strength > 5.0 (according to Richter).

The image below, Image 3.53, shows the distribution of epicentres of all recorded earthquakes near Palagruža. For better visibility Palagruža is marked with a black triangle. The distribution of magnitudes has been done according to classes of width

0.5. Different values of earthquake magnitudes have been assigned different colours and proportional size of circle radiuses. The earthquake magnitudes are expressed according to Richter.

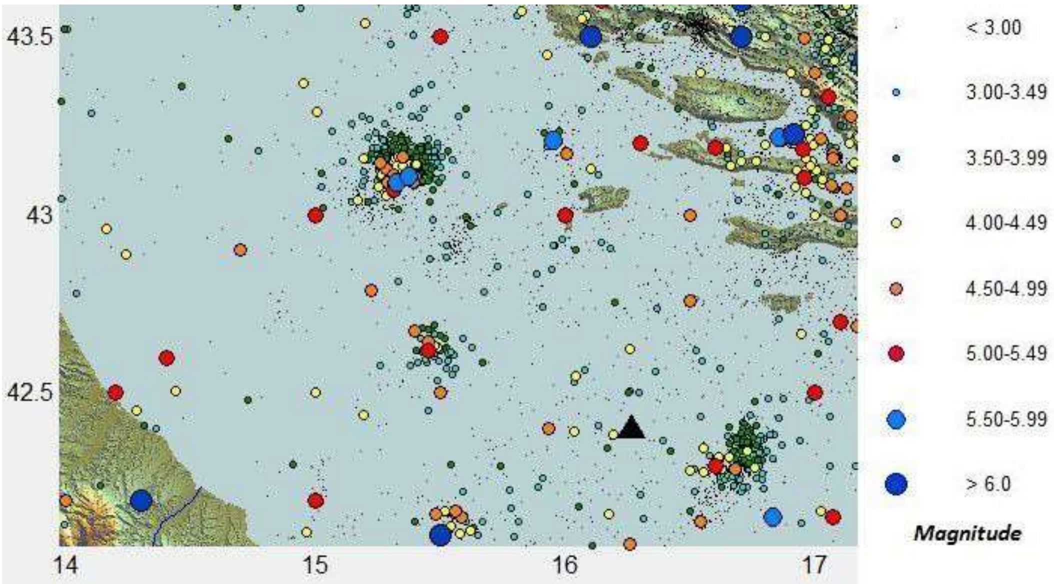


Image 3.53 Map of earthquake epicentres in the wider area of the Island of Palagruža (Source: Geophysical department of the Faculty of Science, 2011)

Observing the time characteristics of the Palagruža epicentral region, it is necessary to emphasize that due to an insufficient number of seismographs (instruments for recording earthquakes) right up to the 1950's, a large number of earthquake registrations were not collected, so it is not justified to carry out a quality time analysis for earlier periods. Up until then, there were only descriptions and a few records of stronger earthquakes. In this time period, the most noticeable seismic activity occurred during 1988. The beginning was characterized by moderately strong earthquake (magnitude m = 3.1) that occurred on 28 February 1988 at 22.18 hr and 28.4 seconds, at a depth of 5.8 km and with an epicentre in the sea right next to Palagruža, barely 2 km southeast. It was followed by a strong earthquake on 20 March of the same year, with an epicentre also southeast of Palagruža. Its magnitude was 4.1 (according to Richter) and falls among the 10 strongest earthquakes recorded in the near vicinity of Palagruža. The absolute maximum seismic activity was noted in April 1988, particularly on 26 April, when a series of 36 earthquakes was recorded. The majority of the listed earthquakes were of magnitude m > 3.0, and fall within a group of moderately strong and strong earthquakes. The seismic activity of this series of earthquakes ended with a few weaker earthquakes (smaller magnitude) at the end of 1990, that is, at the beginning of 1991 (earthquake of magnitude 3.5 which was recorded on 09 January 1991). The period of increased seismic activity of the wider Palagruža area was also recorded in 2010, primarily in the month of June. In this year thirty or so earthquakes were also recorded. However, aside from one stronger, one of magnitude 4.2 that occurred on 04 June 2010 at 18.44 hr and 53.9 seconds, also southeast of Palagruža, all the rest were significantly weaker earthquakes, with magnitudes of 1.0 < m < 2.5. Most of the series of these earthquakes occurred in the month of June, while the entire activity gradually weakened and stopped at the end of September.

The strongest earthquake of all recorded to date in the epicentral region of Palagruža occurred on 26 April 1988 at 00.53 hr and 45.6 seconds with a hypocentral depth of 9.3 km, with epicentre coordinates 42.293 °N, 16.602 °E. It was a 5.3 magnitude earthquake and falls in the category of strong earthquakes. As shown in the image below, its epicentre was spatially located southeast of the Island of Palagruža.

Even according to the spatial features of earthquakes in the Palagruža epicentral region, a number of separate entities stand out, the so called group of epicentre earthquakes that we may observe separately. The first and closest extends at a distance of about 30 km southeast of Palagruža, and as can be seen below, also contains the strongest closest earthquake from the group of narrow epicentral region of Palagruža (epicentral distance less than 50 km). The greatest number of earthquakes from this region are of a magnitude of about m = 3 (according to Richter), and originate from various times. The strong earthquake from 1938 with magnitude of 5.5 and hypocentral depth of 20 km and epicentre distance of 70 km from Palagruža, and another three earthquakes of which the strongest occurred on 17 April 1962 at a depth of 21 km, and had a magnitude of 5.2 also belong to this group of earthquakes. The second largest group of earthquakes with mutually close epicentres were located northwest of Palagruža, with a mean distance of 75 km from Palagruža. A large number of earthquakes from this group occurred in the earlier observed series of earthquakes from 1988, and the highest magnitude observed was m = 5.0 and it occurred on 11 January 1986. It was very shallow, with a focal depth of 1.6 km.

Another group of earthquake epicentres is located northwest of Palagruža, which, according to distance, does not belong to the epicentral region of Palagruža. However, according to other characteristics it is very important and it is necessary to describe it separately. It is a case of a large group of earthquakes near the Island of Jabuka. Their epicentral distances from Palagruža are mostly between 110 and 120 km. The series of Jabuka earthquakes began on 27 March 2003 with a weaker earthquake, of magnitude m = 1.6. Already 9 hours later a strong earthquake of magnitude m = 4.8 followed. In the entire, nearly continuous series of earthquakes, until the end of November of the listed year, a few thousand weaker earthquakes were recorded, arising as subsequent earthquakes from the main quake. It occurred on 29 March at 17.42 hr and 13.6 seconds, with epicentre coordinates 43.093 °N, 15.325 °E at a depth of 3.8 km. Even though it is an area that does not belong to the epicentral area of the Island of Palagruža, due to the significant level of seismic activity and relative small distance from Palagruža, it is necessary to emphasise the great seismic potential of this area, which is best confirmed by the described large series of earthquakes from 2003.

Taking into account the described seismic area of the planned activity of the OPP, it will be necessary to take this into account when selecting a platform, which will be the subject of detailed analyses when drafting the Assessment of acceptability of the environmental impact of the project / Acceptability assessment of the project on the ecological network, drafting of which will be required for each individual project. Generally, for platforms that are impacted by seismic waves, it can be determined that the effect of hydrodynamic damping is generally small. For supported platforms with submarine construction in the shape of a tower (piled platform), the radial damming is significantly less than with fixed gravity platforms, Image 3.54.

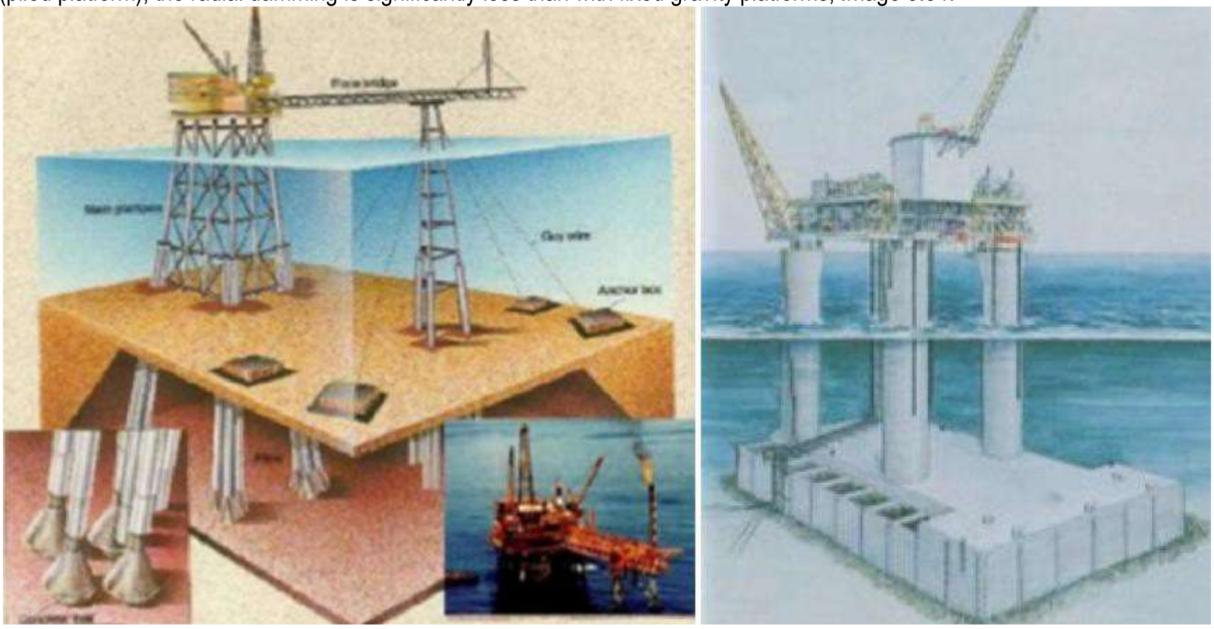


Image 3.54 Supported platform with submarine construction (left) and gravity platform (right) (Source: Jüttner Preradović, 2005)

Liquefaction occurs when, due to shaking of the ground caused by an earthquake, water saturated, grainy, well sorted sediment temporarily loses its firmness and begins to behave like a liquid. This phenomenon may cause significant damage to bridges, buildings and all other facilities, which usually lean or sink into such "liquid" sediment. This commonly appears in well sorted unconnected sediments – sand, like the sand of Holocene age in the underground of the Adriatic saturated with water and a thickness of less than a metre. Such deposits are frequently seen in rivers, as dunes, and they are also in terrains comprised of loess. An example of this in the Adriatic is the Island of Susak. Even though this phenomenon has long been known, particularly its negative effect when the ground loses its bearing capacity, it is only in 1964 after the earthquake in Niigati, Japan and Alaska that its destructive power was observed and since then seismologists and civil engineers have paid great attention to the phenomenon of possible liquefaction when drawing up design.

Given the safety of platforms and their construction, it should certainly be taken into account that big, strong earthquakes may generate stress of sufficient intensity and sufficiently long duration that will provoke liquefaction of non-consolidated sediments to a depth of 300 metres and even deeper. In actuality, the maximum depth to which liquefaction may be expected depends directly on the depth of non-consolidated sand and silts, and on their porosity and hydraulic conductivity. That means that data on the depth of non-consolidated deposits and the probability of a big earthquake must be obtained for each location of interest. According to recent data such sediments are present in the Adriatic in thickness even greater than 1000 metres. Referring to, for example the formation Melita (Vaniček, 2013.) comprised of homogenous packet of finer grained sediments with progradation features.

A **slump** is a texture of underwater subsidence, and shows itself as stronger or weaker deformed "folded" layers, often with interrupted continuity of individual layers, within non-deformed and mutually concordant ordered layers in the roof and floor. A slump arises from the rotational sliding of one or more layers of semi-rigid or semi-plastic sediment on clay, usually fluid substrate due to gravitation or increased slope of incline at the bottom (Tišljar, 2004). Earthquakes also contribute to the formation of slumps.

3.5 Noise

Noise represents undesirable, disturbing sound in a specific area. It may be caused by natural processes or human activity. To prevent the undesirable and harmful impact of noise, the Noise Protection Act (OG 30/09, 50/13 and 153/13) has stipulated:

- Ordinance on maximum permitted noise levels in environments in which people work and reside (OG 145/04)
- Ordinance on activities for which it is necessary to implement noise protection measures (OG 91/07)
- Ordinance on measures for protection of noise sources in open spaces (OG 156/08)

3.5.1 Natural noise

Natural noise is the result of one or more processes that occur in nature. It may arise through the activity of waves, wind or interaction of the sea surface with precipitation and with wind. Furthermore, sea organisms (mammals, fish, shellfish) and birds also produce natural noise. The frequency of natural noise depends on meteorological conditions.

Waves
Waves produce noise when they break or when they hit rocks or the beach. Foaming of the sea as a result of waves breaking produces narrowband sounds of frequencies from 15 to 30 kHz. Noise produced in the foaming zones is a complex process that can be heard even 9 km off the coast. The produced noise is the result of foaming in water columns and transport of sediments during spraying, knocking and turbulence. The type of sound depends on the shape of the beach, direction of the waves and size of the sediment. If the sediment of the beach is mostly pebbly, the noise of sediment transport will be dominant, however if the sediment on the beach is sand or clay, the foaming sound will dominate. The noise also depends on the distance from the beach and the depth of the sea.

Precipitation
Small raindrops coming into contact with the sea surface produce sound of frequency 15 kHz, while larger raindrops produce impact noise. Ice and snowflakes coming into contact with the sea surface produce sound of a frequency from 2 to 20 kHz. The greater the wind, the greater the contact noise will be.

Wind
Noise resulting from the interaction of the wind and sea depends on the wind speed. Wind at greater speeds breaks waves, thus producing sounds caused by the foaming of the sea. At slower wind speeds noise is produced when the wind passes across the sea surface during which air enters the sea. The noise level of the wind depends on the wind speed. Frequencies from 500 Hz to 25 kHz are produced upon contact of the wind with the sea surface. In deep water a noise level of 51 dB was measured at a wind speed of 2.57 m/s.

Sea turbulence
Sea turbulence caused by tides or movement of the sea floor produces low frequency sounds.

Biological noise
Organisms found in the sea (sea mammals, fish, shellfish) and those that feed in the sea (sea birds) contribute to natural noise. It depends on the type and number of individual organisms producing sound in a certain area, so the increase in individual organisms in one area also increases the noise.
Whales produce sounds up to 100 kHz, however the most common ones in the Adriatic use sound spectrums under 80 kHz for echolocation. Toothed whales produce sounds of a lower spectrum than their clicks. The noise produced by the common bottlenose dolphin during echolocation is 228 dB re 1μPa 1m. Louder sounds have been discovered in sperm whales ranging from 236 dB re 1μPa 1m. Baleen whales produce sounds under 1 kHz with a noise level of 180 dB re 1μPa 1m.
The bird varieties widespread along the whole Adriatic which feed in the sea are: Cory's shearwater, Mediterranean shearwater, European shag and yellow-legged gull. According to the Institute for Oceanography and Fisheries, neither is the data on the noise levels produced by these varieties known, nor have the frequency ranges of the sounds they produce been studied.

Thermal noise
In the absence of the above listed noise sources, thermal noise dominates in the sea with frequencies above 100 kHz. It includes movement of molecules and increases with increases in temperature.

3.5.2 Noise caused by human activity

Human activities that produce noise encompass operating machinery, navigation, cavitation, and use of sonars and air guns.

Industrial plants
There are three hydrocarbon exploitation fields in the region of the epicontinental belt of the Republic of Croatia. These are the

exploitation fields in the northern Adriatic: "Izabela", "Northern Adriatic" and "Marica", on which exploitation of natural gas and its transport to land has been carried out for a long range of years.
During regular exploitation of gas, noise levels are very low. Diesel generators work only as required, and the noise levels do not exceed a value of 80 dB at the edge of the plant, while short-term impulse noise (up to 1 second) may reach a level of 150 dB (Richardson and others, 1995).

Boring rig

The boring rig is located on the drilling platform for the needs of creating a well. The typical boring rig is comprised of a bearing structure – a drilling derrick (derrick), crown block system, air-hoist, engine, gear-box, rotary table, mud pumps, travelling blocks, system for preparation and conditioning of mud, system for protection against blowouts – blowout preventer (BOP), drill tools (drill pipes, rigs and drill collar), drill bits, etc. During drilling, noise levels produced range up to 262 dB re 1 µPa at 1 m (Harland and others, 2005). Currently there is no drilling in the Adriatic Sea for the needs of hydrocarbon exploration and exploitation, however in the period from 1961 to 2004 in the Croatian part of the Adriatic Sea 51 wells were drilled, and in the Italian part more than 1000.
During well construction an increased noise level is produced during drilling, i.e. during operation of the drill and other accompanying activities. The majority of drilling platforms produce a noise level ranging between 90 and 120 dB, while the third and fourth generation of platforms produce noise levels less than 100 dB. Large drilling platforms may produce noise levels over 120 dB, the maximum value is about 185 dB (Green, 1987).

Watercraft

Ships, ferries, yachts and speedboats produce noise. Noise produced by ships consists of low frequency broadband spectrum, which itself is comprised of many tones caused from engines. The noise from distant waterway vessels may reach frequencies of 50 to 300 Hz (Harland and others, 2005). An increase in vessels, as well as an increase in their speed, increases noise. The sound of waterway vessels may vary between 50 and 500 Hz.
According to the Directive of the European Parliament and Council laying down technical requirements for inland waterway vessels (2006/87/EC), the noise arising from navigation, and in particular the engine air intake and exhaust noises shall be dampened by appropriate means. During the normal work of machinery, the level of noise at a distance of 25 m from the side of the ship may not be greater than 75 dB. The noise level produced by a standing ship may not exceed 65 dB at a distance of 25 m from the side of the ship, excluding loading and unloading activities (Article 8.10 Directive 2006/87/EC).

Table 3.12 Overview of watercraft noise (Source: Richardson and others, 1995)

Source of noise	Noise level (dB at 1m under the sea surface)
Tugboats and cargo ships (18 km/h)	171
Supply ship	181
Tanker	186

Cavitation

Cavitation is a phenomenon of vapourisation or "bubbling" of water due to extreme reductions in pressure at the reverse part of the propeller. During cavitation vapour cavities are formed in a liquid. These cavities burst at which point they produce noise mostly in a range of frequency between 100 Hz and 1 kHz. Propellers and all other objects moving quickly through water cause cavitation.

Sonar

Sonars are used to identify underwater moveable and fixed objects, and for navigation. Depending on its type, sonar may emit sound frequencies up to 1000 Hz, from 1, 000 to 10, 000 Hz and from 30 to 500 kHz. Active sonar consists of a source of ultrasound frequencies from 10 to 30 kHz and a receiver, a so called hydrophone. For frequencies from 26 to 300 kHz it produces noise of 220 dB re 1 µPa at 1 m (Harland and others 2005).

Table 3.13 Quantity of noise created by sonars of various frequencies (Source: Renzo and others)

Sonar frequency (kHz)	Sound measured in water (dB re 20 µPa)
10	167
20	167
40	177
50	177
80	177
100	177

Air gun

The air gun is used for 2D and 3D seismic research, where the gun injects a bubble of very compressed air into the water. The spectrum of frequencies depends on the quantity of air in the bubble, air pressure and water depth, however it most commonly ranges between 5 and 200 Hz. If a wider spectrum of frequencies is to be attained, multiple devices of varying sizes must be used. The noise produced by air guns is maximally 260 dB re 1 μPa at 1 m. This intensity of noise is produced at a distance of 1 m from the source and spreads radially, vertically towards the floor. If the noise intensity is 260 dB at a distance of 1 m, at 100 m from the source it shall be 220 dB. Horizontal spreading of noise is reduced by 18 – 29 dB; however, there is no data on how far this noise goes (http://www.geoexpro.com/articles/2010/05/marine-seismic-sources-part-iv).

Air guns create large impulses of low frequencies that are directed towards the bottom of the sea under pressure. There is varying information about the exact quantities and methods of spreading noise with this source. According to Harland and others (2005), the noise levels produced reach 250 dB 1 re 1 μPa at 1 m, and the frequencies range between 50 and 100 Hz. According to Caldwell and others, (2000), the noise levels produced from the release of air from air guns correspond to 240 – 246 dB during vertical spreading and 220 – 230 dB during horizontal spreading; however, the radius in which noise is horizontally spread is not indicated. According to Continental Shelf Associates, noise spreads horizontally a few hundred metres. According to Amundsen L. and Landrø M., the maximum sound that may be produced by an air gun is 260 dB and is produced at 1 m from the source; however, horizontal spreading of sound is not listed. According to Caldwell and others (2000) the noise level is less than 15 – 24 dB at horizontal spreading compared to vertical spreading.

The quantity of noise caused by human activity in the Adriatic is increasing primarily with the increase in quantity and intensity of economic and other human activities (ships for transport of various cargos, cruise ships, fishing boats, vessels used for tourism purposes, etc.).

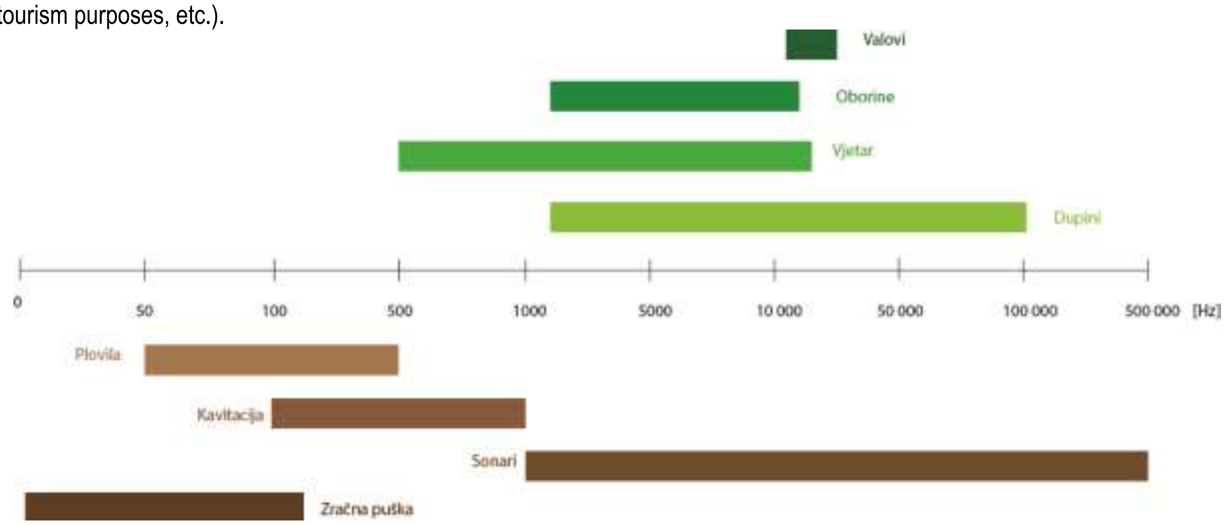


Image 3.55 Comparison of frequencies caused by natural processes and processes caused by human activity

Table 3.14 Overview of noise sources, their frequencies and levels

Natural noise			Noise caused by human activities		
Source of noise	**Frequency [kHz]**	**Noise levels [dB]**	**Source of noise**	**Frequency [Hz]**	**Noise levels [dB]**
Waves	15 – 30		Watercraft	50 – 500	171-186
Precipitation	2 – 20		Cavitation	100 – 1000	
Wind	0,5 – 25		Sonars	1000 – 500 000	
Dolphins	2 – 110	230 dB	Air guns	5 – 200	to 260 dB
			Boring rig		90-262 dB
			Noise from the platform		80 dB

3.6 Biodiversity

3.6.1 Marine Mammals and Reptiles

3.6.1.1 Cetaceans

3.6.1.1.1 Common bottlenose dolphin (*Tursiops truncatus*)

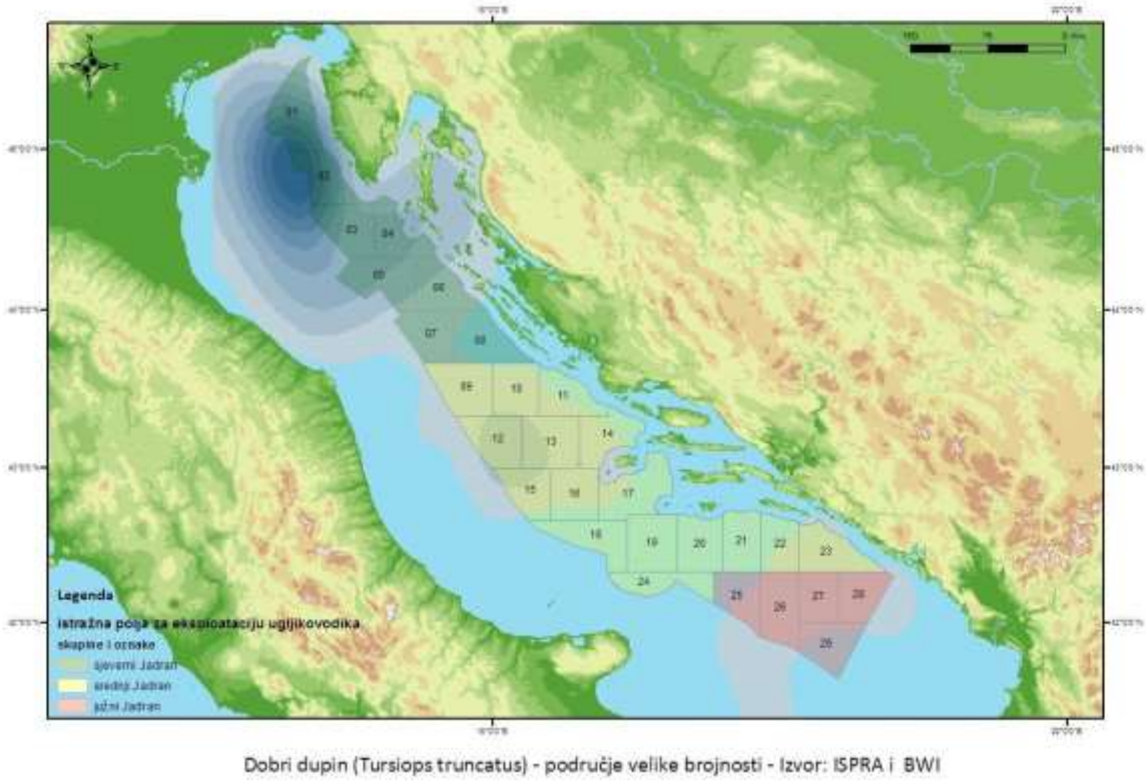
3.6.1.1.1.1 Distribution and Abundance

The common bottlenose dolphin (*Tursiops truncatus*) is found throughout the Mediterranean Sea (Bearzi et al. 2008b). It prefers important neritic regions such as the northern Adriatic Sea (Notarbartolo Di Sciara et al. 1993). It can also be found in other habitats, ranging from open sea to lagoons and river deltas (see Bearzi et al. (2008b) for a review).

Since the 1980s long-term research and monitoring of the ecology of common bottlenose dolphins has been ongoing in the Lošinj-Cres archipelago and its adjacent areas (Notarbartolo Di Sciara et al. 1993; Bearzi and Notarbartolo di Sciara 1995; Bearzi et al. 1997; Bearzi et al. 1999; Bearzi et al. 2008b; Bearzi et al. 2009). The core research tool used in this region is photo-identification. This research has provided the first quantitative information on population dynamics of the local population of common bottlenose dolphins in the Adriatic Sea (Bearzi et al. 1997; Fortuna et al. 2000; Fortuna 2006; Pleslić et al. 2014). Other studies of populations of the common bottlenose dolphin were initiated in Slovenia (Genov et al. 2008; Genov et al. 2009b), in the central Croatia in 2002 (Impetuoso et al. 2003), and in southern Croatia in 2007 (Holcer et al. 2008c; Holcer et al. 2009; Holcer 2012). Additional data have been collected from short and medium-term research from both Italian and Croatian waters (Bearzi et al. 2008a; Kammigan et al. 2008; Triossi et al. 2013).

Bearzi et al. (2008a) observed that the distribution of the common bottlenose dolphin in the north-western part of the northern Adriatic was dependent on seasonal water forcing. The topography of the seabed in their study area was relatively uniform, hence they concluded that habitat usage seemed to depend on the interaction of hydrological variables, caused by seasonal change which was likely to determine prey distribution.

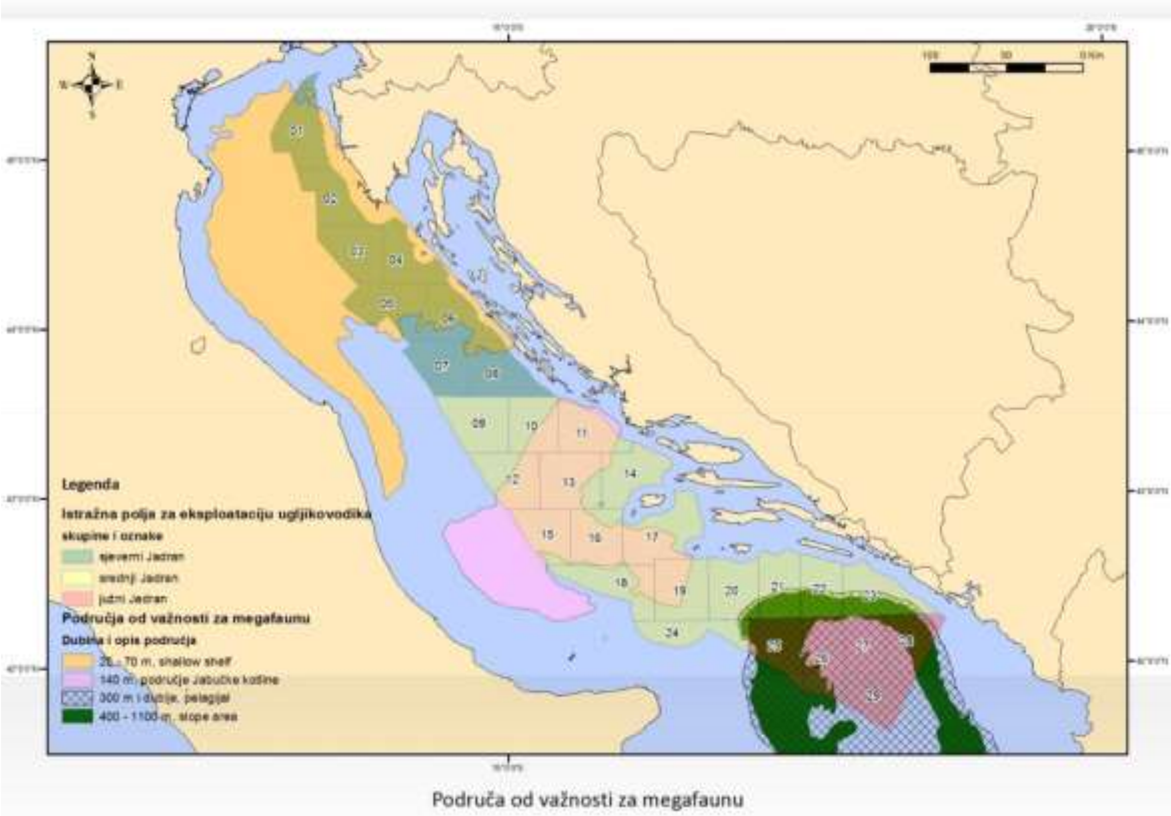
Aerial survey was carried out in 2010 and 2013 by the ISPRA and the Blue World Institute (Holcer et al. 2010a; Fortuna et al. 2011b; Fortuna et al. 2014b; Holcer et al. 2014a) to provide a snapshot of the summer distribution and abundance of common bottlenose dolphins throughout the Adriatic Sea basin. The aerial surveys confirmed that the common bottlenose dolphin is the only cetacean species regularly observed in the Adriatic Sea (Notarbartolo Di Sciara et al. 1993; Bearzi and Notarbartolo di Sciara 1995; Bearzi et al. 2008b). It is clear that this species prefers the neritic environment (<200m) to the pelagic zone (five times more, see figure below), especially areas with depths <100m. Kernel density maps of sightings identify areas of northern Adriatic and southern Adriatic as areas of particular interest for this species (Figure 3.56 and Figure 3.57).



Common bottlenose dolphin (Tursiops truncatus) – area of great abundance - Source: ISPRV and BWI

Legend: Hydrocarbon production blocks, groups and markings: northern Adriatic, central Adriatic, southern Adriatic.

Figure 3.56 Areas of great abundance of the common bottlenose dolphin in the Adriatic Sea (source: ISPRA and IPS, unpublished data): core density analysis, ARCGis algorithm (Fortuna et al. 2014b) and hydrocarbon blocks in the Adriatic (MINGO, 2014)



Areas important for megafauna

Legend: Hydrocarbon production blocks; groups and markings: northern Adriatic, central Adriatic, southern Adriatic. **Areas important for megafauna,** depth and description: 26 – 70 m, shallow shelf; 140 m, Jabuka Pit area; 300 and deeper, oceanic zone; 400 – 1100 m, slope area.

Figure 3.57 Areas of great importance for megafauna in the Adriatic Sea (Holcer et al. 2014b) and hydrocarbon blocks in the Adriatic (MINGO, 2014)

Table 3.15 Minimum abundance estimates of common bottlenose dolphins in the Adriatic Sea from the 2010 aerial survey (Fortuna et al. 2011b)

Area	Sample size	Model	Group density/km² (CV)	Animal density/km² (CV)	Uncorrected estimate (CV; 95% CIs)	Estimated mean group size (CV)
Entire Adriatic Sea (space between transects: 20 km; area: around 133,400 km²)	61	Half-normal/Cosine	0.014 (21.6%)	0.043 (25.7%)	5.772 (25.7%; 3.467-9.444)	3.87 (20.7%)
Northern Adriatic Sea (space between transects: 20 km)	35	Uniform/Cosine	0.025 (26.0%)	0.074 (30.2%)	3.608 (30.2%; 1.971 – 6.604)	2.80% (14.9%)
Central and southern Adriatic (space between transects: 20 km; area: around 73,900 km²)	23	Uniform/Cosine	0.010 (28.9%)	0.024 (34.8%)	1.786 (34.8%; 903-3.534)	2.87 (18.5%)

It was previously believed that the Adriatic common bottlenose dolphin was scattered into relatively small inshore "local populations". Data gained by aerial surveying indicates that this perception bias is probably related to the fact that small (100 – 3,000 km²) coastal areas were selected for surveys within existing and previously carried out projects. Taking a larger sea area into consideration gives a different picture of the distribution of this species, which includes other habitats as well and also indicates a greater population abundance.
The initial assessment of this species' status in Italy, created according to the Marine Strategy Framework Directive (MSFD, 2008/56/EC) provided an important overview on the "Adriatic Sea" sub-region (Fortuna et al. 2013). The assessment was based on the above mentioned data, including the 2010 aerial survey.
Preliminary abundance estimates (not corrected for researchers' perception and animal availability bias), based on the data from the 2010 aerial survey (Fortuna et al. 2011b), for the common bottlenose dolphin population for the entire Adriatic Sea are shown in Table 3.15 above.
Animal density is not high, but it is comparable to other areas of the Mediterranean Sea (i.e. Alboran Sea, Balearic Islands, see Bearzi et al. (2008b)). When density and abundance estimates are corrected for researchers' perception and animal surface availability bias (diving behaviour), the values increase by more than 20%. Estimate values additionally increase for about 50% when applying correction for the group size. New abundance estimates which will account for researchers' perception and animal availability bias corrections will be available by the end of 2014 (ISPRA and BWI, unpublished data).
Abundance data obtained by mark-recapture methods in local character studies are summarised in Table 3.16 below.

Table 3.16 Selected mark-recapture abundance estimates of common bottlenose dolphins in the Adriatic Sea

Location (Sampling year)	Model	Total estimate (CV; 95% CIs)	Source
North-west Adriatic, Slovenia and Croatia (2005)	M_{th} Chao assessor	68 (0.18; 62 – 81)	Genov *et al.* 2008
North-west Adriatic, Slovenia and Croatia (2008)	M_t	69 (0.08; 68 – 70)	Genov *et al.* 2008
Cres-Lošinj Archipelago, Croatia (1995)	M_{th} Chao assessor	168 (0.14; 132 – 229)	Fortuna 2006
Cres-Lošinj Archipelago, Croatia (1998)	M_{th} Chao assessor	130 (0.11; 108 – 152)	Fortuna 2006
Cres-Lošinj Archipelago, Croatia (2001)	M_{th} Chao assessor	105 (0.20; 76 – 160)	Fortuna 2006
Cres-Lošinj Archipelago, Croatia (2004)	M_{th} Chao assessor	197 (0.16; 162 – 272)	Pleslić *et al.* 2013
Cres-Lošinj Archipelago, Croatia (2007)	M_{th} Chao assessor	200 (0.13; 172 – 252)	Pleslić *et al.* 2013
Cres-Lošinj Archipelago, Croatia (2010)	M_{th} Chao assessor	186 (0.11; 164 – 230)	Pleslić *et al.* 2013
Islands Vis and Lastovo Archipelago, Croatia (2008)	M_h jacknife	396 (0.09; 350 – 456)	Holcer 2012
Islands Vis and Lastovo Archipelago, Croatia (2010)	M_{th} Chao assessor	474 (0.22; 352 – 638)	Holcer 2012

3.6.1.1.1.1.1 Distribution and Abundance Trends

The absence of quantitative historical information limits the possibility to infer population trends in the Adriatic Sea. However, local experts believe that the common bottlenose dolphin numbers possibly declined by as much as 50% in the second half of the 20th century, largely due to deliberate killing, but also due to additional stresses from habitat degradation and overfishing of species which are these animals' prey (Bearzi et al. 2004; Bearzi et al. 2008b; Bearzi and Fortuna 2012). A recent study on genetics does not seem to support the theory of an abrupt and dramatic abundance decline at the basin level (Gaspari et al. in review). The aerial survey data collected in 2010 and 2013 can provide a baseline for a quantitative comparison for the entire basin and for its sub-regions in the future (Fortuna et al. 2011b; Fortuna et al. 2014b).

3.6.1.1.1.2 Population Structure

The Adriatic Sea population structure of common bottlenose dolphins follows the “meta-population concept”, comprising of "local populations" that are separate or relatively separate entities in space, communicating during migrations and the related gene flow (Hanski and Gaggiotti 2004). The meta-population concept implies that the processes of "geographical extinction" and "recolonisation" may occur "regularly". The fragmentation of a habitat represents the most visible anthropogenic threat to the survival of natural populations (e.g. Hanski 2005). This can occur within the range of a local population, particularly for highly mobile species, in extreme cases leading to genetic and geographical isolation (Freedman et al. 2003; Hanski and Gaggiotti 2004). In the marine environment it is difficult to detect and explain landscape fragmentation, but there is increasing evidence that both oceanographic and anthropogenic factors can induce genetic fragmentation in cetaceans (e.g. Natoli et al. (2005)).

The genetic structure of the common bottlenose dolphin in the Adriatic Sea, based on mitochondrial (mtDNA) and nuclear DNA analysis, was analysed for 63 samples (Gaspari et al. 2013). The results of the analysis support the view that the population cannot be considered as a single "unit-to-conserve". The Adriatic common bottlenose dolphins reveal a fine-scale genetic structure with differentiation between north and central-south sub-basins (mtDNA), and between the western and eastern coasts (nuclear DNA). This subdivision reflects the existing physiographic differences along both latitudinal and longitudinal axes of the basin. The genetic structure suggests that females are the principal gene flow mediators. Migration rates indicate a relatively high level of gene flow from the northern Adriatic to adjacent areas, with mtDNA and nuclear DNA analysis revealing several levels of genetic differentiation between the Adriatic putative local populations and the Tyrrhenian Sea, i.e. the Aegean Sea. This reinforces the MSFD sub-region "Adriatic Sea" as an ecologically congruous area for the management of this species. However this requires that additional research be undertaken in the Adriatic Sea for the development of appropriate management and conservation measures. Gaspari et al. (2013), despite potential sample size limitations, suggest that the appropriate level for conservation issues is at the "sub-regional", if not the "local" population level, rather than basin-wide. Potential threats should be evaluated accordingly.

The data from photo-identification research also suggests that the common bottlenose dolphins of the Adriatic Sea are structured in corresponding local populations (Fortuna 2006; Genov et al. 2008; Genov et al. 2009b; Holcer 2012; Pleslić et al. 2013). Social characteristics play an important role in structuring a meta-population and should be investigated to inform on average minimal home ranges of populations.

3.6.1.1.1.3 Conservation Status

The Mediterranean common bottlenose dolphin subpopulation is listed as "Vulnerable" (VU) under the IUCN (World Conservation Union) and criterion A2dce (Bearzi and Fortuna 2012).

As a part of its commitments towards the MSFD, Italy has made a report for the European Commission (Fortuna et al. 2013) stating the initial assessment for this species encompassing the entire area of the Adriatic Sea. It has been suggested that any assessment at the sub-region level - of both cetacean species' status and potential threats to these species - can only be meaningful if carried out cooperatively with all bordering countries (not only the European Union Member States). The data collected during the Italian initial assessment for the MSFD and for the common bottlenose dolphin species in the Adriatic Sea sub-region are shown in Table 3.17, below.

Table 3.17 Italian initial assessment (2012) on the common bottlenose dolphin status according to the MSFD (based on Fortuna et al. (2013))

ODMS subject	Criteria	Assessment	Data reliability
Initial status assessment	**Distribution (1.1)**	Within total Adriatic Sea standards	High
	Abundance (1.2.1)	Minimal assessment for the entire Adriatic Sea: over 5000 animals	High
	Population genetic structure (1.3.2)	Division on at least two units (northern and central-southern Adriatic) and additional division on east/west unit considering males*	High
Potential threats	**Bycatch**	Unknown cumulative impact of all fisheries. Bycatch rates for Italian pelagic trawlers (GSA 17) = 0.001 animals per trawl, 19 animals in total (CV=59%; 95% CIs 10 – 29) annually for this fishery alone (Fortuna and Filidei 2012).	High
	Chemical pollution	Unknown	Middle
	Overfishing of demersal resources	Unknown	Low
Key: ODMS = Marine Strategy Framework Directive; High = based on repeat analysis of reliable data gathered in the sub-region; Middle = based on published data gathered in some part of the region; Low = based on expert opinion; * conclusions reassessed according to Gaspari *et al.* 2013.			

According to UNEP (2011) the Cres-Lošinj Archipelago (Kvarnerić area) represents the habitat of a resident population of common bottlenose dolphin researched since 1987. Based on the results of this research, this area was included in the Croatian National Ecological Network (CroNEN) and it was suggested that it should be included in the Natura 2000 ecological network of the EU (HR3000161). From 2006 to 2009 it functioned as a special marine zoological reserve, i.e. a marine protected area.

The Cres-Lošinj special marine reserve was established in 2006 with the specific aim to conserve the common bottlenose dolphin population and to sustainably manage the natural resources of the Cres-Lošinj archipelago (Ministry of Culture of the Republic of Croatia 2006). The archipelago is of national importance with regard to an abundance of tourist activities and so it was proposed that it should be used as a multi-purpose area (Mackelworth et al. 2002; Mackelworth et al. 2003; Holcer et al. 2006). Between July 2006 and July 2009 this was the largest marine protected area in the Adriatic Sea (approximately 525 km^2).

The Cres-Lošinj special marine reserve helped to fulfil Croatian commitments to many international environmental agreements. However, local community's demands conflicted with the goals of establishing the protected area and so the support for the concept waned with time. The inactivity of state institutions and the mismatch between local development and international commitments led to a protection category downgrade and, ultimately, to its complete abolishment (Mackelworth and Holcer 2011; Becker et al. 2013; Mackelworth et al. 2013).

Five additional areas significant for conserving species and habitat types (POVS) for the inclusion in the NEN and Natura 2000 network (HR5000032; HR4000001; HR3000419; HR3000469; HR3000426) were proposed later with the goal of conserving common bottlenose dolphins in the Adriatic.

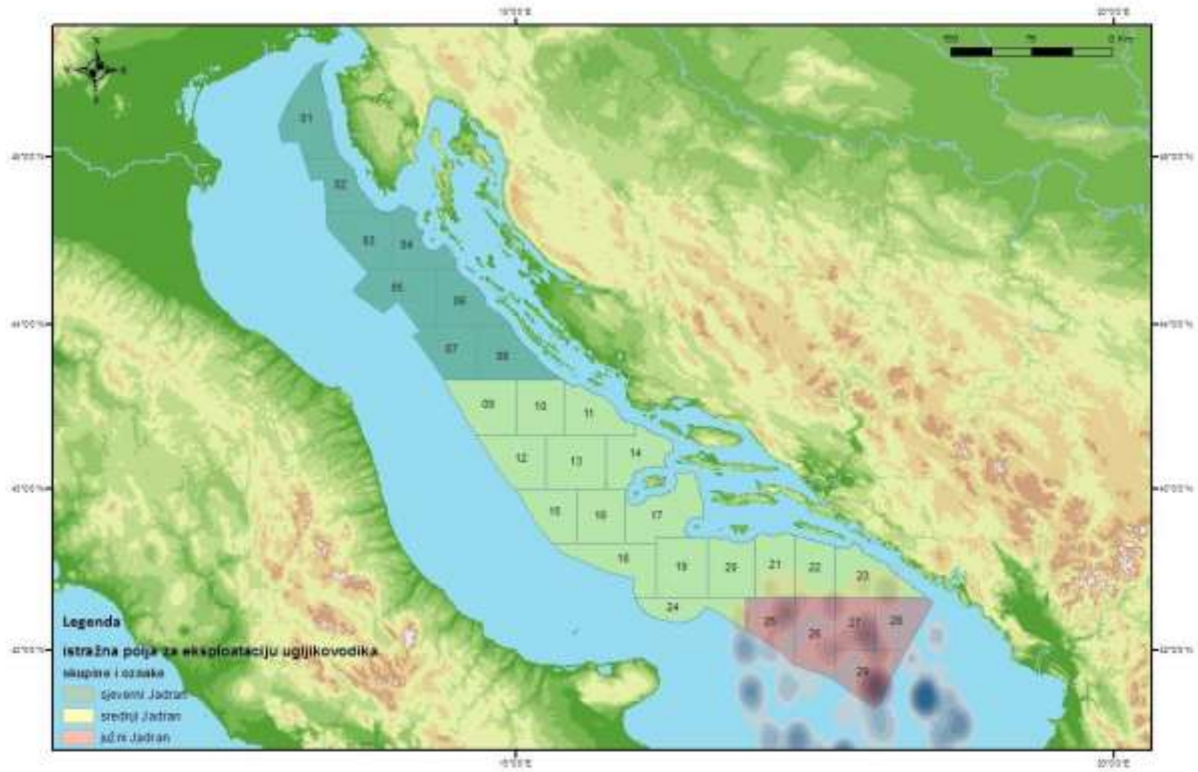
Based on the conclusions reached in the Natura 2000 biogeographical seminar on the representativeness of the proposed NEN in November 2014, it was concluded that the POVS area coverage for the common bottlenose dolphin was sufficient in near shore areas, but that it is necessary to consider establishing areas in the open sea (ETCBD 2014). Based on additional research and the known distribution it is possible to expect additional areas to be established.

Triossi et al. (2013) studied the behaviour of the common bottlenose dolphins near the offshore gas fields off Ravenna (Italy). Their analyses showed that dolphin density was 80% higher within 750 m of gas platforms (compared to densities >750 m from platforms). They noticed that higher frequencies of feeding or milling behaviour were observed closer to gas platforms. On the other hand, further away animals exhibited higher frequencies of travelling and socialising. Platforms are known to provide a refuge for demersal fish and act as aggregation points for pelagic fish. It is therefore possible that common bottlenose dolphins may be opportunistically using these structures as feeding areas. Under the Italian law, it is forbidden to anchor, fish or navigate within 500 m of the 130 platforms scattered over the Adriatic Sea. In some ways, oil and gas platforms in this region may act as a de facto network of highly protected marine micro-areas.

3.6.1.1.2 Striped Dolphin (Stenella coeruleoalba)

3.6.1.1.2.1 Distribution and Abundance

The striped dolphin is considered to be the most numerous species of dolphins in the Mediterranean Sea (Aguilar 2000). This appears also to be the case in the Adriatic Sea (Fortuna et al. 2011b), although its presence appears to be only regular in the southern part of the basin (Figure 3.58).



Prugasti dupin (Stenella coeruleoalba) - područje velike brojnosti - Izvor: ISPRA i BWI

Striped dolphin (Stenella coeruleoalba) – area of great abundance - Source: ISPRV and BWI
Legend: Hydrocarbon production blocks, groups and markings: northern Adriatic, central Adriatic, southern Adriatic.

Figure 3.58 Areas of great abundance of the striped dolphin in the Adriatic Sea (source: ISPRA and IPS, unpublished data): core density analysis, ARCGis algorithm (Fortuna et al. 2014b) and hydrocarbon blocks in the Adriatic (MINGO, 2014)

The distribution of the striped dolphin reflects the oceanographic characteristics of the regions sub-basins (Notarbartolo Di Sciara et al. 1993; Fortuna et al. 2011b). They dwell at sea depths greater than 600 m, feeding mostly on cephalopods and epipelagic fish (Aguilar 2000). It is only exceptionally found in areas with depths below 200 m (Notarbartolo Di Sciara et al. 1993; Fortuna et al. 2007). On occasion, solitary dolphins or small groups appear in the shallow northern portion of the basin (Bearzi et al. 1998; Francese et al. 2007; Rako et al. 2009; Nimak-Wood et al. 2011). Striped dolphin is a social animal. Large groups of several hundred animals can be found in the southern Adriatic Sea (Fortuna et al. 2011b), in contrast to the northern Adriatic Sea where group size ranges from one to three animals (Bearzi et al. 1998; Francese et al. 2007; Rako et al. 2009; Nimak-Wood et al. 2011).

Reports of striped dolphin sightings along the northern Adriatic coastline are becoming more frequent. This could be due to an expansion of the specie's distribution as has been reported for other Mediterranean areas (Bearzi et al. 1998), or due to an increased public interest and easier documentation of cetacean sightings (Francese et al. 2007; Rako et al. 2009).

Data on the abundance of this species in the Adriatic Sea is summarised in Table 3.18, below. The fact that the presented data is considered to be a minimum estimate (uncorrected for researchers' perception and animal availability bias) should be taken into account.

Table 3.18 Abundance estimates of striped dolphins in the Adriatic Sea (2010 aerial survey)

Location (Sampling year)	Total estimate (CV; 95% CIs)	Source
Central and southern part of the Adriatic Sea (2010)	15.343 (0.28; 8.545-27.550)	Fortuna et al. (2011)

Note: This abundance estimate was not corrected for researchers' perception and animal availability bias, so these are values below actual abundance.

3.6.1.1.2.2 Population structure

The genetic structure of the striped dolphin population in the Adriatic Sea is unknown. However, a preliminary study (n=15) suggests that animals dwelling in this area are not strongly genetically separate from those of other parts of the Mediterranean Sea (Gaspari 2004).

3.6.1.1.2.3 Conservation status

The Mediterranean striped dolphin subpopulation is listed as "Vulnerable" (VU) under the IUCN (World Conservation Union) and criterion A2bcde (Aguilar and Gaspari 2012).

3.6.1.1.3 Cuvier's Beaked Whale (*Ziphius cavirostris*)

3.6.1.1.3.1 Distribution and Abundance

The Cuvier's beaked whale is a mid-sized Cetacean. Adults reach between 5.5 and 7 m in length (MacLeod 2006). It is the species of beaked whale with the widest distribution range, appearing globally, absent only in polar waters (Heyning 1989).

Cuvier's is the only beaked whale species known to regularly appear throughout the entire Mediterranean Sea. There are no notable differences in distribution between the western and the eastern basins (Notarbartolo di Sciara and Demma 1997, Notarbartolo di Sciara 2002), with a relatively higher abundance in the areas of Alboran Sea (Cañadas 2011), along the Hellenic trench, from Rhodes to NW Corfu (Frantzis et al. 2003) and in the Ligurian Sea where a long-term site fidelity has been established through photo-identification (Revelli et al. 2008; Rosso et al. 2011). The estimate of population size exists only for areas of the Alboran Sea and the Gulf of Vera (Cañadas 2011) where availability bias-corrected estimate of abundance for 2008-2009 was 1994 animals (CV=39.7%) and the northern Ligurian Sea where mark-recapture analysis in the period of 2004-2005 yielded a total estimate of 85 animals (CV=0.24), that is, 94 (CV=0.21) animals (left/right side) (Rosso et al. 2007). This species has been recorded through sightings and strandings in a number of other locations in the Mediterranean Sea (D'Amico et al. 2003; Frantzis et al. 2003; Podestà et al. 2006; Holcer et al. 2007a; Gannier and Epinat 2008; Notarbartolo di Sciara and Birkun 2010; Gannier 2011).

The distribution of the Cuvier's beaked whale is often associated with habitats situated at the edges of continental shelves, where the seabed is very steep. It was established that they prefer submarine canyons, steep slopes, scarps or submarine reefs (D'Amico et al. 2003; MacLeod 2005; Gannier and Epinat 2008). In the area of the Pelagos Sanctuary, Moulins et al. (2007) found that sightings of Cuvier's beaked whales were most frequent where depth was between 756 and 1389 m (if the slope was steeper). Encounter rate was also high between depths of 1389 and 2021 m (where the slope was flatter). In Greece animals were observed between depths of 500 and 1500 m along slopes (Frantzis et al. 2003).

Data collected between 1990 and 2010 for the purposes of habitat modelling of Cuvier´s beaked whales in the Mediterranean Sea identified the Alboran Sea, the central Ligurian Sea, the Hellenic Trench and the south Aegean Sea (north Cretan Sea) as the areas of highest predicted density (Figure 3.59).

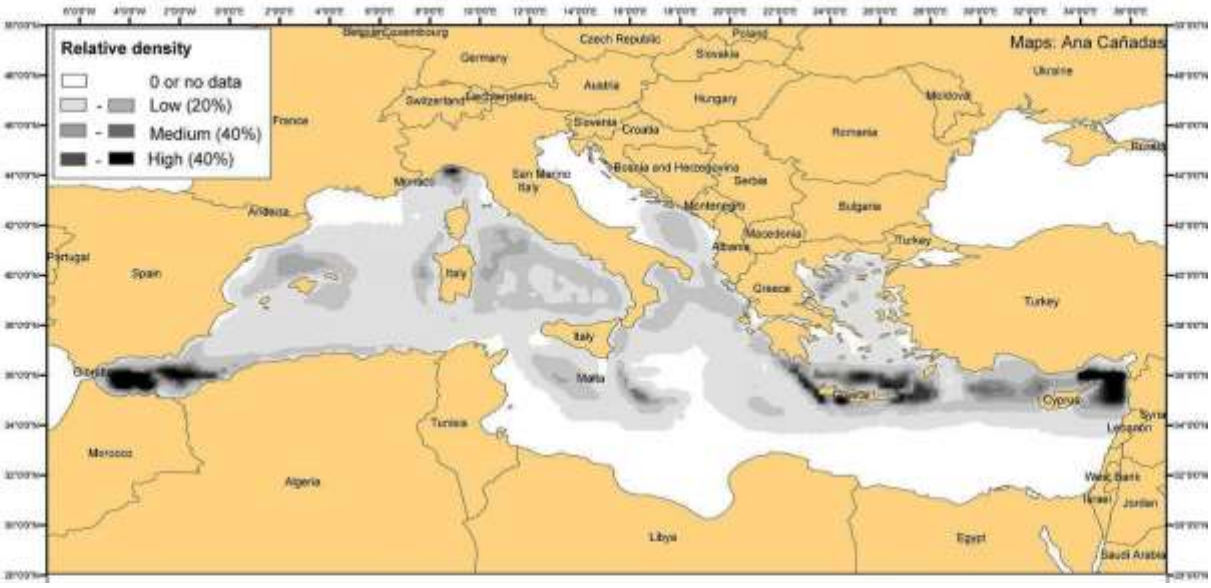


Figure 3.59 Areas in the Mediterranean Sea of great importance for the Cuvier´s beaked whale - upper value 95% confidence interval of the relative density index (Cañadas et al. 2011)

The areas of the Tyrrhenian Sea, the southern Adriatic Sea, some areas to the north of the Balearic Islands and the south of Sicily had higher predicted densities compared to the rest of the Mediterranean (Cañadas et al. 2011). Records collected from the Adriatic Sea at a later time were not included in the model, making this area's density under-evaluated (Figure 3.60).

Područje od važnosti za Cuvierovog kljunastog kita (Ziphius cavirostris) - Canadas et al 2011

Cuvier's beaked whale (Ziphius cavirostris) – area of great abundance – Canadas at al 2011

Legend: Hydrocarbon production blocks, groups and markings: northern Adriatic, central Adriatic, southern Adriatic.

Figure 3.60 Areas in the Adriatic Sea of great importance for the Cuvier´s beaked whale - upper value 95% confidence interval of the relative density index (Cañadas et al. 2011) and hydrocarbon blocks in the Adriatic (MINGO, 2014)

The Cuvier's beaked whale is mainly teuthophagic although fish may also be an important component of their diet (MacLeod 2005). The most common prey that they hunt in the Mediterranean Sea are oceanic and pelagic (meso- or bathy-) cephalopods of the families Histioteuthidae, Cranchiidae and/or Octopoteuthidae (Podestà and Meotti 1991; Carlini et al. 1992; Lefkaditou and Poulopoulos 1998; Blanco and Raga 2000; MacLeod 2005).

An exceptional concern has been expressed over the status of this species. The impact of anthropogenic noise has been linked to several atypical mass strandings coinciding with the use of naval mid-frequency sonars (Frantzis 1998; Arbelo et al. 2008; ACCOBAMS SC 2012b), and possibly when using air guns (Gentry 2002). Additionally, seismic surveys for hydrocarbons generally increase sea ambient noise, and its cumulative effects are a cause for concern (Gordon et al. 2003; ACCOBAMS SC 2012a). Therefore, the Scientific Committee of ACCOBAMS presented several initiatives to the signatory parties, including the Guidelines for noise mitigation and subsequntly astatement of concern (ACCOBAMS 2010; ACCOBAMS SC 2012b; ACCOBAMS 2014). Based on the existing knowledge of disturbance-causing noise thresholds, it has been suggested that beaked whales should not be exposed to sound with source levels higher than 140 dB re 1 μPa at 1 m (ACCOBAMS SC 2011).

3.6.1.1.3.1.1 Adriatic Sea

Information regarding the distribution and occurrence of this species in the Adriatic Sea is scarce. Historically, the species was considered an occasional visitor to the deeper southern basin, where stranded animals have been regularly found (Lamani et al. 1976; Centro Studi Cetacei 1987; Notarbartolo di Sciara et al. 1994; Centro Studi Cetacei 1995; Storelli et al. 1999; Holcer et al. 2002; Holcer et al. 2003; Gomerčić et al. 2006a; Podestà et al. 2006). The review paper by Holcer et al. (2007a) presents a detailed overview on the occurrence of the species in the Adriatic Sea concluding that the southern Adriatic Sea could be an important habitat for Cuvier's beaked whale (Figure 3.60). Total of eleven stranded Cuvier's beaked whales had been documented in the Adriatic Sea by 2004 (Holcer et al. 2007a). Five of these were recorded along the Italian Apulian coast, one in Albania, and another five strandings along the Croatian Adriatic shore. Additionally, in 2008 a newborn was found stranded in Trstenica bay on the Pelješac Peninsula in Croatia (Kovačić et al. 2010). Two stranded animals, previously unreported, were examined by Pino d'Astore et al. (2008). Finally, two additional stranded animals were recently reported by the Museo Civico in Gallipoli and the Department of Pathology, University of Bari, to the Italian stranding database (http://mammiferimarini.unipv.it). Strandings of the Cuvier's beaked whale in the Adriatic Sea have been reported along all shores surrounding the south Adriatic basin. There have been no reports of stranded animals in the northern Adriatic Sea, while the occurrence of this species in the central Adriatic is probably not significant. Considering the ecology of the Cuvier's beaked whale as a deep diving species with preference for deep slope habitats, the lack of occurrence in the rather shallow part of the continental shelf of the northern Adriatic is not surprising.

The analysis of the stomach contents of an animal from the Adriatic Sea revealed similar prey species as found in stranded animals from other parts of the Mediterranean Sea. Diet included animals from the families Histioteuthidae (34.7%), Octopoteuthidae (39.1%; not found in the Adriatic Sea), Chiroteuthidae (17.7%), Cranchiidae (8.2%%; not found in the Adriatic Sea) and Sepiolidae (0.2%) (Kovačić et al. 2010). Furthermore, some of the prey species found in the stomach contents do not dwell in the Adriatic Sea indicating either the occurrence of migration from other parts of the Mediterranean Sea or a severe lack of information on the occurrences of various species of deep living cephalopods of the Adriatic Sea.

In addition to strandings, the presence of Cuvier´s beaked whales in the Adriatic Sea has been confirmed through two aerial surveys in 2010 and 2013 (Fortuna et al. 2011b; Fortuna et al. 2013; Fortuna et al. 2014b). In total, five confirmed sightings of were made in areas with a steep seabed and depths varying between 700 and 1200 m. It is notable that the sightings have been grouped along the northern and eastern part of the south Adriatic basin where there is a steep drop to the depth of 1000 m. Within the sighing areas several prey species can be found. Sightings included females with juvenile animals indicating that the southern Adriatic could be an important area for young animal growth and development.

3.6.1.1.3.2 Population Structure

No information exists on the population structure of Cuvier´s beaked whales in the Mediterranean Sea. The mean group size in the Mediterranean ranges between 2.2 to 2.3 animals (Canadas et al. 2005; Moulins et al. 2007; Gannier 2011). The mean group size value, based on five sightings during aerial surveys in the Adriatic Sea, is 2.6 (authors' data). The analysis of genetic diversity based on 87 samples obtained worldwide (10 in the Mediterranean Sea, 2 in the Adriatic Sea) found that mtDNA haplotypes from the Mediterranean Sea were not found elsewhere and were highly distinct from the neighbouring Eastern North Atlantic (Dalebout et al. 2005). This could indicate a low level of genetic material exchange between the two basins. Of the two haplotypes (T3 and T4), only one haplotype (T3) was found in the two animals stranded on the Croatian coast (Dalebout et al. 2005).

3.6.1.1.3.3 Conservation Status

In 2011 the Scientific Committee of the International Whaling Commission (IWC) revised the status of the beaked whales species in the Atlantic and concluded that "the evidence for one or more discrete populations of Z. cavirostris in the Mediterranean Sea is sufficient to merit "subpopulation" assessment for the IUCN Red List" and it recommended to " submitt it for consideration to the Cetacean Red List Authority" as soon as possible. The Cuvier´s beaked whale in the Mediterranean Sea is currently listed as "Data Deficient" (DD) (Cañadas 2012).

3.6.1.1.4 Risso's Dolphin (*Grampus griseus*)

3.6.1.1.4.1 Distribution and Abundance

Risso’s dolphins are relatively large animals measuring up to 4 m in length (Kruse et al. 1999). The most distinctive feature of this species is the blunt head without a beak (rostrum) and the dark colouration dominated by scars which they accumulate throughout life. Older animals appear almost white in colour. Risso’s dolphins are distributed worldwide in tropical and temperate seas. They prefer deep offshore waters with narrow continental shelves (Leatherwood et al. 1980).

The Risso’s dolphin is distributed throughout the Mediterranean Sea and it is considered a regular inhabitant, although abundance is unknown (Notarbartolo di Sciara and Birkun 2010). The Risso’s dolphin is encountered in deep pelagic waters, over steep slope shelves and submarine canyons in the Mediterranean Sea (Gaspari 2004; Azzellino et al. 2008; Gómez de Segura et al. 2008). Gaspari (2004) suggested that the distribution of the Risso's dolphin is not conditioned by depth but by habitat, since they prefer areas of greater depth and areas where the continental slope is deeper and steeper. Such distribution is possibly related to the feeding specialization. The analysis of the stomach contents of stranded Risso’s dolphins indicate that the species feeds mostly on cephalopods inhabiting oceanic waters over steep continental slope areas (Podestà and Meotti 1991; Wurtz et al. 1992). The analysis of Blanco et al. (2006) indicates that Risso’s dolphins feed mainly on cephalopods from the middle slope of the continental shelf edge (depths between 600 and 800 m).

Risso's dolphins are regularly observed or found stranded in most areas of the Mediterranean Sea (Bearzi et al. 2011b), although no data exists for the northern coast of Africa (Notarbartolo di Sciara and Birkun 2010). The Ligurian Sea is an important area for Risso’s dolphins.

Abundance estimates were made only in certain years and only in a few areas in the Mediterranean basin, such as the Spanish central Mediterranean, where aerial surveys were made between 2001 and 2003. The data provided an uncorrected estimate of 493 Risso’s Dolphins (95% C.I. 162–1,498) in an area of 32,270 km² (Gómez de Segura et al. 2006). Within other parts of the western Mediterranean Sea basin aerial and ship based surveys did not yield a sufficient number of observations to obtain an abundance estimate (Fortuna et al. 2007; Panigada et al. 2011). Even in the Ligurian basin densities are low: 0.035 specimens/km^2 during winter and 0.011 specimens/km^2 during summer (Laran et al. 2010).

3.6.1.1.4.1.1 Adriatic Sea

There have been numerous sightings of Risso's dolphins in the Adriatic Sea. First records originate from the 19th century (Giglioli 1880; Faber 1883; Brusina 1889; Kolombatović 1894). Most records concern stranded animals found along Italian and Croatian coastlines (Trois 1894; Valle 1900; Hirtz 1938; Notarbartolo di Sciara et al. 1994; Francese et al. 1999; Storelli et al. 1999; Holcer et al. 2002; Zucca et al. 2005; Gomerčić et al. 2006b; Bilandžić et al. 2012). According to available information no animals have been observed or found stranded on the coasts of Slovenia, Montenegro or Albania. In most cases animals were found stranded live. While some did die, others were successfully returned to the sea (Zucca et al. 2005). In most instances records concern single animals. More animals were observed only in two cases. Three animals were observed near the Gulf of Trieste (Francese et al. 1999) and two animals were found stranded on the Island of Molat (Gomerčić et al. 2006b). Most authors agree that the Risso's dolphin is only occasionally present in the Adriatic Sea (Bearzi et al. 2004).

During the surveys carried out in the northern Adriatic Sea between 1988 and 2013 (Bearzi et al. 1997; Fortuna 2006; Bearzi et al. 2008a; Bearzi et al. 2009; Pleslić et al. 2013), there have not been any recorded sightings of Risso's dolphin. Additionally, local surveys in the central Adriatic (Holcer et al. 2008a; Holcer et al. 2008b; Holcer et al. 2008c; Fortuna et al. 2010; Holcer et al. 2010b; Holcer and Fortuna 2011; Holcer 2012) have not recorded any sightings of the Risso's dolphins either. It must be considered, however, that all research effort was undertaken in areas which would not normally represent a usual habitat for Risso's dolphins, and thus their absence could be expected.

The two aerial surveys carried out on the basin-wide scale confirm such conclusions (Fortuna et al. 2011b; Lauriano et al. 2011; Fortuna et al. 2014b). Risso's dolphins were only observed in the southern Adriatic along the steep slope areas at depths between 600 and 900 m. Several opportunistic observations have been reported from the ferries traversing the southern Adriatic Sea (Giovagnoli 2013). Such results are consistent with the known habitat preferences and feeding specialisation of Risso's dolphins (Azzellino et al. 2008). A preliminary abundance estimate was obtained from the aerial survey taken in 2010 (510 specimens; CV=78.1%; 95% CI=124-2,089), indicating that the southern Adriatic could potentially host several hundred Risso's dolphins (Fortuna et al. 2011a).

Many deep diving cetaceans are sensitive to the influence of anthropogenic sound. Consequently, several international bodies expressed concern for the well-being of this species (ACCOBAMS SC 2012b).

3.6.1.1.4.2 Population Structure

The overview of the current status and ecology of Risso's dolphin in the Mediterranean Sea are given by Bearzi et al. (2011b) and Gaspari and Natoli (2012). Little is known of the social structure and behaviour of Risso's dolphins in the region.

Reported group size in the Ligurian basin can range from 2 to 70 animals, with an average group size of 14.5 animals and a median group size of four to five animals (Gaspari (2004). Average group size varies according to season: 9.8 during summer and 11.3 during winter (Laran et al. (2010). In the Alboran Sea the average group size was 12.5 (Canadas et al. 2005) and off the south-eastern coast of Spain it was 21.7 (Gómez de Segura et al. 2008). During the aerial survey group sizes from 1 to 12 animals were recorded, with the most frequent group size of four and six animals (authors' data).

There are no strong connections between Risso's dolphins in the Ligurian Sea, although there are some long-lasting relationships between individual animals which last for years (Gaspari 2004).

The genetic data available, based on the microsatellite and mitochondrial DNA analysis, shows that the Mediterranean Risso's dolphins are genetically differentiated from the nearest eastern Atlantic population and the gene flow is limited (Gaspari et al. 2007). There is no data for the Adriatic Sea, although the research of Gaspari et al. (2007) indicates that there is potentially a Mediterranean regional population structuring.

Photo-identification data from the Ligurian Sea indicates that animals show site fidelity (Airoldi et al. 2005), but there are seasonal (summer/winter) changes in density (Laran et al. 2010) which may indicate seasonal migration within the Mediterranean Sea.

3.6.1.1.4.3 Conservation Status

The Risso's dolphin of the Mediterranean Sea is listed as "Data Deficient" (DD) (Gaspari and Natoli 2012).

3.6.1.1.5 Fin whale (Balaenoptera physalus)

3.6.1.1.5.1 Distribution and Abundance

Fin whales are most commonly found in the deep waters (between 400 and 2,500 m) of the Mediterranean Sea. However, they can dwell in slope and shelf waters, depending on the distribution of their prey (e.g. Canese et al. (2006)). They favour upwelling and frontal zones (Notarbartolo-Di-Sciara et al. 2003) and coastal areas (Canese et al. 2006) with high zooplankton concentrations.

Most records in the Adriatic Sea rely on strandings and sightings of stray specimens which are scattered throughout the northern and central Adriatic ((Lipej et al. 2004); BWI unpublished data) and some regular sighting in the central Adriatic which suggests distribution is likely related to the seasonal presence of their primary prey (Holcer, unpublished data, (Fortuna et al. 2011b)).

Recent research indicates that fin whales regularly enter the southern and central Adriatic Sea. Large krill (small euphausiid shrimp) biomass has been recorded in the central Adriatic, in the area of Jabuka Pit, but more research is required for an accurate estimate of seasonal presence and abundance. Fin whales were observed feeding in the vicinity of the Island of Vis, and faeces samples analysis indicated a connection between the occurrences of fin whales and krill, which could mean that this area has an important seasonal role (Holcer, unpublished data).

There are no abundance estimates for the fin whale in the Adriatic Sea or the eastern Mediterranean Sea.

3.6.1.1.5.2 Population Structure

The Mediterranean fin whales are largely resident, although limited but persistent gene flow was detected in the genetic samples (Palsboll et al. 2004). According to the IUCN definition for subpopulation (i.e., less than one migrant/year), the Mediterranean fin whale population is considered to be a sub-population of the western Atlantic population (Palsboll et al. 2004).

The only genetic information available for a fin whale from the Adriatic Sea is the analysis of a single animal which had an allotype typical from the Ligurian Sea (Caputo and Giovannotti 2009).

3.6.1.1.5.3 Conservation Status

The fin whale is listed as "Vulnerable" (VU) in the Mediterranean under the IUCN (World Conservation Union) and criterion C2a(ii) (Panigada and Notarbartolo di Sciara 2012).

3.6.1.1.6 Other occasionally present species

3.6.1.1.6.1 Short-beaked common dolphin (*Delphinus delphis*)

The short-beaked common dolphin has a world-wide distribution. Historically it was distributed throughout the Mediterranean Sea and was once considered the most abundant Cetacean species in the region. The abundance of this species is in steep decline throughout the central and eastern Mediterranean (Bearzi et al. 2003). The only notable population remaining is in the Alboran Sea (Canadas and Hammond 2008). The overview of this species' status and ecology is presented in Bearzi et al. (2003).

The Mediterranean short-beaked common dolphin is found mainly in pelagic and neritic habitats (Notarbartolo di Sciara and Birkun 2010), where they feed mainly on epipelagic and mesopelagic shoaling fish, but also on cephalopods (Bearzi et al. 2003). The short-beaked common dolphin was once widely distributed in the Adriatic Sea until the mid-19th century. Numerous records support the view that the short-beaked common dolphin used to be the most numerous species in the Adriatic Sea (Faber 1883; Brusina 1889; Trois 1894). In the late 1970s there was a sharp decrease in the average size of short-beaked common dolphin groups in the Adriatic Sea (Pilleri and Gihr 1977). Since then the species has disappeared from the northern Adriatic Sea (Bearzi 1989; Notarbartolo di Sciara and Bearzi 1992; Bearzi and Notarbartolo di Sciara 1995; Bearzi et al. 2000). Only solitary specimens or small groups have been documented since the late 1990s (Bearzi 2000; Rako et al. 2009; Boisseau et al. 2010; Genov et al. 2012; Lazar et al. 2012). Overfishing, organised culling and habitat degradation are suggested as the main reasons for the decline and disappearance of this species from the Adriatic Sea (Bearzi et al. 2004). Due to the lack of information about the central and southern Adriatic this species was listed as "Data Deficient" (DD), although it was indicated that the species could be critically endangered (Holcer 2006). In the last few decades only rare sightings of stray animals or animals leftover from the former population are reported. Aerial surveys from 2010 and 2013 included the entire Adriatic Sea (Fortuna et al. 2011b; Fortuna et al. 2014b), but no sightings of the short-beaked common dolphin were reported, which leads to the conclusion that this species is regionally extinct in the Adriatic Sea.

The short-beaked common dolphin of the Mediterranean is listed as "Endangered" (EN) under the IUCN (World Conservation Union) and criterion A2abc (Bearzi 2003).

3.6.1.1.6.2 Sperm Wwhale (Physeter macrocephalus)

The sperm whale population of the Mediterranean is genetically unique (Drouot et al. 2004). There is no estimate of population size for the region. Preferred Mediterranean habitats are deep sea areas, above continental slopes, where cephalopods on which they feed are abundant (Azzellino et al. 2008; Praca and Gannier 2008).

The occurrence of sperm whales in the Adriatic Sea includes 36 strandings documented from as early as 1555 (Bearzi et al. 2011a). This is the only Cetacean species for which a mass stranding on the Adriatic Sea coast was reported. In December 2009 seven males were stranded on the northern side of the Gargano promontory (Mazzariol et al. 2011). Last recorded occurrence of a group of sperm whales was in summer of 2014 when seven animals were observed swimming along the Croatian coast, heading north. They reached northern Dalmatia and several days later the group got stranded near Vasto, Italy. Four animals were re-floated, while three died on the beach. Sperm whales are deep diving Cetaceans, meaning there is no suitable habitat for them in the central and northern Adriatic. The deeper southern Adriatic may host animals during seasonal migration or those passing through from the Ionian Sea. Given its physiography and size, the southern Adriatic probably cannot be considered an area of regular distribution for the sperm whale. This is consistent with the results of the aerial surveys (Fortuna et al. 2011b; Fortuna et al. 2014b) and the results of acoustic surveys during which animal sounds were recorded by towed hydrophones, which did not produce any sightings or recordings (Boisseau et al. 2010).

3.6.1.1.7 Adriatic Sea visitor species

3.6.1.1.7.1 Long-finned pilot whale (*Globicephala melas*)

There has been only one confirmed sighting of the long-finned pilot whale in the Adriatic Sea. Two animals were caught in a tuna trap on the Island of Rab in 1922 (Hirtz 1922). The larger animal managed to escape, while the smaller one was killed by local fishermen. The animal that was caught was a male approximately 5.5 m long and was well described by Hirtz (1922).

3.6.1.1.7.2 False killer whale (*Pseudorca crassidens*)

There is one well recorded capture of a false killer whale which occurred on the Island of Korčula in the central Adriatic, recorded by Hirtz (1938). Additionally, three specimens from a pod of 30-40 were reportedly captured near Ravenna, Italy, between 1959 and 1961 (Stanzani and Piermarocchi 1992).

3.6.1.1.7.3 Humpback whale (Megaptera novaeangliae)

Humpback whales are rare in the Mediterranean (Notarbartolo di Sciara and Birkun 2010). They have been reported in the Adriatic Sea on two occasions. The first occurrence was reported off Senigallia, Italy, in August 2002 (Affronte et al. 2003) and two weeks later what could have been the same animal was spotted in the Ionian Sea (Frantzis et al. 2003). The second sighting occurred in the Piran Bay in 2009 (Genov et al. 2009a) where the animal remained for almost three months.

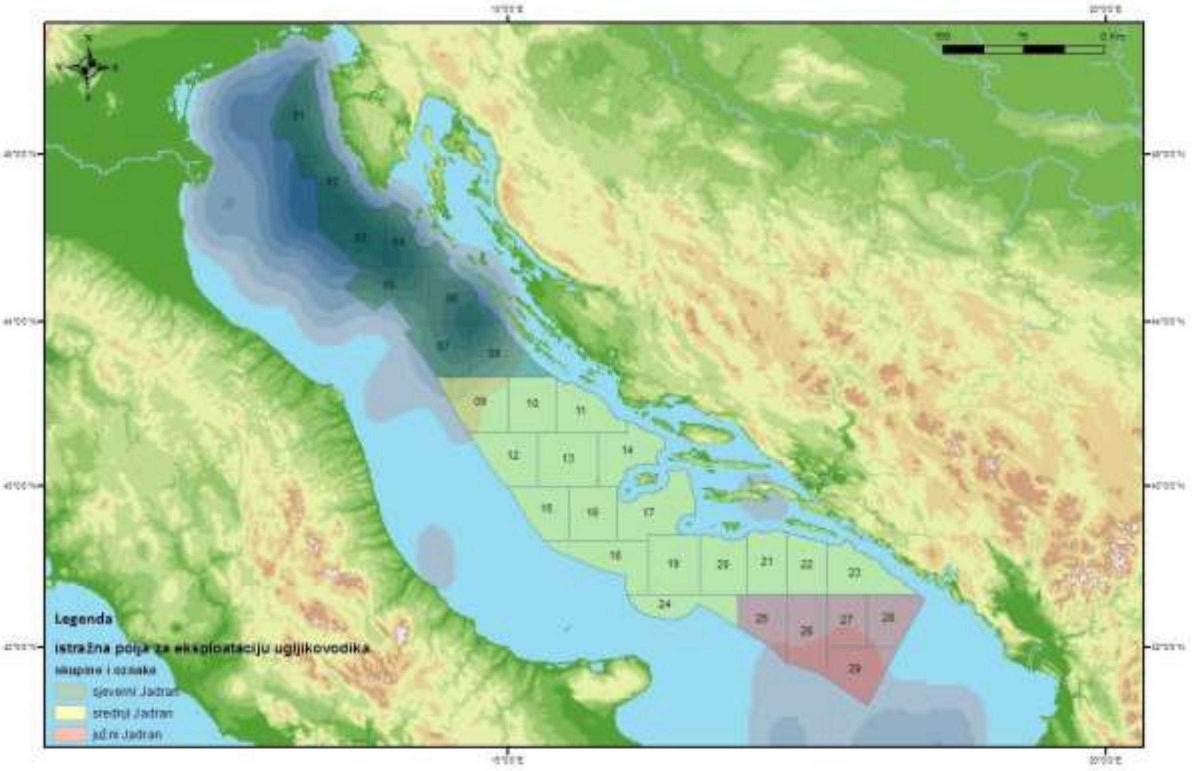
3.6.1.2 Sea turtles

3.6.1.2.1 Loggerhead sea turtle (*Caretta caretta*)

3.6.1.2.1.1 Distribution and Abundance

The loggerhead sea turtle is the most common species of sea turtles in the Mediterranean. This species' life cycle is complex, evident in the fact that it uses and switches different habitats 2003b; Casale et al. 2008). During its lifetime it changes its trophic status and position within marine organisms' food webs (Bjorndal et al. 1997; Bjorndal 2003). Adult females lay eggs on sandy beaches. Hatchlings enter the sea, where their distribution is affected by oceanographic features like gyre systems and oceanic fronts (Musick et al. 1997; Bolten 2003a). They spend the first period of their lives in the open sea regions (pelagic zone) and utilize epipelagic habitats as their feeding and developmental grounds. This period is known as the oceanic phase of juvenile turtles. After a few years, juvenile turtles go through the ontogenetic habitat shift so they leave pelagic habitats and start to inhabit neritic zones. They also start to feed predominantly on benthic prey (Bolten 2003a; Bolten 2003b). Tag-return studies showed that loggerhead turtles are in this period tied to neritic areas. Once settled in one area, the chance they will move to another neritic areas is very small (Casale et al. 2007). Neritic juveniles inhabit these areas until reaching sexually maturity, when they undertake reproductive migrations. After reproductive season is finished the females return to the neritic areas, which are probably the same ones they inhabited as juveniles (Limpus and Limpus 2001; Limpus and Limpus 2003). Adults also show strong fidelity to natal areas, which are the same where they were hatched (natal homing; (Bowen et al. 1993)).

The loggerhead turtle is also the most abundant sea turtle species in the Adriatic Sea, and the Adriatic is recognized as one of the most important foraging areas for the species in the Mediterranean basin (Casale and Margaritoulis 2010), as initially evidenced by bycatch records (Lazar and Tvrtković 1995; Casale 2011) and stranding records (Casale et al. 2010). Two loggerhead turtle aerial surveys were carried out recently, encompassing the entire Adriatic Sea (Fortuna et al. 2011b; Fortuna et al. 2013; Fortuna et al. 2014b; Fortuna et al. 2015). They provided information on distribution and abundance of sea turtles during the summer (Figure 3.61).



Glavata želva (Caretta caretta) - područje velike brojnosti - Izvor: ISPRA i BWI

Loggerhead sea turtle (Caretta caretta) – area of great abundance - Source: ISPRV and BWI

Legend: Hydrocarbon production blocks, groups and markings: northern Adriatic, central Adriatic, southern Adriatic.

Figure 3.61 Area of great abundance of the loggerhead turtle in the Adriatic (source: ISPRA and IPS, unpublished data): core density analysis, ARCGis algorithm (Fortuna et al. 2014b) and hydrocarbon blocks in the Adriatic (MINGO, 2014)

The estimation of abundance from the year 2010 yielded over 25,000 sea turtles (CV=21%) for the entire Adriatic Sea. The estimated number increases to over 70,000 animals when corrected for animal surface availability (time at surface vs. dive time; (Fortuna et al. 2015). However, it should be noted that the distance from the aeroplane to the sea surface limited the possibility to identify sea turtles smaller than 30-40 cm. Because of this reason it is necessary to additionally increase the number of animals, taking into consideration the differences in animal size and age as well (Fortuna et al. 2015). The data from the 2013 survey are still being analysed, but the presence of a large population in the Adriatic Sea can already be confirmed based on the collected data (Holcer and Fortuna, personal communication). The abundance estimation method by aerial surveying is limited, seeing as it is impossible to differentiate the two species occurring in the area. However, long-term ship-based research yielded a very low number of green sea turtle sightings (Chapter 3.6.1.2.2) as compared to loggerhead turtle sightings (Lazar et al. 2004a; Lazar et al. 2010), suggesting that population estimates above refer primarily to loggerhead turtles.

Temporal analysis of data shows that loggerheads are resident in the Adriatic throughout the year, but the spatial pattern of habitat use differs (Lazar 2009). A wide continental shelf of the northern and the central Adriatic Sea, with depths <200 m (Cushman-Roisin et al. 2001), rich benthic communities (Gamulin-Brida 1974; Kollmann and Stachowitsch 2001) and favourable temperature regimes during the summer (Supic and Orlic 1992) make this region one of the key neritic feeding habitats for loggerheads in the Mediterranean, shared by juveniles and adults (Lazar and Tvrtković 2003; Margaritoulis et al. 2003; Casale and Margaritoulis 2010; Lazar et al. 2011a). The importance of the northern Adriatic with depths <200m as a neritic habitat crucially important for loggerhead turtles was further proved by animal satellite tracking (Casale et al. 2012) and aerial survey results as well, with about 70% of sea turtle sightings deriving from this part of the Adriatic basin (Figures 3.61 and 3.56; (Fortuna et al. 2015)). Size-class and dietary analyses showed that the northern Adriatic was inhabited by small juveniles with carapace length of 25.0–30.0 cm, suggesting an early ontogenetic habitat shift to neritic habitats (Lazar et al. 2008a; Lazar 2009).

Diet composition analyses showed that benthic molluscs (Gastropoda and Bivalvia), decapod crustaceans (Crustacea: Decapoda), sea urchins (Echinoidea) and sea anemones (Cnidaria: Anthozoa) were the most common prey, making up 85.6% of their diet (Lazar et al. 2006a; Lazar 2009; Lazar et al. 2011a). The analyses of the exclusive and preferential species found in the diet pointed out six benthic communities loggerhead turtles use as feeding grounds: biocenosis of Posidonia oceanica meadow, biocenosis of infralittoral algae, biocenosis of coarse sands and fine gravels influenced by waves, biocenosis of well-sorted fine sands, biocenosis of coastal detritic seabeds and biocenosis of coastal terrigenous muds. Based on occurrence frequency of the characteristic prey species, four benthic communities are considered as the key neritic feeding habitats of loggerhead turtles in the Adriatic Sea: biocenosis of infralittoral algae, biocenosis of well-sorted fine

sands, biocenosis of coastal detritic bottoms, and biocenosis of coastal terrigenous muds (Lazar 2009). All of these communities are widely distributed throughout the northern and central Adriatic Sea (Bakran-Petricioli 2007).
Beside the importance of this area as a summer feeding ground, high bycatch rates of loggerhead turtles in bottom trawls during the winter also indicated a role of the northern and central Adriatic as a wintering habitat (Lazar and Tvrtković 1995; Lazar and Tvrtković 2003; Casale et al. 2004). Sea turtle bycatch in bottom trawls in the eastern Adriatic (Croatia, Slovenia) have been estimated at 2135 - 4334 captures per year (Lazar and Tvrtković 1995; Lazar et al. 2011b). Simultaneously, a study in the western Adriatic (Italy) established a rate of 4273 captures per year by the Italian trawling fleet operating in the northern Adriatic (Casale et al. 2004). The bottom-trawl bycatch in Croatian northern Adriatic was estimated at 2020–4239 captures per year (Lazar 2009). It was ascertained that the bottom trawl bycatch rate is increased during the "cold" (winter) season, with peak values in January and February period (Lazar 2009; Lazar et al. 2011b). It should be noted that the bycatch rates increase ten times as one moves from the colder western Adriatic (Italy) towards the east (0.043 vs. 0.701 catches per fishing day; (Casale et al. 2004)), which additionally indicates an important role of Croatian waters as a wintering habitat for loggerhead turtles. Analysis of bycatch data, verified by on-board observers, showed that the wintering habitats in Croatia are situated in fishing zones B and I, with sea temperatures of 11°C and depth between 45 and 85 m (Figure 3.62); (Lazar et al. 2003; Lazar and Tvrtković 2003; Lazar 2009; Lazar et al. 2011b).

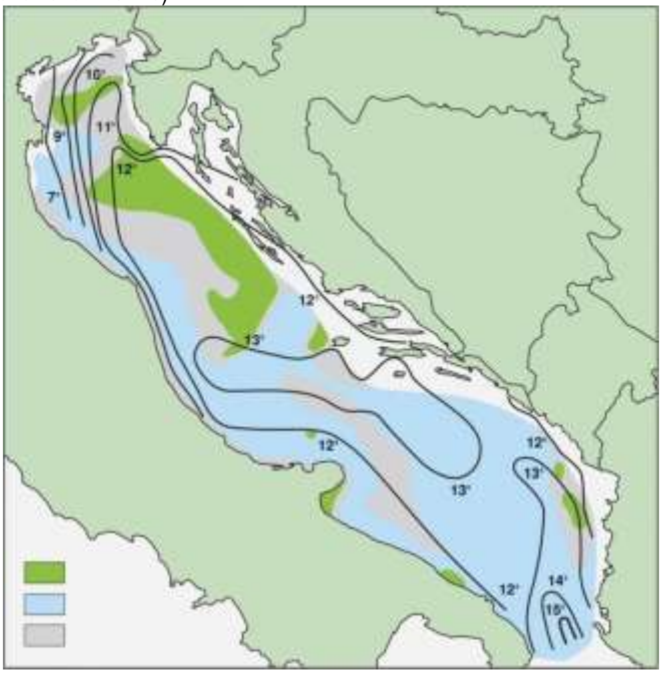


Figure 3.62 Distribution of sediments in the Adriatic Sea (modified according to Pigorini 1967) and winter isotherms (modified according to Buljan and Zore-Armanda 1971). The area with the highest bycatch of loggerhead turtles in bottom trawls is marked with rectangle (Lazar 2009).

On the other hand, oceanic zone of the southern Adriatic seems to be the developmental habitat for your sea turtles still in the pelagic phase, confirmed by sea turtle distribution analysis according to size categories and tag-recovery data (Casale et al. 2005; Casale et al. 2007), as well as post-hatching dispersal simulations (Casale and Mariani 2014). However, data from that region are lacking.
As a region with dynamic sea temperature regimes, shared by juveniles and adults, the Adriatic Sea is an area with different patterns of loggerhead turtle movement. Three types of movement patterns have been observed in the Adriatic: the best documented and most obvious one is the adult breeding migration from foraging to breeding grounds and vice-versa (Hays et al. 2010a; Hays et al. 2010b) (Schofield et al. 2009; Schofield et al. 2010; Schofield et al. 2013) (Zbinden et al. 2008; Zbinden et al. 2011). The second type of movement, with a less obvious pattern, but with a growing body of evidence, is seasonal migration. Satellite tracking of both adults (Zbinden et al. 2011) and juveniles (Casale et al. 2012) indicate movements from the northern Adriatic towards the southern when sea temperatures drop in the winter months. This movement is characterized by a lower occurrence of turtles in the northernmost part of the Adriatic Sea during winter (Lazar et al. 2003). However, there is evidence from bycatch (Casale et al. 2004) and stranding records (Casale et al. 2010) that at least some loggerhead turtles frequent the wider northern Adriatic area during winter as well. Furthermore, one satellite-tracked turtle was observed in the northernmost part of the Adriatic (Gulf of Trieste) (Casale et al. 2012) which is the coldest part of the Mediterranean during winter, with low temperatures (below 11–12°C). It was thought that low temperatures induced turtles to leave this area and migrate to the south (Lazar et al. 2003). The capacity of loggerhead turtles to maintain some level of activity in comparable or somewhat higher temperature conditions is known (min. 11.8°C; (Hochscheid et al. 2007). The third type of movement is erratic, because sea turtles dwell in areas of various sizes which

may be as large as certain parts of the Adriatic Sea (Casale et al. 2012). Despite a relatively large number of sea turtles whose movements have been tracked, showing how some animals display site-fidelity to specific feeding areas, the number of marked animals whose movements are known is still insufficient to identify sub-areas with more frequent animal occurrence. However, for both breeding and seasonal migrations, most of the observed routes were along the western and eastern coasts of the Adriatic Sea (Casale et al. 2012) (Hays et al. 2010a; Hays et al. 2010b) (Schofield et al. 2009; Schofield et al. 2010; Luschi et al. 2013; Schofield et al. 2013) (Zbinden et al. 2008; Zbinden et al. 2011), suggesting that these may be considered as migratory corridors.

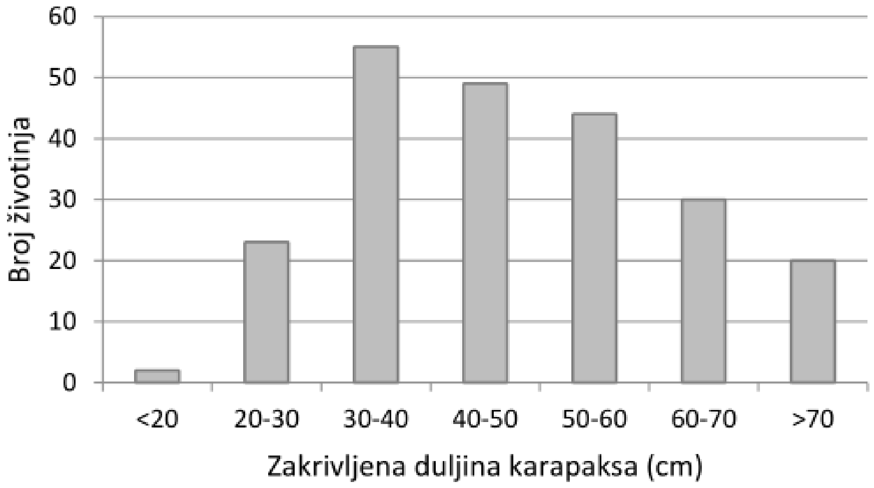
3.6.1.2.1.2 Population Structure

The Adriatic Sea is a habitat shared by juvenile and adult loggerheads of both sexes (Table 3.19). The mean size (CCL) of loggerheads in the eastern Adriatic is 47.4 ± 15.6 cm (N = 223), with CCL range between 8.5 and 88.5 cm. The majority of records (90.1%) refer to juvenile turtles (<70 cm CCL), while adults (>70 cm CCL) were referred to in only 8.9% (Figure 1; (Lazar 2009)).

Table 3.19 Sex ratio of loggerhead turtles as determined by the visual examination of gonadal gross-morphology [CCL – Curved Carapace Length, mean ± SD (min. - max.); from Lazar 2009]

	CCL (cm)	N	Gonad morphology			
			Males	Females	Unknown	% of females
Pelagic phase juveniles (CCL ≤ 40 cm)	33.7 ± 4.1 (25.0 – 40.0)	36	9	24	3	72.7
Neritic phase juveniles (CCL = 40 - 70 cm)	54.1 ± 12.4 (40.1 – 84.5)	34	18	16	0	47.1
Adults (CCL >70 cm)	76.9 ± 6.9 (70.0 – 84.5)	5	1	4	0	80.0
Total	44.3 ± 13.9 (25.0 – 84.5)	75	28	44	3	61.1

Seeing as breeding that occurs in the Adriatic is very limited and sporadic (Mingozzi et al. 2008), almost all specimens frequenting the Adriatic Sea immigrate from other rookeries. Genetic markers indicated that the main origin of these animals is Greece (Lazar et al. 2007; Lazar 2009; Garofalo et al. 2013), which hosts the largest European nesting aggregation of loggerhead turtles. From Greece, small sea turtles probably disperse into the Adriatic Sea in the first period of their lives, as suggested by post-hatching dispersal simulations (Casale and Mariani 2014), or later from the oceanic developmental habitats in the Ionian Sea, as suggested by capture-mark-recapture data (Casale et al. 2007).



Number of animals / Curved carapace length (cm)

Figure 3.63 Size-class distribution of loggerhead turtles in the northern and central Adriatic Sea (N = 223; from Lazar 2009)

The Greek origin hypothesis of loggerhead turtles in the Adriatic Sea is further supported by the movements of individual adult females between nesting sites in Greece and foraging grounds in the Adriatic, also reported by capture-mark-recapture methods (Lazar et al. 2004b) and satellite tracking (Schofield et al. 2013). Turkey and Cyprus are the origins of a lower number of sea turtles (Lazar et al. 2004b; Lazar et al. 2007; Lazar 2009). If natal origin and abundance estimates of loggerheads are considered, the Adriatic Sea hosts the most extensive and the most important critical marine habitats for EU populations of this species.

3.6.1.2.1.3 Anthropogenic Threats and Conservation Status

Recognized anthropogenic threats to sea turtles in the Adriatic Sea include fishing interactions (bycatch), boat collisions and pollution (Lazar and Tvrtković 1995; Lazar et al. 2006c; Lazar et al. 2007; Lazar 2009; Lazar 2010a; Lazar et al. 2011b) (Casale et al. 2004; Casale et al. 2010; Casale 2011; Lazar et al. 2011c).

Mortality caused by fishing is by far the most severe threat to loggerhead turtles in the Adriatic Sea, with several thousand of incidentally caught turtles every year (Lazar and Tvrtković 1995; Casale et al. 2004; Lazar et al. 2006c; Lazar 2009; Casale et al. 2010; Lazar 2010a; Casale 2011). Minimal bycatch estimates for bottom trawling in the northern Adriatic range between 6400 and 6800 captures per year (Lazar 2009; Casale 2011; Lazar et al. 2011b), with at least 2020 (Lazar 2009) to 2400 (Casale 2011) captures per year occurring in Croatian territorial waters. The mean curved carapace length (CCL) of captured turtles by Croatian bottom trawling fleet was 54.0 ± 15.4 cm (range: 20.0 – 89.0 cm, N = 91), with the majority of animals (64.8%) belonging to larger size classes (> 50 cm CCL; (Lazar 2009)). Direct mortality have been estimated at 7.5%, with additional 19.4% turtles captured comatose, suggesting the total (potential) mortality of 26.9% (Lazar 2009; Lazar et al. 2011b). The study by (Casale et al. 2004) gave even higher mortality estimates for bycatch of the Italian trawling fleet operating in the northern Adriatic, with direct mortality of 9.4% and potential mortality of 43.8%.

Another fishery with concerning impact on loggerhead turtles in the Adriatic is the gill net (static net) fishery. Gillnet bycatch in the northern Adriatic (Croatia and Slovenia) was conservatively estimated at 468 to 658 captures per year (when catch per unit effort is extrapolated to fishing effort of gillnetters only), with direct mortality of 74%. The majority of sea turtles were captured by fishermen from the Croatian fleet (89%; Lazar et al. 2006b, Lazar 2009, 2010b). Gillnet bycatch estimate by (Casale 2011) for Croatian Adriatic Sea was 700 captures per year. However, if catch per unit effort is extrapolated to fishing efforts of multi-use vessels as well, the total bycatch of gillnet fishery in the northern Adriatic may potentially be as high as 2874 to 4035 captures per year (Lazar 2009). Smaller sea turtles do interact with gillnets (40.4 ± 11.9 cm CCL) and bycatch is positively correlated with the warm period of the year (Lazar et al. 2006c; Lazar 2009; Lazar 2010a).

Lesions on carapace of loggerhead turtles, which may be ascribed to collision with boats, have been recorded in 7.8% specimens found floating or stranded in the northern Adriatic, and in 7.5% turtles in the southern Adriatic Sea. The proportion of collisions in spring and summer was twice that in the cold season, with Adriatic and Tyrrhenian Sea identified as the areas with the highest occurrence of collisions (Casale et al. 2010).

The impact of pollution was assessed as the occurrence of oil/tar and ingested marine debris within the population, and as the tissue contamination levels in the case of organochlorines and metals. Tar was found in 3.6% out of 467 turtles found floating or stranded in the southern Adriatic, and in 0.1% out of 1453 loggerhead turtles from the northern Adriatic Sea (Casale et al. 2010). (Lazar and Gračan 2011) examined the occurrence of marine debris in the gastrointestinal tract of 54 loggerhead turtles from the Adriatic Sea, and have found marine debris present in 35.2% of sea turtles. Recorded debris included soft plastic, ropes, Styrofoam and fishing lines, which were found in 68.4%, 42.1%, 15.8% and 5.3%, respectively, of loggerhead turtles that have ingested debris.

Ecotoxicological studies pointed out a high concentration of Hg and Cd in tissues, which were the highest recorded among all sea turtle species worldwide (Hg in kidney and pectoral muscles), or the highest recorded in Mediterranean loggerhead turtles (renal Cd; (Lazar et al. 2007)). Likewise, the maximum concentration of PCB-153 (1358 ng/g wet mass) found in an adult loggerhead turtle female (CCL = 84.5 cm) from the Adriatic Sea was the highest concentration of this congener reported so far. This relatively non-toxic congener is highly resistant to metabolic breakdown. It passes through the food web relatively unchanged, dominating over other PCBs in animal tissues. This makes it a good congener for comparing relative differences in PCB concentrations among different populations (Pugh and Becker 2001). When using PCB-153 for sample comparison, PCB burdens in loggerhead turtles from the eastern side of the Adriatic Sea are the highest detected in recent years (Lazar et al. 2011c). Similarly, the total DDT levels detected in fat tissue samples from Adriatic loggerhead turtles were almost two times higher than recently recorded in the western Atlantic ((Lazar et al. 2011c) and references therein). However, despite high levels of organochlorines and metals recorded in Adriatic loggerhead turtles and possible sub-lethal effects, there is no clear evidence that contamination directly caused the death of any turtle (Lazar et al. 2007; Lazar et al. 2011c).

The impact of disturbances and habitat degradation by mobile fishing gear and by the methods applied in research and exploitation of hydrocarbons in the Adriatic Sea have not yet been assessed.

3.6.1.2.2 Green sea turtle (*Chelonia mydas*)

3.6.1.2.1.4 Distribution and Abundance

The life cycle of the green sea turtle is similar to the development pattern of the loggerhead turtle. The animal spends its early juvenile phase in the oceanic zone and later moves to near shore neritic waters (Bolten 2003b). This ontogenetic habitat preference shift is accompanied by a change in the diet. Animals which were epipelagic omnivores or carnivores during the oceanic juvenile phase develop a strong tendency for a herbivore diet in the neritic phase (Hirth 1971; Bjorndal et al. 1997). The move to neritic habitats in green turtles generally occurs when the animals are still small, with a carapace length between 30 and 40 cm (Bjorndal and Bolten 1988; Musick et al. 1997). The oceanic phase lasts for one to 10 years (Mortimer 1982). Age at sexual maturity is estimated at 26 to 40 years (Limpus and Chaloupka 1997), after which they commence breeding migrations between foraging grounds and nesting areas, undertaken every few years (Hirth 1971). During non-breeding periods adults reside at coastal neritic feeding areas which they sometimes share with developing juveniles (Limpus et al. 1994; López-Mendilaharsu et al. 2005; Carrion-Cortez et al. 2010), and for which they exhibit strong site fidelity (Broderick et al. 2007).

In the Mediterranean Sea green turtles form a genetically distinct population (Bowen et al. 1992), which has suffered heavy exploitation over the past century (Sella 1995). The main nesting sites are situated in Turkey, Cyprus and Syria. The whole Mediterranean green turtle population numbers between 1116 and 1185 nesting females, which lay eggs 1.9–3.5 times per reproductive season, with breeding occurring every three years (Broderick et al. 2002; Rees et al. 2008).

Data on the biology and distribution of green turtles in marine habitats of the Mediterranean Sea is lacking. Post-nesting satellite tracking of adult females indicated the importance of the African continental shelf (Israel, Egypt, Libya) and Cyprus as important neritic foraging and wintering habitats for adults (Godley et al. 2002; Broderick et al. 2007). Juvenile green turtles have been recorded throughout the Mediterranean Sea, but the locations of developmental habitats are not clearly defined. Their existence have been documented only in the eastern part of the Mediterranean Sea, in Lakonikos Bay on the Peloponnesus, Greece (Margaritoulis and Teneketzis 2001), in the waters off the Fethiye beach in Turkey (Turkozan and Durmus 2000), and along the south-eastern coast of Turkey, near Syria (Yalçin-Özdilek and Aureggi 2006).

Based upon size class distribution, (Lazar et al. 2004a) hypothesized about the possible role of the southern part of the Adriatic Sea as a pelagic habitat for green turtles in the Mediterranean Sea. The number of green turtle sightings in the Adriatic Sea is low in comparison to loggerhead turtle sightings (Lazar and Tvrtković 1995; Pastorelli et al. 1999; Lazar et al. 2004a; Haxhiu and Rumano 2005). This is the consequence of a small and depleted population of reproductively active females (Broderick et al. 2002) and possible misidentification of juvenile green sea turtles as loggerhead turtles (Lazar et al. 2004a), as well as of possible preferences of turtles for the warmer waters of the southern part of the Mediterranean Sea. Regardless, the sightings of juvenile green sea turtles in Albania (Haxhiu and Rumano 2005; Haxhiu 2010), together with the discovery of a developmental habitat in the Ionian Sea (Margaritoulis and Teneketzis 2001), suggest the existence of an Ionian-Adriatic connection, i.e. corridor used by juvenile green sea turtles to come from nesting sites in the eastern Mediterranean Sea, most likely greatly influenced by prevailing sea currents (Lazar 2010a). Therefore, it is possible that the southern Adriatic hosts developmental habitats for this species (Lazar et al. 2004a; Lazar 2010a), but detailed information on distribution and abundance are lacking.

3.6.1.2.2.1 Population Structure

Very little is known about the population structure of green sea turtles in the Adriatic Sea. Size class distribution analysis of green sea turtle findings in Croatia and Italy showed that majority of records refer to juvenile turtles with carapace length between 25 and 50 cm (Lazar et al. 2004a). This is in accordance with recent data from Albania, where green sea turtles captured in the Patok Bay measured <50 cm in carapace length (Haxhiu and Rumano 2005; Haxhiu 2010). Margaritoulis and Teneketzis (2001) reported the mean size of 36.4 cm CCL (range = 30.0–67.0 cm) for green sea turtles in Lakonikos Bay on the Peloponnesus, Ionian Sea.

3.6.1.2.1.5 Anthropogenic threats and conservation status

Green sea turtles are exposed to the same anthropogenic threats as loggerhead turtles, which include bycatch mortality, possible boat collisions and effects of pollution. However, no quantification data on threats exist for the Adriatic Sea.

3.6.1.2.2 Leatherback sea turtle (*Dermochelys coriacea*)

3.6.1.2.2.1 Distribution and Abundance

The leatherback sea turtle has the widest distribution of all reptiles and is a species which inhabits marine environments worldwide. Colonies of nesting females can be mainly found in the tropics, but they regularly utilize temperate seas during trans-oceanic journeys (Hays et al. 2004; James et al. 2005). With the exception of the reproductive season, this species spends its entire life in the open oceans (Bolten 2003b) feeding upon pelagic invertebrates (Bjorndal et al. 1997).

Leatherback sea turtles regularly enter the Mediterranean Sea, most likely originating from Atlantic populations (Casale et al. 2003). Although smaller in number, this species has also been recorded in the Adriatic Sea, with most findings deriving from the southern Italian coast (Casale et al. 2003). In the eastern part of the Adriatic Sea, leatherbacks have been recorded in Albania (Haxhiu 1995), Montenegro, and Croatia (Lazar and Tvrtković 1995). (Lazar et al. 2008b) reviewed the occurrence of leatherback sea turtle in the Adriatic Sea by consulting museum collections, published literature and new sighting records. The largest numbers of these animals (70.4%) were found in the summer, in the oceanic zone of the southern Adriatic (63.3%). The number of sightings in this sub-basin represents 4.5% of the recorded animals in the entire Mediterranean Sea (Casale et al. 2003; Lazar et al. 2008b). Comparing the size of this area to the entire area of the Mediterranean Sea, the occurrence of the leatherback sea turtle in the south Adriatic basin is up to

1.5 times higher than the values recorded in the entire Mediterranean Sea. That suggests possible relevance of the southern Adriatic Sea as a summer foraging habitat for leatherback sea turtles within the Mediterranean (Lazar et al. 2008b).

The distance from the Atlantic Ocean is considered to be one of the factors determining leatherback sea turtle distribution in the Mediterranean Sea (Casale et al. 2003), thus fewer sightings can be expected in the distant northern Adriatic waters. Furthermore, the southern part of the Adriatic Sea is much deeper (maximum depth of 1330 m) than the northern and central Adriatic (maximum depth of 273 m) and can be considered an oceanic zone (Holcer et al. 2007b). Leatherback sea turtles are known to go through a developmental phase connected to the oceanic zone, where both juvenile and adult animals may be found (Bolten 2003b). Therefore, a higher number of sightings in the southern Adriatic may also be explained by the species' preference for pelagic habitats, rather than shallow areas.

3.6.1.2.2.2 Population Structure

Size-class analysis, based on data on carapace length of leatherback sea turtles recorded in the Adriatic Sea, showed that most animals were large immatures and adults of both sexes, with carapace length >120 cm (Casale et al. 2003; Lazar et al. 2008b). Based on the size-class analysis, (Eckert 2002) suggested that leatherback sea turtles spend their early juvenile stage (before reaching CL of over 100 cm) in tropical waters, probably because of temperature regulation constrains. Immigrations into the Mediterranean and Adriatic Seas thus take place in late juvenile and/or adult stage, most likely for feeding reasons (Casale et al. 2003).

3.6.1.2.2.3 Anthropogenic Threats and Conservation Status

No specific data on the impact of anthropogenic threats on leatherback sea turtles in the Adriatic Sea exist. However, the majority of Mediterranean leatherback sea turtle sightings relate to animals accidentally caught by various fishing gear, with a significant number of instances resulting in mortalities. Highest mortality rates were documented in gillnets (at least 36.0%, (Casale et al. 2003)). Based on low catch per unit effort (CPUE) of leatherback sea turtles in the Mediterranean Sea in comparison to the Atlantic, (Casale et al. 2003) determined bycatch in Mediterranean fisheries to have an negligible impact on the population. Conversely, (Lewison et al. 2004) estimated that just longline fishery bycatch of leatherback sea turtles in the Mediterranean Sea may range from 250 up to 10,000 animals per year.

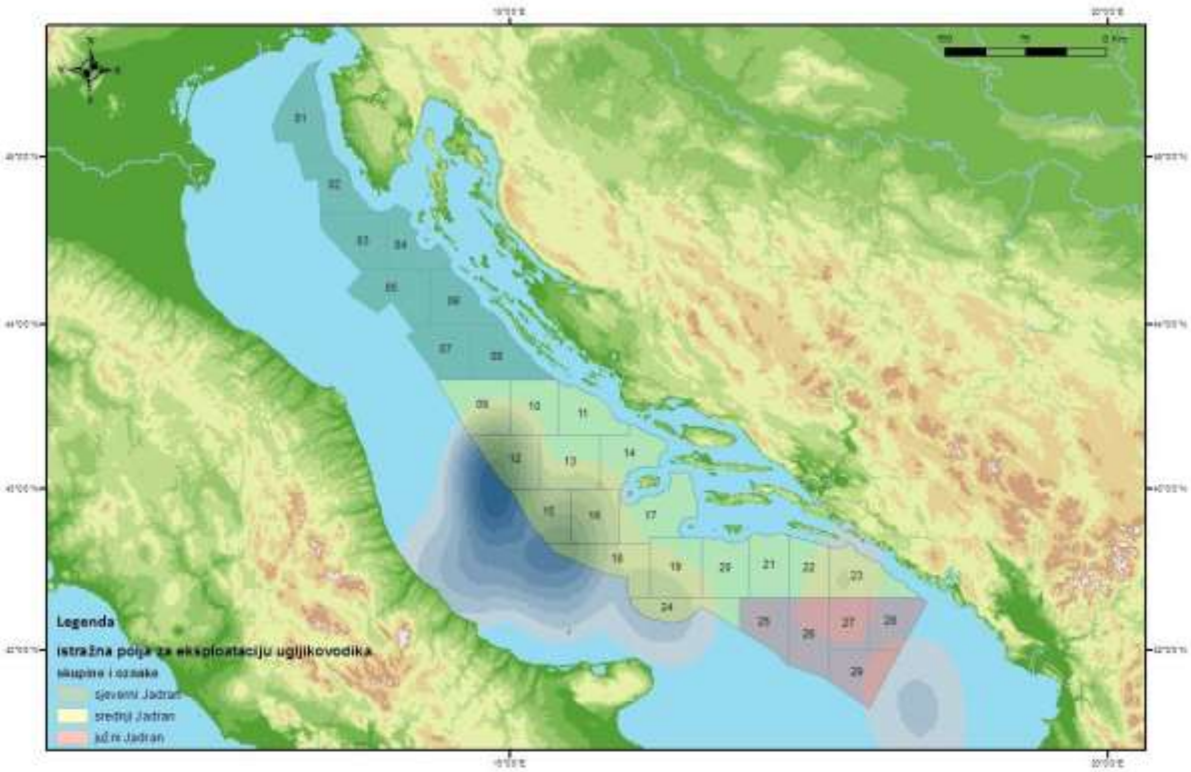
Atlantic nesting sites are natal areas for animals which immigrate into the Mediterranean Sea, which are stable or their status is improving (Chevalier et al. 2000; Dutton et al. 2000; Dutton et al. 2005). Despite the low CPUE, the problem of leatherback sea turtle bycatch in the Mediterranean Sea should not be neglected for two reasons. First, large immatures and adults, which have the highest reproductive potential, are the most frequent casualties. Second, it is still unknown to which natal population (or populations) Mediterranean leatherback sea turtles belong. Even if they originate from the same population, fishery impact could be an obstacle for efficient conservation, depending on population size and trends (Lazar et al. 2008b).

3.6.2 Fish

3.6.2.1 Cartilaginous Fish

There are 84 cartilaginous fish species recorded in the Adriatic Sea (Serena and Barone 2009). Ferretti et al. (2013) studied the decline of cartilaginous fish in the Adriatic Sea using trawling data and found that sharks have declined by 95% and rays by nearly 88% since the 1950s. Eleven species are no longer considered to be a regular part of the Adriatic fauna. The research in question suggest that a precautionary principle should be applied when the impact on cartilaginous fish in the Adriatic Sea is assessed seeing as this group could be sensitive to the introduction of new environmental stressors. In the Adriatic Sea a total of 49 shark species (Selachimorpha superorder), 34 batoid ray species (Batoidea superorder) and one species belonging to the Chimaeriformes order (the rat fish) have been recorded (Serena and Barone 2009). Bycatch rates of non-commercial cartilaginous fish by pelagic trawlers working in pairs, operating in the northern and central Adriatic, are worrisome (Fortuna et al. 2010).

Aerial surveys carried out in 2010 and 2013 provided some insight into the distribution of large marine vertebrates in the Adriatic Sea, including several shark and ray species. In 2010, a total of 68 sightings of species from the Myliobatiformes order were recorded. In 42 of these sightings, the species observed was the giant devil ray (*Mobula mobular*) (Figure 3.64).



Golub uhan (Mobula mobular) - područje velike brojnosti - Izvor: ISPRA i BWI

Giant devil ray (Mobula mobular) – area of great abundance - Source: ISPRV and BWI
Legend: Hydrocarbon production blocks, groups and markings: northern Adriatic, central Adriatic, southern Adriatic.

Figure 3.64 Area of great abundance of the giant devil ray in the Adriatic (source: ISPRA and IPS, unpublished data): core density analysis, ARCGis algorithm (Fortuna et al. 2014b) and hydrocarbon blocks in the Adriatic (MINGO, 2014)

After analysis the population estimate for M. *mobular* was 3255 animals (CV= 0.56) (Fortuna et al. 2014a). **Table 3.20 Sharks, Batoids and Chimeria species recorded in the Adriatic Sea (according to Serena and Barone (2009))**

ORDER	FAMILY	SPECIES
HEXANCHIFORMES	HEXANCHIDAE	*Heptranchias perlo*
		Hexanchus griseus
SQUALIFORMES	ECHINORHINIDAE	*Echinorhinus brucus*
	SQUALIDAE	*Squalus acanthias*
		Squalus blainvillei
	ETMOPTERIDAE	*Etmopterus spinax*
	OXYNOTIDAE	*Oxynotus centrina*
	DALATIIDAE	*Dalatias licha*
SQUATINIFORMES	SQUATINIDAE	*Squainta oculata*
		Squatina squatina
LAMINFORMES	ODONTASPIDIDAE	*Carcharias Taurus*
		Odontaspis ferox
	ALOPIIDAE	*Alopias vulpinus*
	CETORHINIDAE	*Cetorhinus maximus**
	LAMNIDAE	*Carcharodon carcharias**
		Isurus oxyrinchus
		Lamna nasus
	SCYLIORHINIDAE	*Galeus melastomus*
		Scyliorhinus canicula
		Scyliorhinus stellaris
	TRIAKIDAE	*Galeorhinus galeus*
		Mustelus asterias
		Mustelus mustelus
		Mustelus punctulatus
	CARCHARHINIDAE	*Carcharhinus plumbeus*
		Prionace glauca
	SPHYRNIDAE	*Sphyma zygaena*
CHIMAERIFORMES	CHIMAERIDAE	*Chimaera monstrosa*

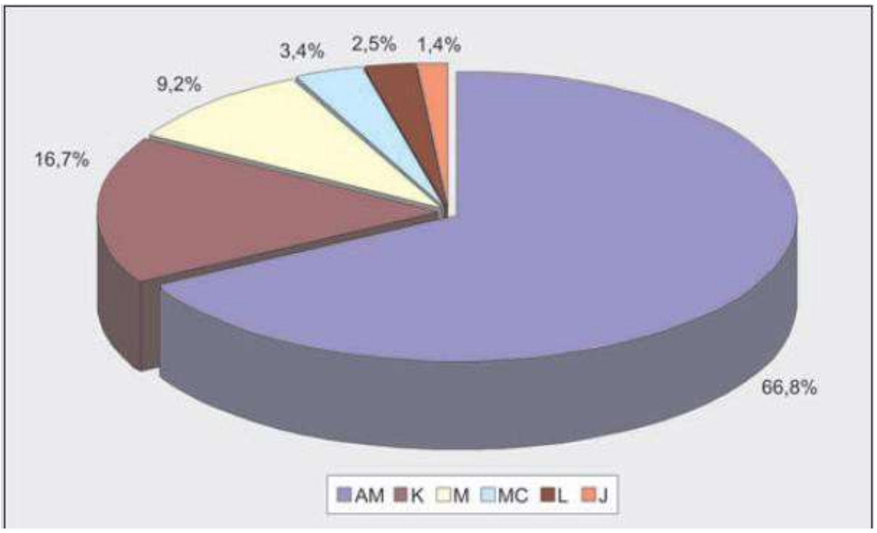
RAJIFORMES	PRISTIDAE	*Pristis pectinata*
	RHINO BATIDAE	*Rhinobatos rhinobatos*
	TORPEDINIDAE	*Torpedo marmorata*
		Torpedo nobiliana
		Torpedo torpedo
	RAJIDAE	*Dipturus batis*
		Dipturus oxyrinchus
		Leucoraja circularis
		Leucoraja fullonica
		Raja asterias
		Raja clavata
		Raja miraletus
		Raja polystigma
		Raja radula
		Raja undulate
		Rostroraja alba
	DASYATIDAE	*Dasyatis centroura*
		Dasyatis pastinaca
		Pteroplatytrygon violacea
	GYMNURIDAE	*Gymnura altavela*
	MYLIOBATIDAE	*Myliobatis Aquila*
		Pteromylaeus bovinus
	MOBULIDAE	*Mobula mobular**
** protected by Croatian laws*		

As part of the survey, a group of four giant devil rays was observed north-east of the Otranto strait. Three animals had an estimated disc width (DW) of about 3 m and one appeared to be smaller. Animals were observed for about 6 minutes, swimming in anticlockwise circles. During this observation, the smaller animal was swimming belly-first towards a larger one, which behaved in the same manner. During this both animals circled and flipped over in a column of water. Such behaviour in species from the Myliobatiformes order is usually associated with courtship and mating (Tricas 1980; Yano et al. 1999). Further research is necessary for this area to be potentially recognized as important for mating, growth and development, and also feeding, seeing as currently available data are not sufficient for making such conclusions.
There is little information available regarding the distribution of basking sharks and great white sharks in the Adriatic Sea. Since the 19th century only 61 sightings of the great white shark and 27 sightings of the basking shark were recorded in the eastern part of the Adriatic Sea (Soldo and Jardas 2002). De Maddalena (2000) collected data on 79 confirmed sightings and a total of 83 animals, found in the Italian great white shark database, concerning the period from 1887 to 1999. The latest record of a great white shark's presence in the Adriatic was made in 2003, when one animal was captured in a purse seine net in the central Adriatic (Soldo and Dulčić 2005). Basking sharks are considered to be a rare, but constantly present species in the Adriatic Sea with 13 recorded sightings between 2000 and 2002 (Soldo et al. 2008). Carlucci et al. (2014) reported 15 sightings and two incidental catches of the basking shark in the north-western Ionian Sea and the Adriatic Sea between 2011 and 2014, of which 3 sightings were recorded in the southern part of the Adriatic Sea.

3.6.2.2 Osteichthyes (bony fish)

Fish are the most divers, the most numerous and the most widely geographically distributed group of vertebrates on Earth and as such are considered to be an important part of biodiversity. Conversely, they are also the most endangered group of vertebrates because of their economic significance. Around 440 species have been recorded in the Adriatic Sea, making up for around 65% of the known fish species in the Mediterranean Sea. This makes the Adriatic one of the richer seas. This great biodiversity was enabled by numerous geological, geographical, climatological and biological conditions.

Amongst species and subspecies of fish recorded up to now in the Adriatic, the most numerous biogeographical elements are: the Atlantic-Mediterranean element (almost 67%), followed by the Cosmopolitan element, including species and subspecies of another wider geographical distribution (almost 17%) and the Mediterranean (endemic) element (slightly over 9%). Other biogeographical ichthyofauna elements, like the Mediterranean-Black Sea, Lessepsian and Adriatic (endemic) elements are sparse in the Adriatic ichthyofauna (making up a combined total of slightly over 7.3%), Figure 3.65.

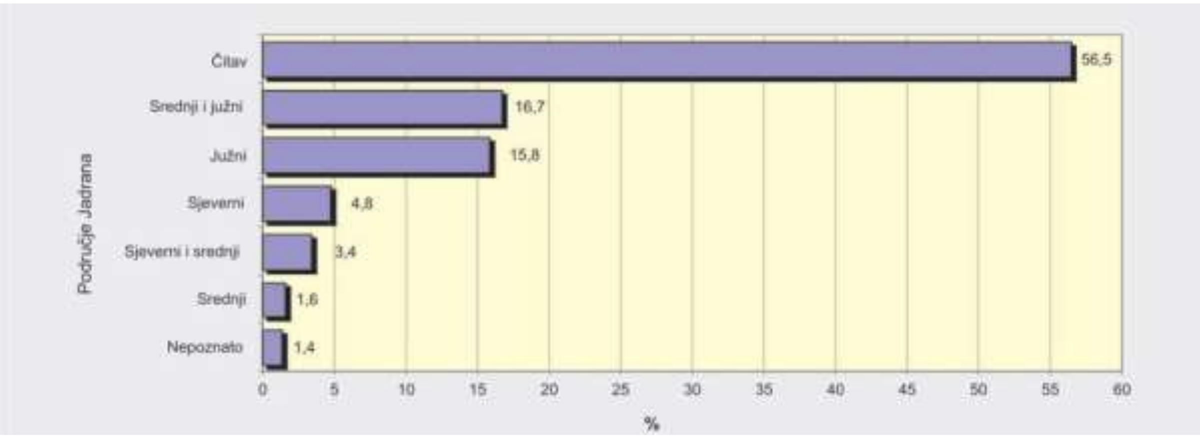


AM=AM; K=C; M=M; MC=MB; L=L; J=A

Figure 3.65 Presence of biogeographical ichthyofauna elements in the Adriatic ichthyofauna: AM - Atlantic-Mediterranean, Cosmopolitan and other widely distributed species, M - Mediterranean, MB - Mediterranean-Black Sea, L - Lessepsian and A - Adriatic species (source: Jardas, I et al. 2008)

The greatest number of species of fish are those distributed throughout the whole of the Adriatic (247 or 56.5%), followed by species recorded in the central and southern Adriatic (73 or 16.7%), and then those recorded only in the southern Adriatic (69 or 15.8%). The number of species which have so far been recorded only in the northern, central or northern and central Adriatic is significantly smaller (for about 43 or 9.8%). There are only 5 species for which Adriatic localities are unknown. Figure 3.66 shows the number of recorded species and subspecies of fish in specific parts of the Adriatic Sea. The number of fish species drops when one moves from the southern to the northern Adriatic. Around 89% of species of fish have been recorded in the southern Adriatic, around 78% in the central and around 65% in the northern Adriatic.

According to environmental affiliation and horizontal distribution of fish, the southern Adriatic is generally characterised by a greater presence of thermophilic and bathyphilic species, while the northern Adriatic is characterised by a greater presence of boreal species, or at least by a greater abundance of that species. In that respect, the central Adriatic acts as a transit area (Jardas, 1983).

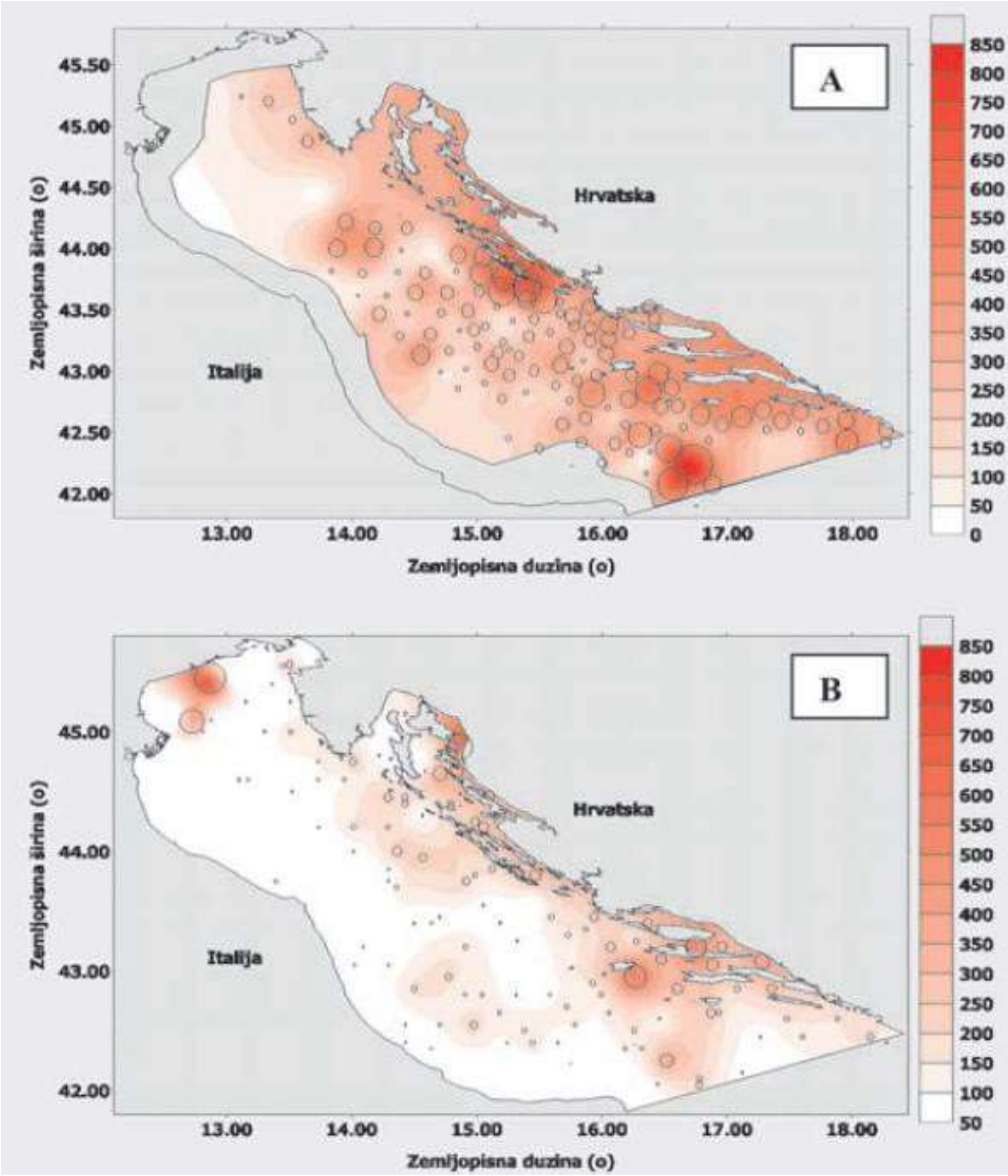


Adriatic area (top to bottom): whole; central and southern; southern; northern; northerb and central; central; unknow.

Figure 3.66 Percentage of recorded species and subspecies of fish in specific geographic parts of the Adriatic Sea (source: Jadras, I et al. 2008)

A large number of open and coastal sea fish populations are today sparse due to long-term, senseless exploitation. A constant drop in catch numbers has been recorded in areas which have been more intensely surveyed up to now, like Kornati, Split area, islands of central Dalmatia, Palagruža and the southern Adriatic. In other words, most of the central and the entire southern Adriatic.

The "Hvar" expedition, organized in 1948/49 with the goal of assessing the size of Adriatic demersal settlements and the possibilities of their sensible exploitation, is considered to be the beginning of systematic research (Šoljan, 1977). The great value of this expedition comes from the insight it gave into resources of the Adriatic Sea, before those conditions were changed by intensive fishing. In fact, modern trawling was just getting started then (Kotthaus and Zei, 1938; Zei, 1940, 1942, 1949; Šoljan, 1942; Zei and Sabioncello, 1940). Therefore, settlement status during the "Hvar" expedition can be considered a baseline and may today be used as a reference point for estimating changes which occurred as a consequence of subsequent fishing. The comparison of data collected during the "Hvar" expedition and recent international research covering the entire Adriatic Sea (EU MEDITS3, FAO Adria Med4) warns of very negative changes which have occurred in the settlements as a consequence of half a century of intensive exploitation, Figure 3.67.



Zemljopisna širina = latitude; zemljopisna dužina = longitude. Hrvatska = Croatia; Italija = Italy.

Figure 3.67 Biomass distribution of species commercially important for trawling during the "Hvar" expedition, 1948/49 (A) and during the 1996/2006 period (B), (source: Jardas, I et al. 2008)

During expeditions undertaken between 1996 and 2007, 86 species of bony fish were caught by bottom trawlers in the open central Adriatic area.

Table 3.21 List of caught bony fish by abundance (N/km2) and biomass (kg/km2) indexes, source: Institute of Oceanography and Fisheries, 2009

Osteichthyes (bony fish)	N/km^2	kg/km^2	Osteichthyes (bony fish)	N/km^2	kg/km^2
Acantholabrus palloni	2.70	0.05	*Phycis phycis*	0.85	0.01
Alosa fallax	2.48	0.54	*Polyprion americanum*	0.33	0.91
Antonogadus megalokynodon	24.11	0.21	*Pomatoschistus minutus*	3.81	0.01
Aphia minuta	5.69	0.01	*Psetta maxima*	0.95	2.70
Argentina sphyraena	50.00	0.41	*Sardina pilchardus*	11.83	0.47

Arnoglossus laterna	70.69	0.21	*Scomber japonicus*	2.22	0.49
Arnoglossus rueppelli	32.58	0.06	*Scomber scombrus*	2.19	0.19
Arnoglossus thori	4.20	0.04	*Scorpaena elongata*	0.47	0.06
Aspitrigla cuculus	139.66	1.36	*Scorpaena notata*	1.61	0.03
Blennius ocellaris	2.22	0.03	*Scorpaena porcus*	0.71	0.04
Boops boops	14.55	1.15	*Scorpaena scrofa*	0.74	0.01
Buglossidium luteum	1.61	0.02	*Serranus cabrilla*	1.03	0.04
Callionymus maculatus	43.07	0.15	*Serranus hepatus*	110.86	1.29
Callionymus risso	15.20	0.03	*Sphyraena sphyraena*	0.74	0.01
Capros aper	4.87	0.02	*Spicara flexuosa*	2.75	0.09
Cepola rubescens	202.35	2.66	*Spicara maena*	0.92	0.09
Citharus linguatula	31.78	0.50	*Spicara smaris*	8.36	0.28
Chlorophthalmus agassizii	1.77	0.01	*Sprattus sprattus*	1.28	0.04
Coelorhynchus coelorhynchus	0.90	0.01	*Symphurus nigrescens*	24.22	0.21
Conger conger	5.10	0.85	*Trachurus mediterraneus*	81.39	1.17
Dalophis imberbis	0.95	0.04	*Trachurus picturatus*	28.47	0.31
Dentex macrophthalmus	1.62	0.01	*Trachurus trachurus*	2097.59	16.58
Diplodus sargus	2.41	0.03	*Trachinus draco*	2.47	0.21
Echelus myrus	1.27	0.13	*Trigla lucerna*	2.11	0.67
Engraulis encrasicholus	438.30	8.19	*Trigla lyra*	4.86	0.10
Eutrigla gurnardus	109.13	2.15	*Trigloporus lastoviza*	3.62	0.25
Gadiculus argenteus	344.12	1.00	*Trisopterus minutus capelanus*	545.81	4.76
Gaidropsarus mediterraneus	3.81	0.03	*Uranoscopus scaber*	2.24	0.34
Gnathophis mystax	2.61	0.04	*Zeus faber*	6.12	2.08
Gobius niger	0.96	0.01			
Gobius quadrimaculatus	2.90	0.01			
Lesueurigobius suerii	5.00	0.01			
Helicolenus dactylopterus	58.64	0.71			
Lepidopus caudatus	471.97	107.53			
Lepidorhombus boscii	38.57	0.83			
Lepidorhombus whiffiagonis	36.48	1.60			
Lepidotrigla cavillone	22.46	0.27			
Lepidotrigla dieuzeidei	18.96	0.23			
Lophius budegassa	69.23	7.90			
Lophius piscatorius	5.07	1.04			
Leusueurigobius friesii	182.69	0.31			
Macrorhamphosus scolopax	30.90	0.16			
Maurolicus muelleri	854.98	0.82			
Merluccius merluccius	2436.30	58.61			
Micromesistius poutassou	1407.33	27.27			
Microchirus variegatus	4.34	0.06			
Mola mola	0.29	8.67			
Molva dipterygia	2.40	0.04			
Molva molva	2.58	0.04			
Mullus barbatus	291.66	11.88			
Mullus surmuletus	2.80	0.23			
Ophidion barbatum	0.60	0.01			

Pagellus acarne	1.81	0.09			
Pagellus bogaraveo	3.31	0.20			
Pagellus erythrinus	1.45	0.05			
Phycis blennoides	40.83	0.80			

The most common species by abundance (N/km^2) were: the European hake (*Merluccius merluccius),* the Atlantic horse mackerel *(Trachurus trachurus)* and the blue whiting *(Micromesistius poutassou).* The most common species by mean biomass share (N/km^2) were: the silver scabbardfish (*Lepidopus caudatus),* the European hake *(Merluccius merluccius)* and the blue whiting *(Micromesistius poutassou).* An assessment of the distribution and population volume of small pelagic fish in the Adriatic Sea was carried out in 2009 by ultrasonic detection (echo-monitoring), Table 3.22.

Table 3.22 Estimated value of pelagic fish population in the Adriatic

Area (surface (Nm^2))	Estimated mean value of species' presence (ton/Nm^2) / population estimate in the observed area (ton)		
	European pilchard (*Sardina pilchardus*)	European anchovy (*Engraulis encrasicolus*)	European sprat (*Sprattus sprattus*)
Open sea - northern part (5134)	34.21/175,619	8.14/41,787	0.14/718.7
Open sea - central part (4306)	3.19/13,730	0.78/3,367	/
Open sea - southern part (682)	0.01/5.7	0.38/258	/
Internal waters - northern part (2070)	17.25/35,711	20.68/42,817	2.44/5,056
Internal waters - southern part (1386)	4.87/6,743.2	24.49/33,941	/

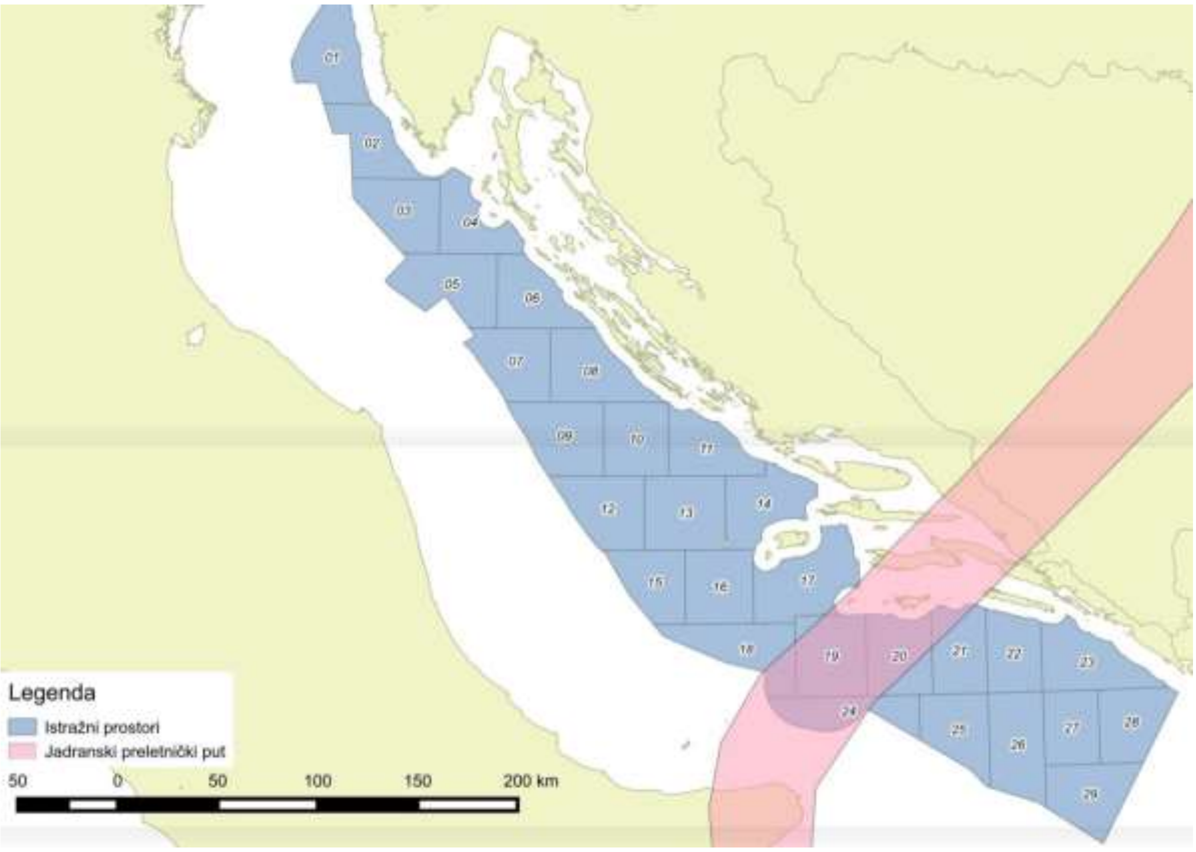
As part of the MEDITS program, a survey to determine fish populations was carried out in the Croatian past of the Adriatic. The most common species were: the red mullet (*Mullus barbatus*) - 16.97%, the Atlantic horse mackerel (*Trachurus trachurus*) - 16.77%, the picarel (*Spicara smaris*) - 16.66%, the European hake (*Merluccius merluccius*) - 13.53%, the common pandora (*Pagellus erythrinus*) - 6.34% , the blotched picarel (*Spicara flexuosa*) - 5.13%.

3.6.3 Seabirds

The most important groups of birds which use the area of the Adriatic are the so-called "seabirds", whose life cycle is directly connected to the marine environment, and passage migrants that migrate between Europe and Africa over the Adriatic Sea.

Seabirds nest in the salt belt of coastal zones, capes and small islands, and feed mostly on fish and other marine fauna, so they rarely dwell on land, except for nesting and at night. Some species are even physiologically adapted to drinking sea water. 27 seabird species have been sighted in the Adriatic, around 10 of which nest here permanently, with others appearing here only temporarily during migration or wintering from the north. The most common species are seagulls (*Larus* order), terns (*Sterna*), cormorants (*Phalacrocorax*), shearwaters (*Puffinus* and *Calonectris*) and petrel (*Hydrobates* and *Oceanodroma*).

The Adriatic Sea is a fly zone for some migratory birds wintering in Africa. Open pelagic areas are a sort of a barrier, since there are no resting and feeding places. Flying over these areas requires a greater amount of energy and causes greater exhaustion to the animal. For these reasons, it is deemed that most birds fly over the Adriatic at its narrowest part, the so-called Adriatic flyway, although birds do fly over other parts of the Adriatic as well. Since birds present in the FPP area are the ecological network's goal species, they are discussed in detail in Chapter 6. Main assessment.



Legend: blocks; Adriatic flyway.

Figure 3.68 Adriatic passage migrants flyway

3.6.4 Invertebrates

Representatives of almost all higher species of invertebrates important for marine ecosystems live in the Adriatic Sea. Only a few representatives, those usually found at great depths of the Mediterranean Sea and the oceans, are not present. A list of species (from phylum to species level) was made by analysing numerous source data on Adriatic invertebrates. 5427 species of invertebrates were recorded. Species of Atlantic-Mediterranean distribution prevail, while Boreal, Cosmopolitan and endemic species are significantly less represented. Thanks to the century-long effort of Croatian researchers, and researchers throughout Europe as well, the Adriatic can be considered as one of the better explored parts of the Mediterranean Sea. The number of reported species amounts to about 80% of the reported species for the Mediterranean Sea. A new list of Adriatic invertebrates is in the making by Croatian researchers working together under the leadership of dr. sc. D. Zavodnik, which will give new insight into the biodiversity of Adriatic benthic invertebrates.

3.6.4.1 Depth Distribution of Communities of Adriatic Benthic Invertebrates

A detailed description of communities of benthic invertebrates, containing descriptions of habitat physical properties, characteristic species, distribution, threat causes and conservation measures is listed in professional literature (Peres and Gamulin Brida, 1973; Bakran-Petricioli 2007).

In the supralittoral zone, on rocky basements in natural and conserved communities, the typical biocenosis of supralittoral rock is found, containing characteristic species, the snail *Melaraphe neritoides* and the crustaceans *Ligia italica* and *Chthamalus depressus*. These species are adapted to constant fluctuations in temperature, moisture and salinity, prevalent in this wave splash zone. In movable basement habitats, like sandy and sand-pebble beaches, there are biocenoses of rapid and slow drying marine wracks with characteristics species of detritivorous amphipod and isopod crustaceans and insects which dwell in sand or in accumulations of seagrass remains. Biocenoses of supralittoral pools, characterized by extreme living conditions marked by high temperature and salinity, contain specially adapted species (the copepod *Harpacticus fulvus* which changes to a latent life regime at salinity of 180‰) and are distributed along the entire Adriatic coast.

The mediolittoral zone on a rocky basement in the Adriatic is characterised by two biocenoses, the biocenosis of the upper and the biocenosis of the lower mediolittoral rocks. This is the part of the littoral zone which stretches through the intertidal zone. Here live plants and animals which can tolerate prolonged dry seasons, but cannot tolerate constant water immersion. Characteristic species of invertebrates in this zone are the Poli's stellate barnacle (*Chthamalus stellatus*) and the snail *Patella* *lusitanica*, in the biocenosis of upper mediolittoral rocks. In the biocenosis of lower mediolittoral rocks, the characteristic species are the snail *Patella aspera*, the crustacean *Pachygrapsus marmoratus* and many infralittoral species like the sea anemone *Actinia equina*, the snail *Osilinus turbinatus*, the bivalvia *Mytilus galloprovincialis* and many other species from the groups bryozoa, polychaete, foraminifera, etc. Many animal species use algae cover as shelter and foraging grounds, which can be abundant in this zone. Mediolittoral movable basement settlements are situated in upper parts of sandy beaches and muddy sand, where the community composition is affected by sea water seeping into interstitial substratum cavities. Characteristic species in the cavities between pebbles and deposits of dead posidonia leaves are isopod and amphipod crustaceans, polychaete (genera Ophelia and Nerine) on sandy basements (mediolittoral sands biocenosis), polychaete *Nereis diversicolor*, bivalvia *Abra alba* and *Cerastoderma glaucum* and various amphipod and isopod crustaceans on a sandy-muddy and rarely on a muddy basement (muddy sands and lagoon and estuary muds biocenosis).

The best and very diverse living conditions for benthic organisms are prevalent in the infralittoral zone. Algae and plant biomass often prevails over animal biomass, although zoobenthos in this belt displays exceptional biodiversity. The photophilic algae biocenosis, dominating the Adriatic rocky coast, is a suitable habitat for numerous echinoderms (sea urchins *Paracentrotus lividus*, *Arbacia lixula*, *Sphaerechinus granularis*, *Psammechinus microtuberculatus*, *Arbaciell aelegans*, *Genocidaris maculata*, starfish *Echinaster sepositus*, *Marthasterias glacialis*, *Coscinasterias tenuispina*, brittle stars *Ophiothrix fragilis*), molluscs (snails *Patella coerulea*, *Haliotis lamellos*, species of the Cerithium, Gibbula, Rissoa, Alvania and other genera), crustaceans (*Acanthonyx lunulatus*, *Clibanarius misantrophus*), sea squirts (*Halocynthia papillosa*) and many other groups of invertebrates. *Posidonia oceanica* seagrass meadow biocenosis, dominating the sandy-muddy seabed, is a biocenosis of great biodiversity. There are several layers with differing living conditions: photophilic animals live in the upper leaf layer, sciophilous animals live in the shadows at stem bottoms, while epi- and endo- fauna lives on and in sediment. Here numerous sessile (bryozoans, sponges, polychaete, hydroids, sinascidians and other), vagil (bivalivia, snails, starfish, crustaceans and other) and nekton (amphipod, copepod, decapod and other crustaceans, jellyfish, cephalopods, fish, seahorses, pipefish and other) species of invertebrates live, feed and breed, permanently or temporarily, together with very important epiphytic microfauna (foraminifera, ciliates, polychaete, crustaceans, various larvae and other). Characteristic species are the bivalvia *Pinna nobilis*, echinoderms *Sphaerechinus granularis*, *Psammechinus microtuberculatus*, *Antedon mediterranea*, *Holothuria polii*, followed by numerous species of hydroids, polychaete, bryozoans and crustaceans. Infralittoral movable seabed biocenoses without vegetation develop on various types of sediment seabed. They are not characterised by great biodiversity. Depending on the depth and the percentage of sandy or muddy sediment, communities with a smaller or greater number of species of invertebrates develop (various species of bivaliva are usually prevalent).

Circalittoral zones take up the greatest portion of the continental shelf (Peres and Gamulin Brida, 1973), where benthic fauna prevails in terms of diversity and biomass. Coralligenous biocenosis developed on solid basements, in which sciophilous species of algae and invertebrates (cnidarians, sponges, bryozoans and other groups) prevail. The coralligenous biocenosis is widely distributed in the Adriatic Sea, especially in the open part of the central Adriatic, where clean and dynamic sea of great transparency prevails, saturated with oxygen, with stable temperature and salinity, weak sedimentation and characterized by a large number of species. Biocenosis of semi-dark caves and biocenosis of offshore rocks are frequent there, in which species of sciophilous invertebrates also prevail (sponges, bryozoans, cnidarians, tunicates and other). Sandy and muddy type sedimentary bottoms prevail along the cost of the mainland and islands and in the open part of the circalittoral zone. Depending on the structure of the sedimentary seabed, different benthic communities develop, in which benthic invertebrates and in some places vertebrates prevail in terms of diversity and biomass. In coarser sandy and sandy-detritic bottoms, the biocenosis of coastal detritic bottoms, in which the bivaliva *Circomphalus casinus* and the sea urchin *Spatangus purpureus* mark strong demersal currents, and the stony coral *Caryophyllia clavus* slow sedimentation. Detritic bottom biocenosis of the more open island area and the open sea developed on the sandy-detritic bottoms of the more open island area and is geographically, environmentally (narrower amplitudes and higher mean salinity values, milder cooling, etc.) and biocenologically different from transitory zones in less indented areas. It is characterised by numerous bivalivia (*Laevicardium oblongum*, *Chlamys flexuosa*, *Chlamys clavata*, *Tellina balaustina*, *Pectenvarius*, *Cardita aculeate*), the snail *Aporrhais pespelecani*, the polychaete *Hermione hystrix*, the starfish *Anseropoda placenta*, the brittle star *Ophiacantha setosa* and the sea urchin *Cidaris cidaris*. Biocenosis of more or less muddy detritic bottoms is developed mainly on mobile bottoms of the northern Adriatic, where it already develops at depths of around 13 m because of low sea transparency in that part of the Adriatic. Because of the special tidal regime, inland waters and other environmental factors affecting the quality and quantity composition of species, three zones are defined: coastal, central and open sea zone. The coastal zone is heavily influenced by land and inland waters. It is characterised by very muddy detritic bottom, dominated by the sea urchin *Schizaster canaliferus* and the starfish *Amphiura chiajei*. The central zone is under the influence of the main Adriatic current and its branches. It is characterised by sandy-detritic bottom and the bivaliva from the genus Tellina. It is rich in epifauna, especially sponges, echinoderms, molluscs and ascidians. The open sea zone is under the influence of the open sea and alpine rivers. It is characterised by sandy-detritic more or less muddy bottom, and by the sea urchin *Schizaster canaliferus*, the brittle star *Amphiura chiajei*, bivalivia *Laevicardium oblongum* and *Chlamys flexuosa*, star fish *Anseropoda placenta* and mudiness indicators: the sponge *Raspallia viminalis*, the cnidaria *Alcyonium palmatum* and the polychaete Aphrodite aculeata. In areas with no or with weakened demersal currents, where minute mud particle sedimentation is possible, biocenosis of coastal terrigenous muds developed. It covers the central parts of most canals, while in the less indented part of the southern Adriatic it forms a broader or narrower coastal zone. It is characterised by polychaete *Sternaspis scutata* and *Aphrodite aculeata*, bivalivia *Cardium paucicostatum* and *Pteria hirundo*, the snail *Turritella communis,* sea cucumbers *Oestergrenia adriatica*, *Trachythyone elongata*, *Trachythyone tergestina* and *Stichopus regalis*, cnidarians

Pennatula phosphorea, *Alcyonium palmatum* and *Virgularia mirabilis*, the crustacean *Dorippe lanata*, the ascidia *Diazona violacea* and other.

The muddy bottom biocenosis of the open central Adriatic and the island zone of the northern Adriatic *Nephrops norvegicus – Thenea muricata*, characterised by the lobster *Nephrops norvegicus* and the sponge *Thenea muricata*, developed on the muddy bottom of the open part of the central Adriatic, in the Kvarner area, in the canals of the northern Adriatic and partially in the southern Adriatic. This is an important fishing area in the Adriatic Sea, where fish from the group Selachia alongside the lobster are found, prawns (e.g. *Parapenaeus longirostris*) and the hake *Merlucius merlucius* and other fish and cephalopods. This biocenosis poses the transition towards the bathyal benthic zone.

The bathyal zone in the Adriatic Sea is located only in the deepest part of the Jabuka Pit and in the south Adriatic basin. Deep-sea fauna makes up the reef biocenosis of colonial deep-sea corals (*Desmophyllum cristagalli*, *Lophelia pertusa* and *Madrepora oculata*) and bathyal muds biocenosis on muddy bottoms with characteristic species (the sponge *Thenea muricata*, crustaceans *Parapeneus longirostris*, *Chlorotocus crassicornis* and *Nephros norvegicus*, cnidarians *Funiculina quandragularis* and *Isidella elongata*, echinoderms *Brisingella coronata* and *Odontaster mediterraneus* and some cephalopods and bathyphilic fish fauna and eurybathic species, including the hake Merlucius merlucius) and accompanying species (echinoderms *Stichopus regalis*, *Cidaris cidaris, Echinus acutus* and *Astropecten irregularis*, the sea snail *Scaphander lignarius* and other).

During expeditions undertaken between 1996 and 2007, in total 23 species of crustaceans and 21 species of cephalopods were caught and recorded by bottom trawlers in the open central Adriatic area.

Table 3.23 List of crustaceans by abundance (N/km^2) and biomass (kg/km^2) indexes, source: Institute of Oceanography and Fisheries, 2009

Crustaceans	N/km^2	kg/km^2
Alpheus glaber	9.82	0.01
Chlorotocus crassicornis	36.65	0.05
Dorippe lanata	2.78	0.03
Goneplax rhomboides	4.65	0.03
Maja squinado	1.39	0.44
Liocarcinus depurator	85.58	0.88
Macropipus tuberculatus	15.20	0.11
Meganyctiphanes norvegica	2.97	0.01
Munida intermedia	0.86	0.01
Munida banfica	12.44	0.06
Nephrops norvegicus	373.22	4.79
Parapenaeus longirostris	330.78	1.71
Pasiphaea multidentata	8.62	0.02
Pasiphaea sivado	20.20	0.01
Philoceras echinulatus	5.60	0.01
Plesionika edwardsii	67.97	0.13
Plesionika heterocarpus	162.66	0.32
Plesionika martia	3.65	0.01
Pontophilus spinosus	36.04	0.05
Pontocaris lacazei	1.02	0.01
Processa canaliculata	19.19	0.04
Solenocera membranacea	57.73	0.11
Squilla mantis	0.55	0.02

Table 3.24 List of cephalopods by abundance (N/km²) and biomass (kg/km²) indexes, source: Institute of Oceanography and Fisheries, 2009

Cephalopods		N/km²	kg/km²
Alloteuthis media	midsize squid	861.1	1.68
Eledone cirrosa	curled octopus	94	16.19
Eledone moschata	musky octopus	12.93	0.8
Illex coindetii	southern shortfin squid	563.27	19.59
Loligo forbesi	veined squid	1.01	0.18
Loligo vulgaris	common squid	26.8	0.26
Octopus salutii	spider octopus	0.71	0.15
Octopus vulgaris	common octopus	6.55	0.65
Rondeletiola minor	lentil bobtail	89.5	0.13
Sepietta neglecta	elegant bobtail	4.86	0.03
Sepietta obscura	mysterious bobtail	0.7	0.01
Sepietta oweniana	common bobtail	26.62	0.12
Sepia elegans	elegant cuttlefish	16.85	0.15
Sepia officinalis	common cuttlefish	1.487	0.04
Sepia orbignyana	pink cuttlefish	10.47	0.22
Sepiola intermedia	intermediate bobtail	0.86	0.01
Sepiola ligulata	tongue bobtail	1.78	0.01
Sepiola robusta	robust bobtail	2.72	0.01
Sepiola rondeleti	dwarf bobtail	7.16	0.01
Todarodes sagittatus	European flying squid	30.28	1.87
Todaropsis eblanae	lesser flying squid	37.21	2.67

3.6.4.2 Corals

Corals are good indicators of environmental conditions, as they are sessile organisms sensitive to minute changes in water chemistry and temperature. Coral communities make up an important habitat containing a great number of various organisms. 92 species of coral have been recorded in the Adriatic Sea up to now, out of which 8 are endemic species and 4 are geographic races, which together makes them endemic elements of the Adriatic (Milišić, 2008).

One of the characteristic species of coralligenous communities is the red coral (*Corallium rubrum*), a spices which was commercially exploited and whose numbers significantly diminished due to fishing in the Adriatic Sea. In shallower waters (15–70 m) this species grows in caves, cracks and overhangs. At greater depths (70–130 m), coral colonies are bigger and more widespread and they grow in open, unprotected areas. The red coral is a long living species (around 100 years) and, like other gorgonians, it grows very slowly and reach sexual maturity late in life (7–10 years). Very little research has been conducted on this species in Croatian waters. There are hardly any data on its ecology and distribution, despite the fact that it has been commercially exploited for ages. Furthermore, species monitoring has not been established, although estimates show that its numbers in the Adriatic have been significantly reduced (2014 Adriatic Sea Monitoring Program).

3.6.5 Plankton

3.6.5.1 Phytoplankton

Planktons are organisms living freely in the water column and driven by sea currents. Phytoplankton is an autotrophic group of planktonic unicellular and colonial organisms, meaning they have the ability to convert inorganic substances into organic, thus they present primary producers in the marine system.

According to the size, they are divided into pico(phyto)plankton (cells between 0.2 and 2 μm), nano(phyto)plankton (cells between 2 and 20 μm) and micro(phyto)plankton (cells larger than 20 μm). The most numerous representatives of larger phytoplankton are diatoms, and of the smaller phytoplankton green algae, golden algae, dinoflagellates and cyanobacteria.

Diatoms and dinoflagellates are most common in the Adriatic Sea. The most numerous diatoms in the Adriatic are the species of the genera *Chaetoceros*, *Cyclotella* and *Pseudonitzchia*, while the most numerous dinoflagellates are the species of the genus *Gymnodinium.*

888 species have been recorded in the eastern Adriatic, of which diatoms and dinoflagellate species are the most numerous. In the coastal waters of the Adriatic, 13 species of the genus *Dinophysis* have been identified, the most common being the species *D. caudata*. 97 species of microplankton have been identified in the northern Adriatic, including diatoms, dinoflagellates, coccolithophores and silicoflagellates. The most numerous reported species in the area of the Jabuka Pit are species of coccolithophores and diatoms.

Any disturbance in the balance of the marine ecosystem is primarily reflected on the first trophic level, thus the state of the

maritime ecosystem is best observed by monitoring the phytoplankton biomass.
Due to its high vulnerability to the process of eutrophication, as well as due to its quick response to the changes in the environment, phytoplankton is one of the main biological elements for water quality assessment.
Open waters of the northern and southern Adriatic have oligotrophic characteristics, and the phytoplankton biomass is significantly less fluctuant compared to coastal waters. Open waters of the northern Adriatic are under the influence of the Po River, which is precisely why the phytoplankton biomass is larger in open waters.

Nanoflagellate organisms contribute most to the total abundance of the phytoplankton community in the Adriatic. They make for over 70% of the total abundance on the annual scale. Following small flagellates, diatoms are the most numerous in the community. The share of dinoflagellates, coccolithophores and silicoflagellates in the total abundance is rather small, the total contribution on the annual scale is below 5%.

DESCRIPTOR
All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity (Descriptor 4 or D4).

3.6.5.2 Zooplankton

Zooplankton are heterotrophic unicellular and multicellular organisms, very significant as regulators of phytoplankton production and an important factor in the food chain of the marine system. Zooplankton are organisms that spend their entire life cycle as plankton, as well as organisms who spend only a part of their life cycle in the plankton before developing to higher organisms. Zooplankton organisms are very significant consumers of organic detritus in coastal seas, yet their most important role is to regulate the amount of phytoplankton organisms and to provide basis for the life of higher predators.

Almost all known types of zooplankton communities have developed in the Adriatic Sea: estuarine, coastal, ocean surface, mesopelagic and deep-sea communities. Around 850 true zooplankton species (holoplanktons) and around 20 species of meroplanktons, that is larvae of benthic organisms and fish, can be found in the Adriatic. There are many areas in which endemic zooplankton populations dwell, such as the species *Speleophria mestrovi* and *Acartia italica*. The population of species *Speleophria mestrovi* is endemic to the Tethys Ocean, and dwells in the caves of the area surrounding Cavtat and Rovinj. The reported species were listed in the Red Book of endangered cave habitat species.

The highest number of zooplankton species is found in the southern Adriatic. The number of species decrease towards the north and the coast. The most numerous zooplankton species fall under the subclass copepod. Copepods are very important as the food source of larvae of fish and numerous other organisms, and any disturbance in their population can cause wider ecological problems.

Table 3.25 Diversity of zooplankton groups

GROUP	Number of species
Choanoflagellata	13
Foraminiferida	15
Heliozoa/Taxopodida	5
Radiolaria	100
Acantharia	27
CILIOPHORA	120
CNIDARIA	
Medusae	80
Chondrophora	2
Siphonophora	23
Stauromedusa	10
Ctenophora	10
ROTATORIA	15
MOLLUSCA	18
ANNELIDA	11
CRUSTACEA	
Phyllopoda	6
Ostracoda	13
Copepoda	230
MALACOSTRACA	
Euphausiacea	12
Decapoda	11
Misidacea	21
Cumacea	10
Isopoda	2
Amphipoda	48
CHAETOGNATHA	11

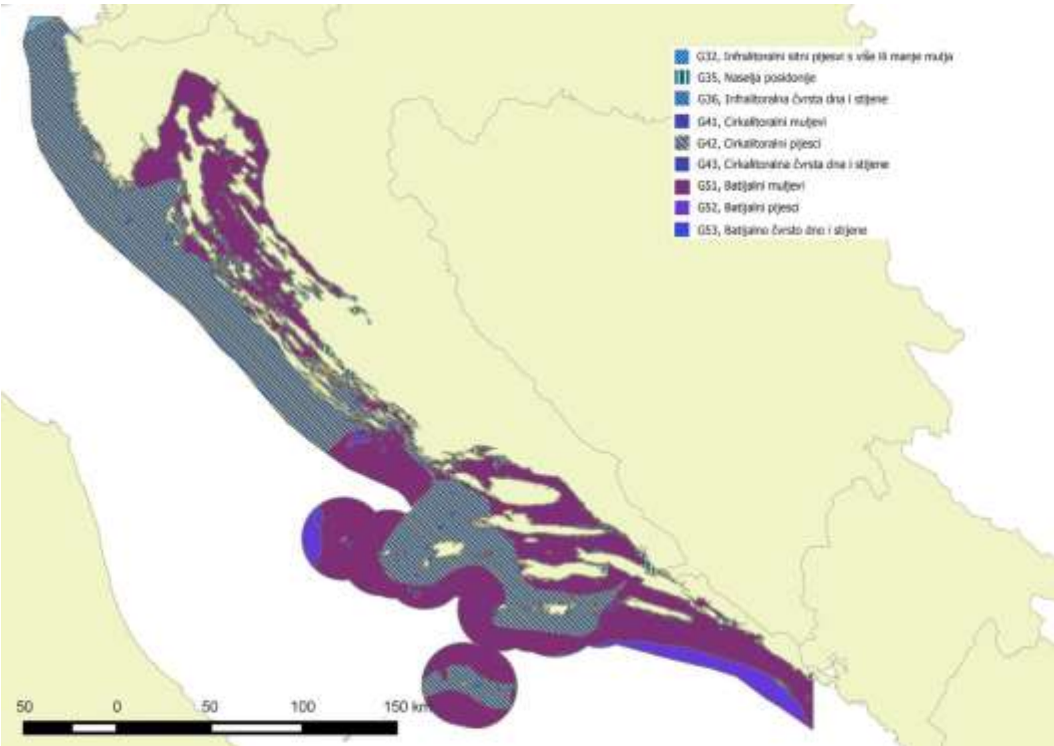
TUNICATA	28
THALIACEA	9
TOTAL	850

The species *Sticholonche zanclea* (Heliozoa/Taxopodida) is very common in the Adriatic Sea. It appears in the fall, exists throughout winter and then disappears. It can be found in coastal areas and in the surface layer of the open sea. Non-loricate ciliates are a very important group of zooplanktons of the Adriatic. They are present in smaller number in the open sea, while the highest numbers are found near the coast and in estuaries.
Among other plankton groups in the Adriatic, one should mention cnidarians (Cnidaria). Hydromedusae and Calycophorae are well known in the northern and southern part of the Adriatic Sea. Hydromedusae are characteristic for the open sea, and the dominant species are *Aglaura hemistoma*, *Liriope tetraphylla* and *Rhopalonema velatum*.
Planktonic gastropods are characteristic of the surface layer of the open sea, although some species are found in the coastal region. Tunicates are an important component of the holoplankton in the open sea, particularly *Doliolidae*, *Salpida* and *Appendicularia*.

DESCRIPTORS
Nonindigenous species introduced by human activities are at levels that do not adversely alter the ecosystems (Descriptor 2 or D2).
All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity (Descriptor 4 or D4).

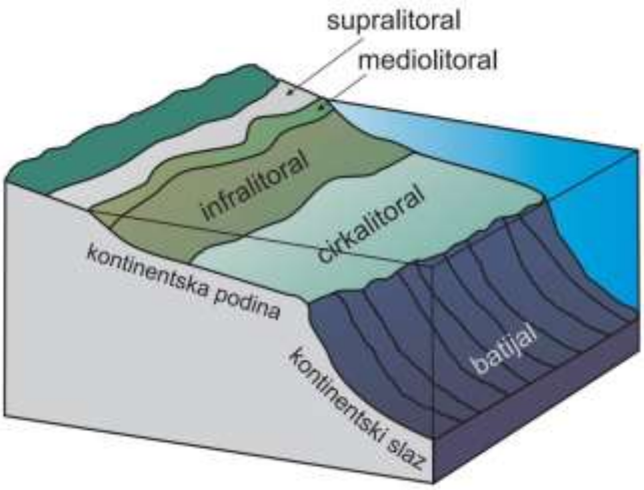
3.6.6 Habitat Types

Due to the very indented coast, the Croatian part of the Adriatic is characterized by a great diversity of habitats. Marine habitats are much less explored and charted than terrestrial or freshwater habitats since research is expensive and technically challenging, and there are not enough experts in the area. The habitat map drafted according to the National Classification of Habitats (NCH) and published in the Official Gazette (119/09), provides an overview of marine habitats, although it contains inaccuracies. According to the basic vertical division, the marine benthic habitats are divided into the littoral and bathyal zone.



G32 – infralittoral fine sans with more or less mud; G35 - Posidonia oceanica meadow; G36 – infralittoral solid bottoms and rocks; G41 – circalittoral muds; G42 – circalittoral sands; G43 – circalittoral solid bottoms and rocks, G51 – bathyal muds; G52 – bathyal sands; G53 – bathyal solid bottoms and rocks

Figure 3.69 Cartographic representation of marine habitats according to the National Classification of Habitats (NCH)



Top to bottom: supralittoral, mediolittoral, infralittoral, circalittoral, continental shelf, bathyal, continental slope

Figure 3.70 Benthic zones in the Adriatic Sea, source, Marine Habitats, Bakran-Petricioli, 2007

The littoral area in the Adriatic is divided in four benthic zones: supralittoral zone (wave splash zone), mediolittoral zone (intertidal zone), infralittoral zone (zone of photophilic algae - on rocky bottom - and seagrasses - on sedimentary bottom permanently under sea level) and circalittoral zone (the zone that covers the bottom from the lower dispersion limit of photophilic algae and seagrasses until the lower dispersion limit of sciophilous algae - algae that live in shady habitats with a significantly lower amount of light compared to the photophilic zone). Deeper down, below 200 meters, the bathyal zone continues after the circalittoral zone. It is a part of the deep sea without algae and with organisms that depend on the organic matter that sinks from the top euphotic sea zone.

Circalittoral bottoms are the most common type of habitat and occupy around 88% of the total surface area of Croatian territorial sea bottom, but they are mostly comprised of sedimentary bottom: muds and sands while coralligenous communities are scarce, which again draws attention to their sensitivity to the impact of human activities. Less common types of habitats in the sea abundant with karst, such as anchialine caves, sea caves, cold sea caves with bathyal elements, undersea sources, karstic estuaries, saltwater lakes and bare underground karst, which are habitats specific for Croatia (Bakran-Petricioli, 2007).

3.6.6.1 Circalittoral Zone

Circalittoral zone is the zone of sciophilous marine vegetation. It occupies the largest part of the continental shelf in the Adriatic, i.e. of Croatian territorial sea. This area is determined by a reduced amount of light and slight fluctuation in salinity and temperature. With increasing depth, the animal biomass prevails over the algae biomass in these communities. Along the coast of the mainland and islands coarser sandy and sandy-detritic sediments prevail. The biocenosis of coastal detritic bottoms is developed here, which also forms the transition from the photophilic infralittoral into sciophilous circalittoral benthic zone.

Due to stronger demersal currents, sandy and sandy-testaceous sediments are formed in a more open island area and in the open sea of the Adriatic. The central parts of the channels between the mainland and the islands and between the islands are covered by coastal terrigenous muds, while the deeper parts of the Velebit Channel, as of open waters of the central Adriatic are occupied by the biocenosis of deep sea muds. This biocenosis poses the transition towards the bathyal benthic zone.

3.6.6.1.1 Coralligenous Formations

On a solid basement, in some places already at the depths below approx. ten meters, coralligenous biocenosis is often developed, which is a part of the sciophilous circalittoral zone. The elements of this biocenosis are sometimes found in the infralittoral zone as well, in places where the environmental conditions, in terms of light, are similar to those in the circalittoral zone.

In the area of testaceous and other detritic sediments, biogenic reinforcement of sediments sometimes occurs. In fact, many organisms - especially red algae from the Corallinaceae family that incorporate calcium carbonate in their talus, also sessile organisms such as for example sponges, cnidarians, bryozoans and squirts - outgrow the sediment particles, thus creating secondary reinforced bottom on which coralligenous biocenosis is developed, characteristic of firm-basement circalittoral zone (Bakran-Petricioli, 2007).
Although coralligenous formations are widespread in the Croatian part of the Adriatic Sea, this habitat is poorly researched and there are hardly any data on its detailed distribution and ecology, with the exception of national parks and nature parks, and some very limited areas. The data on the characteristic species and their abundance in various aspects of coralligenous formations are also limited to very small areas, mostly to coralligenous formations developed at the depths of up to 50 or 70 m.

There are practically no data for coralligenous formations developed deeper. The available data indicate great heterogeneity of this habitat in terms of the composition of species.

3.6.6.2 Bathyal Zone

The bathyal zone of the Adriatic encompasses only a smart part of the deepest part of the Jabuka Pit, and a somewhat bigger part of the south Adriatic basin. The depths of the bathyal zone are completely dark, and the temperature and salinity are constant. The biocenoses and types of the Adriatic bathyal are poorly researched, while the abundance of species and their density are probably very modest. The seabed is mostly muddy, although there are also hard bottoms inhabited by communities of deep-sea corals.

3.6.7 Seagrass and Benthic Algae Communities

3.6.7.1 Seagrass Communities

Seagrasses are plants that have adapted to life in the sea, and belong to the group of flowering plants. They have developed organs such as the root, steam, leaf and flower. Four species of seagrass are found in the Adriatic: *Posidonia oceanica* (endemic to the Mediterranean Sea)*, Cymodocea nodosa, Zostera marina* and *Zostera noltii.*

Seagrass communities have a key ecological role in the ecosystem and are one of the most important types of habitat in the Adriatic Sea. The negative anthropogenic influence on these communities is significant and on increase, while the restoration of destroyed habitats is a long-term process. This is precisely why a drop in the population of seagrasses was recorded in the Mediterranean Sea and why the majority of countries legally protected these communities.

Some of the main environmental characteristics of the seagrasses are as follows:

- Their leaves serve as traps for sediment deposited near the plant, thus seagrasses contribute to the purification of the marine column.
- Seagrasses produce organic matter and are a direct source of food for many animals.
- They pose the basement for the settlement of epiphytes, as well as sessile and motile animals.
- Seagrasses are important carriers of nutrient salts from sea water and surface sediment to various processes of organic matter cycling.

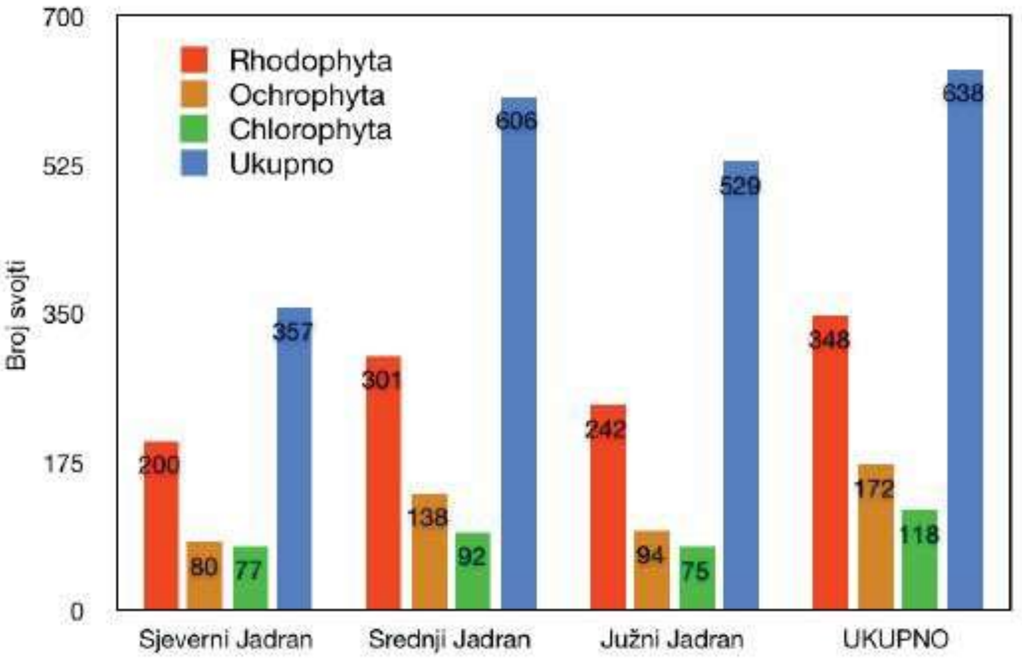
Posidonia oceanica
Posidonia is endemic to the Mediterranean Sea, and in the Adriatic it forms meadows that stretch to the depth of 35 m on average. It is best developed in the central and southern Adriatic. Since the habitat of the species *Posidonia oceanica* belongs to the ecological network (Natura 2000), it will be discussed in a separate chapter (Main Assessment - Influence on habitats).
Cymodocea nodosa
This species is well represented in all parts of the Adriatic Sea, especially in protected coves. Its meadows are found at depths of several meters, and most often they are located before the meadows of Posidonia.
Zostera marina
The species *Zostera marina* is most widely distributed in the northern Adriatic. It lives on sandy and muddy bottoms at relatively small depths up to 4 meters.
Zostera noltii
This species inhabits sandy and muddy bottoms up to 5 meters in depth. The best developed meadows of this species are found in the northern Adriatic.

Although seagrasses are of high ecological importance, their distribution in the Adriatic Sea is very poorly explored. Since the seagrass communities are priority habitats according to international agreements on environment protection, as well as a biological element of water quality, it is necessary to devote more attention to their more detailed study.
As they are very sensitive to disturbances in the marine environment, seagrasses, especially *Posidonia oceanica*, present a very good environmental bioindicator.
DESCRIPTOR
Seabed integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected (Descriptor 6).

3.6.7.1 Benthic Algae Communities

Benthic macroalgae include species of compartments of red, brown and green algae. Macroalgae pose an important habitat for a number of smaller organisms and epiphytic algae, have an important role in the cycling of matter in seawater column and together with phytoplankton they participate in the process of primary production of organic matter. Benthic species of organisms live in close contact with the seabed, so each change in the marine system leaves consequences for these organisms.

With respect to biodiversity, biomass, distribution and role in the ecosystem, macrophytobenthos is a sensitive indicator of changes in the environment. The dynamics of benthic algae communities as a whole represents the most reliable indicator of the state of the environment. Under the influence of stress, natural or anthropogenic changes, the algae communities display decreased biodiversity.
Geographical diversity and indented coast of the Adriatic Sea condition the division of benthic flora into the flora of the coastal and channel waters and the flora of the outer zone of the open waters. Due to the great diversity of the seabed structure, there is a large number of microhabitats and ecological niches, which is considered to be the main factor of diversity of benthic communities.



Legend: Number of species / northern Adriatic, central Adriatic, southern Adriatic, TOTAL. Ukupno = total.

Figure 3.71 Main systematic compartments of benthic algae in the Adriatic Sea in numbers (source: Institute of Oceanography and Fisheries, 2012)

638 species of benthic macroalgae have so far been recorded in the Adriatic Sea. Benthic macroalgae are found in several marine habitats, on mediolittoral rocks, in biocenosis of infralittoral algae and coralligenous biocenosis. Macroalgae from the most important communities in these biocenoses.
Benthic bionomical zones are defined according to characteristic biological communities of organisms that inhabit them. According to this division, we distinguish between the following benthic bionomical zones and macroalgae communities that inhabit them:

The supralittoral zone is the seacoast exposed to constant wave splashing. Epilithic species of cyanobacteria dominate this zone, while macroalgae, such as red algae *Catenella opuntia*, are rarely found.

The following communities dominated by macroalgae are distributed in the supralittoral zone: Biocenosis of supralittoral rock, association with species of genera *Entophysalis* and *Verrucaria,* pools with variable salinity (mediolittoral enclave), facies of supralittoral karst sea lakes.

The eulittoral or mediolittoral zone is the seabed zone whose upper limit is the level of the highest tide, and the lower limit is the level of normal low tide. This bionomical zone is the largest in the northern part of the Adriatic where it reaches up to 75 cm, while in the central and southern Adriatic it reaches 50 cm. Species *Cystoseira amentacea var. spicata* and *Corallina elongata*, found in protected sites, have developed on the lower limit of the mediolittoral zone.

In polluted areas, close to utility wastewater discharges, special vegetation of benthic algae has developed, dominated by species from the genera *Ulva* and *Enteromorpha*.

The following communities dominated by macroalgae are distributed in the mediolittoral zone: Biocenosis of upper mediolittoral rocks, association with species *Bangia atropurpurea*, association with species *Porphyra leucosticta*, biocenosis of lower mediolittoral rocks, association with species *Lithophyllum lichenoides*, association with species *Lithophyllum byssoides*, association with species *Tenarea undulosa*, association with species of genera *Ceramium* and *Corallina*, association with species *Enteromorpha compressa*, association with species *Fucus virsoides*, association with species *Gelidium* spp., biocenosis of mediolittoral caves, association with species *Phymatolithon lenormandii* i *Hildenbrandia rubra* and communities of mediolittoral karst sea lakes.
The infralittoral zone stretches from the middle limit of low tide to depths between 120 or 150 meters. This zone is further divided

into upper infralittoral zone (between middle low tide limit and depths between 6-8 m), middle infralittoral zone (depths between 6-8 m and 35-45 m) and lower infralittoral zone (depths between 35-45 m and 120-150 m)

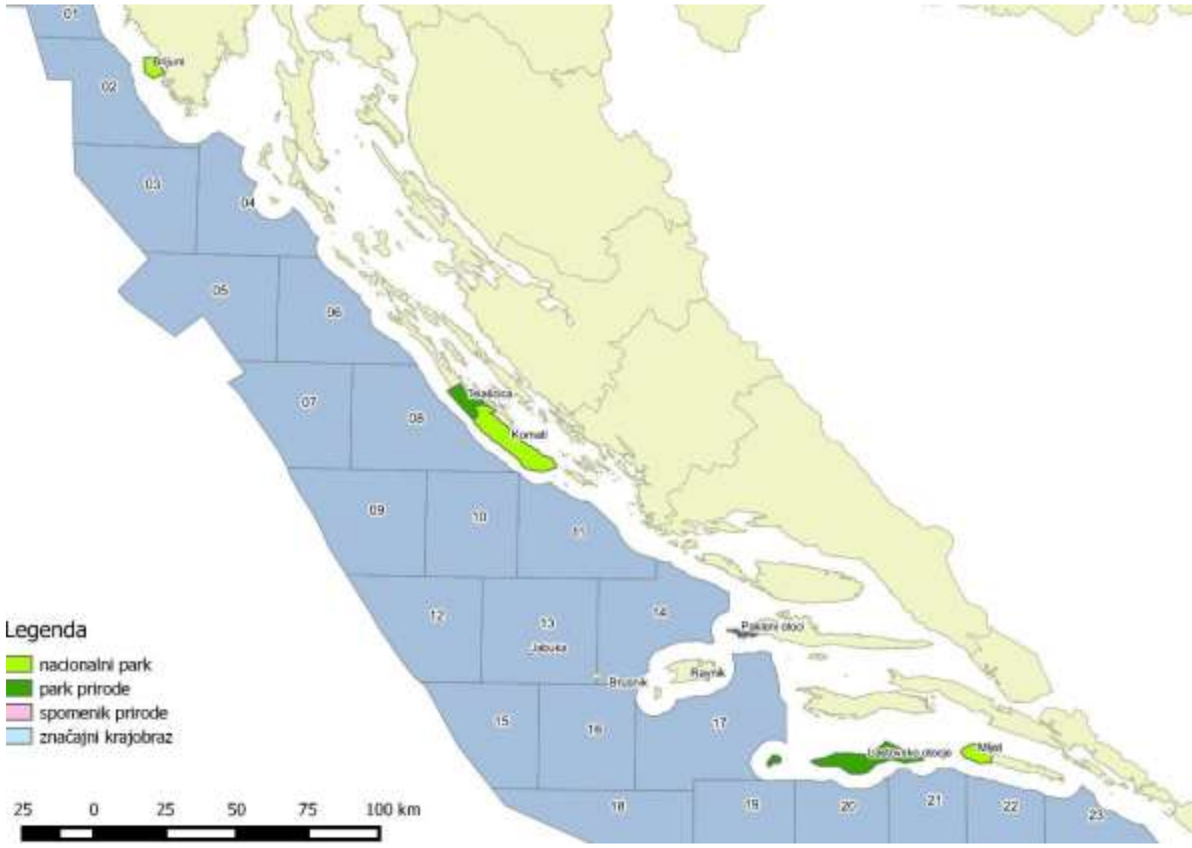
In the upper infralittoral zone the most developed are benthic algae communities. The upper limit on exposed sites consists of *Cystoseira amentacea var. spicata*, and on less exposed sites red algae *Corallina elongata* is present. Below this zone it the zone of many species from the genus *Cystoseira*. In addition, numerous epilithic species are located here. *Padina pavonica*, *Halopteris scoparia*, *Dictyota dichotoma*, *Saragassum vulgare* and many others.
On movable bottoms of this zone, the vegetation of benthic algae is poorly developed. However, seagrasses are well-developed in this zone (*Zosreta marina, Zostera noltii, Cymodocea nodosa*) and some species of photophilic algae. Small species from the genera *Acrochaetium, Ceramium, Fosliella, Sphacelaria, Myrionema, Feldmannia, Cladophora* and other grow as epiphytes on leaves of seagrass.
On the sandy bottom of the middle infralittoral zone, *Posidonia oceanica* seagrass meadow with a large number of epiphytic algae is developed. 230 species of benthonic algae have been reported on leaves and rhizomes of Posidonia in the central Adriatic.
The following communities dominated by macroalgae are distributed in the infralittoral zone: Euryhaline and eurythermal biocenosis, association with the species of genus *Gracilaria*, association with the species of genera *Chaetomorpha* and *Valonia*, association with the species of genera *Ulva* and *Enteromorpha*, association with the species Cystoseira barbata, association with the species of genus *Cladophora* and species *Rytiphloea tinctoria*, biocenosis of well-sorted fine sands, biocenosis of muddy sands on sheltered shores, association with the species *Caulerpa prolifera*, biocenosis of coarse sands and fine gravels mixed by waves, association with rhodolithes, biocenosis of coarse sands and fine gravels under bottom currents, maërl facies, biocenosis of infralittoral pebbles, biocenosis of *Posidonia oceanica* meadow, biocenosis of infralittoral algae, association with species *Cystoseira amentacea* (var. *stricata*, var. *spicata*), association with species *Corallina elongata*, association with species *Codium vermilara* and *Rhodymenia ardissonei*, association with species *Dasycladus vermicularis*, association with species *Ceramium rubrum*, association with species *Cystoseira crinita*, association with species *Sargassum vulgare*, association with species *Dictyopteris polypodioides*, association with species *Colpomenia sinuosa*, association with species *Halopteris scoparia*, association with species *Cystoseira compressa*, association with species *Pterocladiella capillacea* and *Ulva laetevirens*, association with species *Flabellia petiolata* and *Peyssonnelia squamaria*, association with species *Peyssonnelia rubra* and *Peyssonnelia* spp., facies and associations of coralligenous biocenosis, communities of infralittoral karst sea lakes, infralittoral communities with invasive species, community with species *Caulerpa taxifoila*, bommunity with species *Caulerpa racemosa.*
Lower infralittoral or circalittoral zone extends between the lower distribution limit of photophilic algae and seagrass and the furthest distribution limit of marine vegetation, that is, to the edge of the continental shelf. This zone most often extends from the depths of 35 (40) m to 120 (150) m. The following communities dominated by macroalgae are distributed in the circalittoral zone: Biocenosis of coastal detritic bottoms, association with rhodolithes, maërl facies, association with the species *Peyssonnelia rosa-marina*, association with the species *Laminaria rodriguezii*, Coralligenous biocenosis, association with the species *Cystoseira corniculata*, association with the indigenous species of the genus *Sargassum*, association with the species *Mesophyllum lichenoides*, association with the species *Lithophyllum frondosum* and *Halimeda tuna*, biocenosis of semi-dark caves and biocenosis of offshore rocks (on the edge of the continental shelf).
The elittoral zone extends between the depths of 120 (150) m and 200 (250) m, i.e. to the lower limit of vegetation dispersion in the Adriatic. Environmental factors in this area remain virtually unchanged. The algae found in this zone are a continuation of the vegetation of the lower infralittoral zone and include the following species: *Osmundaria volubilis, Sargassum hornschuchii, Laminaria rodriguezii, Halarachnion spathulatum* et al.
DESCRIPTOR
Seabed integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected (Descriptor 6).

3.6.8 Protected Areas

Pursuant to the Environmental Protection Act (OG 80/13), in the zone of potential impact of the FPP implementation, 9 natural values have been protected and entered in the Registry of Protected Natural Values of the Republic of Croatia kept by the Directorate for Nature Protection of the Ministry of Culture under different categories (Table 3.26, Figure 3.72)

Table 3.26 List protected areas in the zone of potential impact of the FPP implementation

Name of the protected area	Protection category	Proclamation year
Brusnik	Natural monument	1951
Jabuka	Natural monument	1958
Kornati	National park	1980
Lastovo Archipelago	Nature park	2006
Mljet	National park	1960
Brijuni	National park	1983
Telašćica	Nature park	1988
Ravnik	Significant landscape	1967
Pakleni Islands	Significant landscape	1968



Legend: national park, nature park, natural monument, significant landscape.

Figure 3.72 Cartographic representation of protected areas in the Republic of Croatia

3.6.8.1 Area Description

3.6.8.1.1 Brusnik

The Island of Brusnik has been protected since 1951 as a natural monument, special due to its geological structure, but also due to its flora and fauna which consist of some endemic species. The islet is 320 m long, 205 m wide, 30 m high, and covers a surface area of 4.5 ha. It is of volcanic origin, which is rare in Dalmatia, as the mainland and islands are predominantly limestone formations. It consists of igneous rocks. Anthropogenically formed pools for storing lobsters, the so-called "jastožere", are of special interest. They were used to store live lobsters, but are no longer used today. "Jastožere" fit into the natural environment and are a monument to the former way of life and local population's bond with nature. Brusnik is a habitat of seabirds, rabbits and a special endemic type of lizard. The most notable members of the flora are the endemic plant by the name "brusnička zečina" (subspecies of Dubrovnik Knapweed, Centaurea ragusina), plenty of capari bushes, small trees with tamarisk, but also other species of plants carried mostly by bird droppings or wind. However, the most numerous inhabitants of the islands are seagulls that nest on it.

3.6.8.1.2 Jabuka

The Island of Jabuka has been protected since 1958. It is located at a distance of approximately 70 km from Komiža on the Island of Vis. The island is of volcanic origin and it does not have a coast suitable for docking, nor a cove sheltered from the wind. The sea surrounding the island is very deep and there is almost no possibility of anchoring, while the rocks are smooth, without natural protrusions suitable for mooring of boats. Two endemic species live on the island: Podarcis melisellensis pomoensis and Centaurea jabukensis. Interestingly, due to a large quantity of iron ore - magnetite, found in the island rock, compasses of boats sailing near the islands of Brusnik and Jabuka become completely useless as the magnetic needles stop pointing to the right direction.

3.6.8.1.3 Kornati

The Kornati Islands National Park makes for a larger part of the Kornati archipelago, which was declared a national park in 1980, due to the exceptional landscape beauty, interesting geomorphology, very indented coastline and especially rich biocenoses of marine ecosystem. The Kornati archipelago stretches over an area of approx. 320 km^2 and includes around 150 land, permanently or occasionally above-sea units. This is the most indented island ecosystem in the Adriatic Sea. More than three quarters of the park consist of the sea, whose offshore is the most important feature of this protected area due to its diversity and rich underwater world.

In the view of natural sciences, particularly biogeography, the Kornati archipelago belong to a separate Adriatic vegetational sector of the Mediterranean region. An important feature of the sector is a mutual association of plants belonging to the east and west Mediterranean floral elements. This is the place where the western, that is, eastern borders of their respective areas meet. Significant floral communities: community of Phagnalon and Dubrovnik Knapweed (Phagnalo-Centaureetum ragusinae), community of rock plantain and sea lavender (Plantagini-Limonietum cancellati), Tree Spurge stand (Oleo-Euphorbietum

dendroidis) and forest community of myrtle and holm oak (Myrto-Quercetum ilicis) with all its degradative stages.
The fauna of the island is poorly explored, but two relatively larger colonies of yellow-legged gull (Larus michahelis) are most prominent, one with approx. 400-500 pairs, the other with around 200-300 pairs. Besides the colony of seagulls, the colony of the common shag (Phalacrocorax aristotelis desmaresti) is also present with approx. 150 pairs.

3.6.8.1.4 Lastovo Archipelago

On 29 September 2006, the Croatian Parliament declared the Lastovo Archipelago Nature Park. The Park consists of 44 islands, islets, rocks and reefs (the largest of them are Lastovo and Sušac) covering a total area of 53 km^2 of land and 143 km^2 of sea. It was declared a nature park due to its landscape value, thick forests and fertile fields rich with ponds, high coastal cliffs, land and sea caves, numerous rare sea and land species and habitats.
The Lastovo Archipelago is one of the richest and best preserved botanical areas in the Mediterranean. Among the 810 flora and fauna species recorded so far, there are also endangered species, as well as endemic and steno-endemic species. Besides Aurinia leucadea, an interesting and rare plant, one must point out Ampelodesmos mauretanica, a plant only found on Lastovo, as well as the steno-endemic and strictly protected species Biserrula pelecinus ssp. dalmatica. The flora includes 278 plant species; among the eight endemic ones, one must point out Brassica cazzaem, which grows in the cracks of rocks along and near the shore. Around 70% of the islands' surface is covered with forest, significant covers are holm oak (Quercus ilex) and aleppo pine forest (Pinus halepensis). Among fauna, the most notable are several species of dolphin: short-beaked common dolphin (Delphinus delphis), bottlenose dolphin (Tursiops truncatus) and Risso's dolphin (Grampus griseus), and turtles - loggerhead sea turtle (Caretta caretta) and green sea turtle (Chelonia mydas)
248 species of sea flora clearly speak of the richness of the underwater world. Rocky seabed regions are covered with colonies of photophilic algae, while shallow nearshore seabeds are covered with endangered and protected Neptune Grass (Posidonia oceanica). Skrivena Luka is an exceptionally rare habitat of the green alga Caulerpa prolifera, the only autochthonous Caulerpa in the Adriatic.

3.6.8.1.5 Mljet

Mljet was declared national park on 11 November 1960, and it includes the north-western part of the Island of Mljet stretching over an area of 5,375 ha of protected land and surrounding sea. Salt lakes, Malo and Veliko, are the most prominent locations of this area and an important geological and oceanographic phenomenon. Numerous endemic and endangered species attest to the importance of its protection. The vegetation of the Mljet National Park is very rich, which is why Mljet is called the Green Island. Mljet was declared a national park due to the following characteristics: Completely preserved forests of aleppo pine, holm oak and Maquis shrubland, salt lakes system interconnected to the sea, the islet of Sveta Marija, remains of a Roman palace and the entire fortification in Polače, remains of the Illyrian fortress on the hill above the Veliko salt lake, geomorphological site Zakamenica, Soline Channel and the Soline Gate.

3.6.8.1.6 Brijuni

Brijuni were declared national park on 27 October 1983 due to its indented coast, history and diverse flora and fauna. The national park is located several kilometres west of the Istrian coast, facing the settlement of Fažana, and consists of 14 islands and islets with the total surface of 33.9 km^2. Almost 700 species of plants and around 250 species of birds can be found in the park. The most specific characteristic of the Brijuni National Park is precisely its vegetation. By taking formerly agricultural land and clearing of part of the forest areas and turning them into landscape parks with vast open grasslands, extraordinary landscape that is unique on the Croatian Adriatic was created. Since people have been present on the Brijuni Islands for centuries, apart from the indigenous animals, the fauna on the islands, especially on the Veliki Brijun Island, has been increased with a number of imported species not characteristic of this habitat.
The Brijuni Archipelago is an important hatching grounds and a representative oasis (marine park) for the typical marine organisms of the northern Adriatic, that is, their habitats and communities. When it comes to protected marine vertebrates, the sea surrounding the Brijuni Archipelago is frequented by sea turtles and dolphins. The submarine world is rich with different species of sponges, shellfish, sea urchins, crabs, fish and others. The most common types of fish are seabass, gilt-head sea bream, mullets, soles, red scorpionfish, European conger, common dentex, brown meagre. In the past, in the waters of Brijuni a great number of species were found that was recorded in the Adriatic for the first time.

3.6.8.1.7 Telašćica

Telašćica was declared a nature park in 1988. It gained the status of a protected area already in 1980 due to its exceptionally valuable plant and animal life, geological and geomorphologic phenomena, valuable seabed colonies and interesting archaeological heritage.
The three basic phenomena are most characteristic of this are: the Telašćica bay as the largest and safest natural haven in the Adriatic, the cliffs of the Island of Dugi Otok, rising up to 200 m above the sea level and falling down vertically up to 90 m below the sea level, and the salt lake called Mir with its curative characteristics. The Telašćica bay is located on the south-east part of the Island of Dugi Otok, surrounded with 13 islands and islets, and also includes six islets of the inner bay. The flora and the fauna of the land and sea consists of more than one hundred species.

3.6.8.1.8 Ravnik

The Island of Ravnik (the Town of Vis) has been protected since 1967 as a significant landscape. It is located along the south-east coast of Vis. There are no buildings on the island, it is covered with the Mediterranean vegetation of Maquis shrubland and aleppo pine. It is significant as a nesting ground for the colonies of the yellow-legged gull (Larus michahelis). Abrasion caves, created by the structure of limestone layers and free impact of waves, are a prominent geomorphic phenomena. The cave on the Island of Ravnik is a representative example of such a cave and it is one of the largest and most beautiful caves of this type on the Croatian coast.

3.6.8.1.9 Pakleni Islands

According to the Environmental Protection Act (OG 80/13), the Pakleni Islands are a protected natural monument, in the category of protected landscape managed by the public institution governing protected areas of nature of the County. According to the Decision of the Croatian Parliament, the islands are under protection since 1972. From west to east, the islands are as follows: V. Vodnjak, M. Vodnjak, Karbun, Travna, Langva, Paržanj, Bobovac, Sv. Klement, Vlak, Dobri otok, Stambedar, Pločica, Hrid, Gojca, Borovac, Planikovac, Marinkovac, Jerolim, Galešnik and Pokonji dol. The islands are very attractive and popular tourist areas in the vicinity of the Town of Hvar. The vegetation is dominated by Maquis shrubland, aleppo pine and some agricultural crops. Some of the islands are still uninhabited, with untouched nature.

3.7 Marine and seabed pollution

3.7.1 Ecotoxic metals (Cd, Pb, Cu, Zn, Cr, Hg), organotin compounds and persistent organic pollutants (lindane, DDT, PCB) in the marine environment

Ecotoxic materials are introduced into the marine environment by natural and anthropogenic means, by river inflow, rock erosion or are introduced from the atmosphere. Some transition metals are necessary for metabolism of certain organisms at low concentrations, while elevated concentrations make them toxic. Other metals (Cd, Hg, Pb) have no biological role and are toxic even at low concentrations. These metals have bioaccumulation and biomagnification characteristics and pose a major threat to marine ecosystems. Some metals (Hg, Cd, Pb) are on the European Environment Agency's core set of indicators list for the marine environment, UNEP/MAP's Strategic Action Programme list (As, Cd, Cr, Cu, Hg, Ni, Pb) and priority substances list of the Water Framework Directive (Cd, Pb, Hg, Ni) (2000/60/EC).

Apart from metals introduced by natural means, persistent organic pollutants introduced by anthropogenic means exclusively are common in the marine environment. Main characteristics of these compounds are resistance to photochemical, chemical and biological degradation, high lipid solubility and semi-volatility. Negative effects of these substances are caused by their high toxicity and high level of bioaccumulation and biomagnification. The best known groups of these compounds are pesticides (DDT, aldrin, dieldrin, endrin, chlordane, heptachlor, mirex, toxaphene, hexachlorobenzene, etc.), industrial compounds such as polychlorinated biphenyls (PCBs), dioxins and furans.

Ecotoxic metals (Cd, Pb, Cu, Zn) in the marine environment

Regular monitoring of ecotoxic metals (Cd, Pb, Cu, Zn) in the marine environment of the Republic of Croatia is performed in the transitional and coastal waters sediment of the Adriatic basin, marine waters sediment and bivalves of the *Mytilus galloprovincialis* species. Bivalve samples from offshore islands were not included in this monitoring. The analysis of ecotoxic metal concentration in the marine environment has shown elevated concentrations of these substances in areas under anthropogenic influences.

Organotin compounds in bivalves

Organotin compounds are used for various industrial applications and the one posing the biggest threat to the marine environment is tributyltin (TBT), which is highly toxic and is on the list of priority pollutants in the framework of the European Water Directive (2000/60/EZ). This compound was used in antifouling paints for boats, but their use was fully banned in 2008. Between 2009 and 2010 organotin compound concentrations were measured in mussels sampled in the Central Adriatic area. The obtained data has shown a significant degree of TBT pollution on the Adriatic coast. Concentrations of these compounds have also been elevated in areas with significant anthropogenic influence.

Monitoring of the persistent organic pollutants (lindane, DDTx, PCBx) in the marine environment

Regular monitoring of lindane, DDT and polychlorinated biphenyls content in sediments and bivalves of the *Mytilus galloprovincialis* species is only carried out in the transitional and coastal water areas. Monitoring of the persistent organic pollutants (lindane, DDTx, PCBx) in sediment has been performed since 2006 and the level of these substances in tissues of the bivalves of the *Mytilus galloprovincialis* species has been monitored annually since 1998. Elevated concentrations of these compounds have been found in anthropogenic activity areas.

The document "Set of Features of Good Environmental Status (GES) of Marine Waters under the Sovereignty of the Republic of Croatia and Set of Targets for the Marine Environment Protection and Corresponding Indicators – draft" has defined descriptors (descriptions of good environmental status) which should be followed in order to ensure implementation of the Marine Strategy Framework Directive. For pollutants, two descriptors have been defined as follows:

- **Concentrations of pollutants of levels which do not cause pollution (Descriptor 8).**
- **Pollutants in fish and other seafood for human consumption do not exceed levels set out by the EU legislation or other applicable regulations (Descriptor 9 or D9).**

3.8 Cultural and historical heritage

The Croatian part of the Adriatic seabed is exceptionally rich in cultural heritage and each year new sites are added to the present plethora of archaeological sites.
Shipwrecks and other underwater archaeological findings are witnesses to numerous storms and battles that took place in the Croatian part of the Adriatic - in its coastal area, around islands and in the open sea. Valuable submarine archaeological findings can be literally found all over the Adriatic and their final count will probably forever remain a mystery.
So far, 176 underwater archaeological findings have been entered into the Republic of Croatia's Register of Cultural Property, ensuring them special legal protection and care. The abundance of findings also contributed to the development of underwater archaeology in Croatia and particular attention has been dedicated to the most threatened sites, protected *in situ*. Underwater cages are used as a means of site protection, enabling visitors to see them at the same time.
Unfortunately, the development of tourism and sport fishing as well as the development of underwater infrastructure put a constant pressure on physical integrity and security of the sites. Some of them have been completely devastated and raided, which caused irreplaceable damage to Croatian cultural heritage.

To this day, numerous underwater sites which significantly contributed to the improved knowledge of maritime history have been discovered and explored and their value for both Croatian and world's culture and science is indisputable (such as remarkably preserved and artistically exquisite statue from the Antiquity known as the Croatian Apoxyomenos discovered near Lošinj or numerous shipwrecks from the antiquity period carrying amphorae or more recent shipwrecks such as the Baron Gautsch shipwreck (Figure 3.73)). Simultaneously with the development of protection and exploration methods, legal acts regulating underwater activities were adopted, and in 2004 the Republic of Croatia ratified the UNESCO Convention on the Protection of the Underwater Cultural Heritage.

Figure 3.73: Protected amphorae site and Baron Gautsch shipwreck (source: Ministry of Culture, http://www.min-kulture.hr/default.aspx?id=4998)

The number of protected underwater sites per block is provided in table 3.27. Exact locations of the sites will be forwarded to investors awarded licenses granting them the right to exploration of hydrocarbons and direct grant of a concession in the event of a commercial discovery. On each of the sites all protection measures provided for protected underwater archaeological sites need to be taken, in the 300m diameter area, which constitutes a site's safety zone.

Table 3.27 The number of protected underwater sites per block, according to the Ministry of Culture's data from 2014

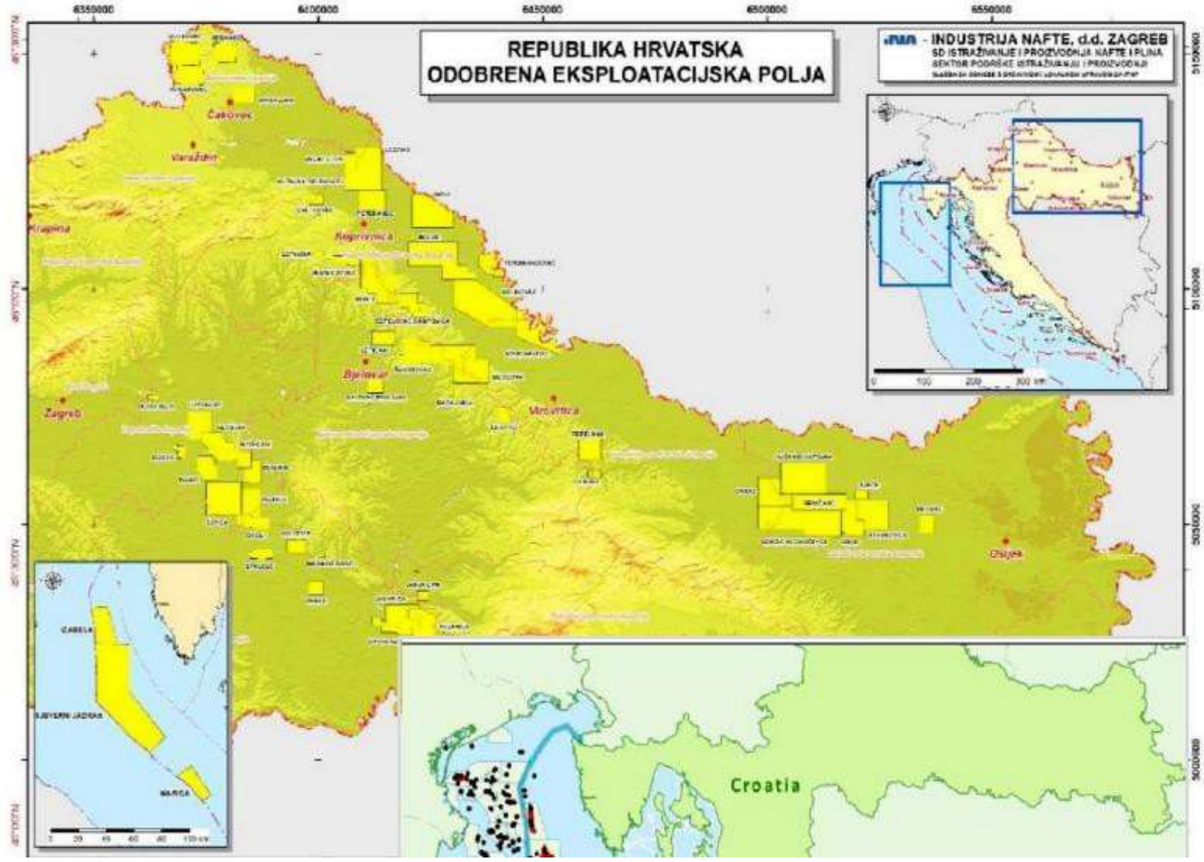
REFERENCE TO BLOCK NO. (according to documents published for the 1st licensing round for the exploration and production of hydrocarbons in the Adriatic published on 2 April 2014)	NUMBER OF PROTECTED ARCHAEOLOGICAL SITES
1	1
2	5
4	1
5	1
6	2
12	3
14	1
17	1
19	5
TOTAL NUMBER OF PROTECTED SITES	**20**

It is possible that the implementation of the FPP will have a negative impact on the cultural and historical heritage, but since exact locations of wells and supporting infrastructure are not determined within the framework of exploration and production blocks, that is, spatial locations of individual projects and structures are unknown, the evaluation will be processed (in accordance with applicable law and practice) through the mechanism of the Assessment of the project impact on the environment/Appropriate assessment of the project impact on the ecological network. Due to the above, in the subsequent steps of the Strategic Study preparation, cultural and historical heritage will not be analysed by all chapters and the Study will provide general recommendations for action within the framework of this environmental component.

3.9 Socioeconomic characteristics

3.9.1 Present state of exploration and production of hydrocarbons in Croatia

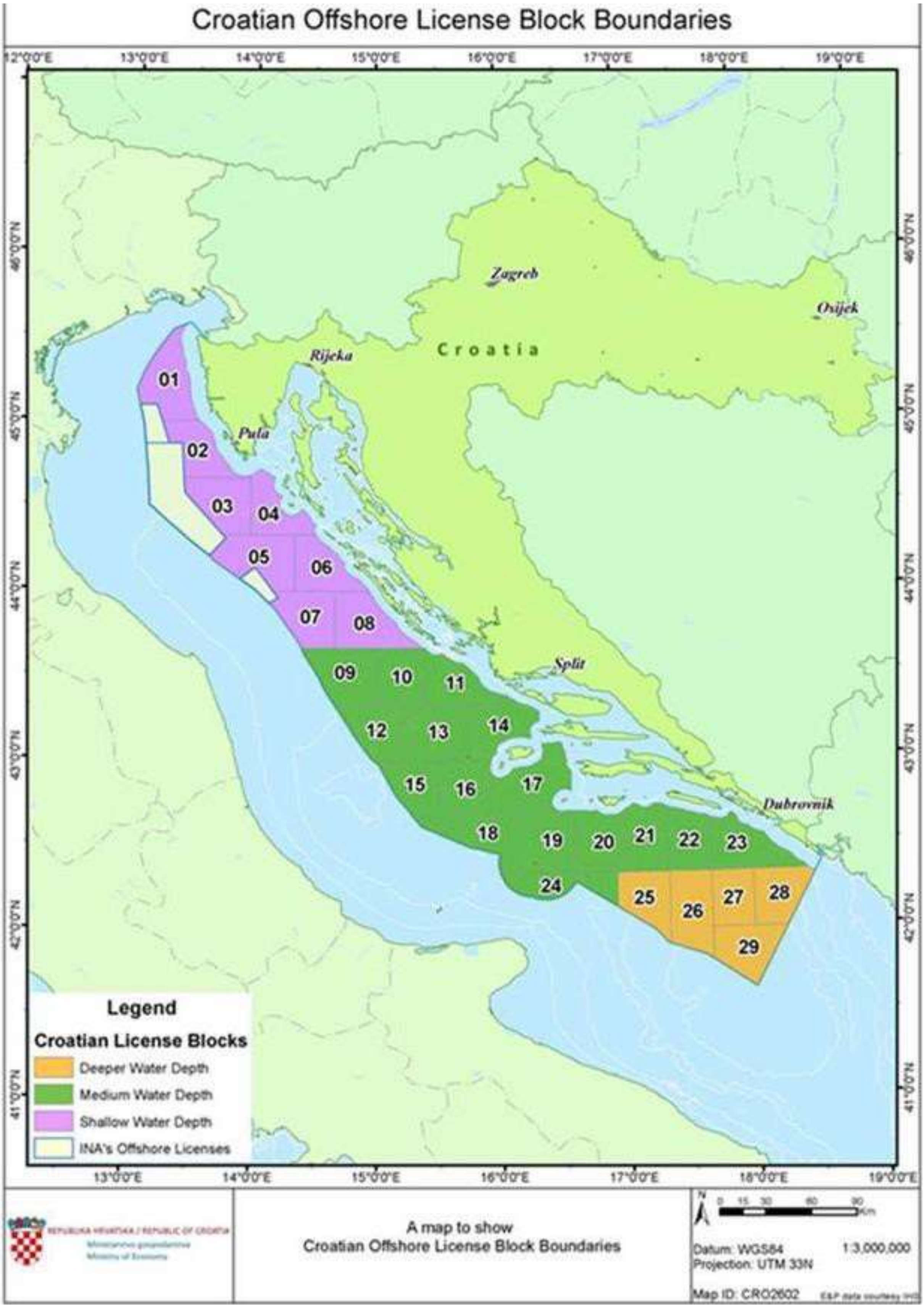
According to the present state of exploration and production of hydrocarbons in Croatia, the following have been approved: 60 hydrocarbon production fields. 57 production fields are located on the Croatian mainland, one of which hydrocarbon production fields are used for storing gas in geological structures (underground gas storage) and three of the hydrocarbon production fields are located in Croatia's epicontinental belt.



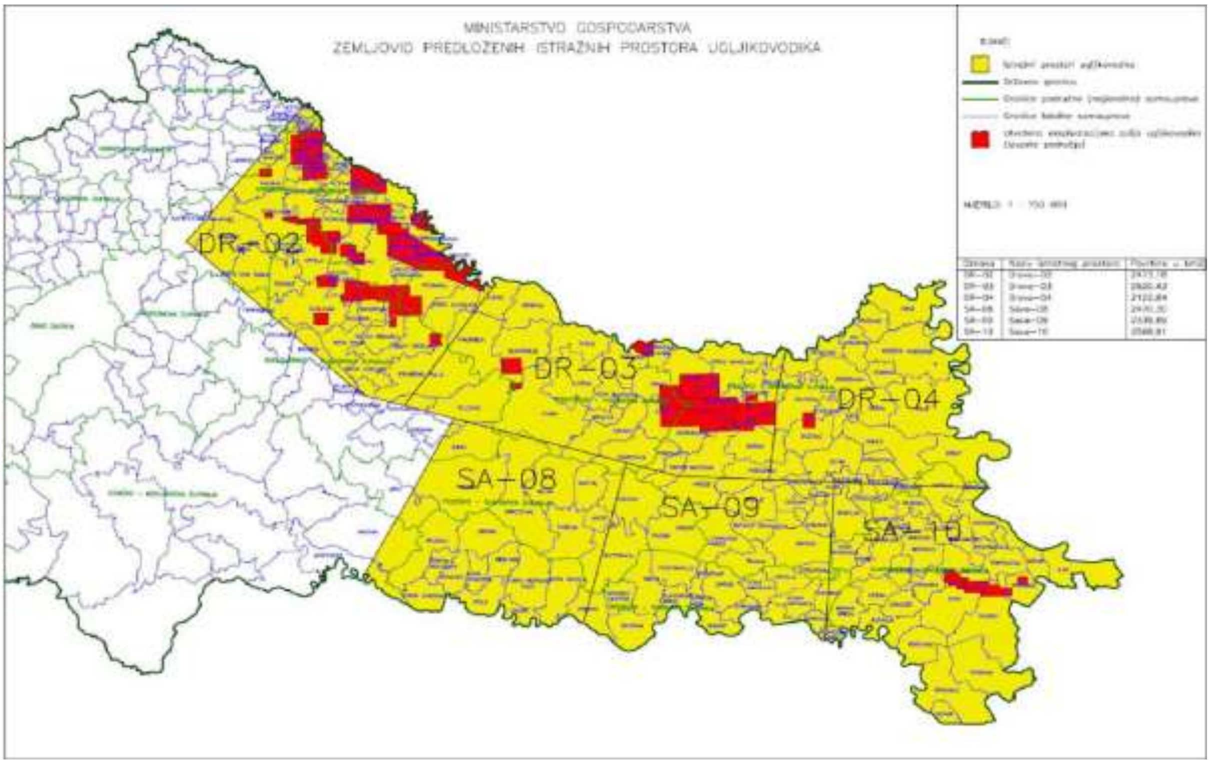
Legend: REPUBLIC OF CROATIA; APPROVED PRODUCTION FIELDS

Pursuant to the Act on the Exploration and Exploitation of Hydrocarbons, the Croatian Hydrocarbon Agency is the main authority. The Agency's main task is to define investigative activities in accordance with the best international practices, set out rules and conditions for the establishment of exploration and production fields, participate in tenders for exploration and production of hydrocarbons and monitor fulfilment of all contractual obligations in accordance with the strictest environmental standards.

The public offshore licensing round for the exploration and production of oil and gas in the Croatian part of the Adriatic, launched on 2 April this year, was closed on 3 November 2014. Interested applicants were given a chance to apply for exploration of 29 blocks covering an area of 1,000 to 1,600 square kilometres. 8 fields are located in shallow waters, 16 fields in medium water depth areas and 5 in deeper water depth areas. A total of 6 companies applied for the public licensing round and they expressed interest in 15 blocks. Blocks offered in the public licensing round are subject to the assessment of the Strategic Study.



The first onshore licensing round for licenses for the exploration and production of hydrocarbons was published on 18 July 2014. The area offered for the Licensing Round is part of the onshore belonging to the Republic of Croatia. Licences shall be granted to Selected Applicants to carry out exploration on blocks on the basis of competitive Applications under the terms and conditions provided in the Tender Guidance.



Legend: MINISTRY OF THE ECONOMY; MAP OF SUGGESTED HYDROCARBON BLOCKS

3.9.2 Economic characteristics

Economic effects on the economy of a country where petroleum operations are carried out have been divided into three groups (source CHA):

- **Direct financial gain** - inflow of funds in form of production sharing, royalty for recovered hydrocarbons (mining royalties), other fees related to the petroleum operations, direct and indirect taxes, surtaxes, contributions, quasi-fiscal payments and other public charges that the investor will be required to pay,
- **Direct economic effects** - direct effects to the economy caused by the demand for goods and services of industries directly related to the petroleum operations (a direct result of capital investments and operational costs of activities),
- **Indirect economic effects** - side effects impacting the economy, caused by the demand for goods and services of industries dependent on industries directly related to the exploration and production of hydrocarbons process.

3.9.2.1 Direct financial gain

Financial model analysis in contracts with oil companies
The analysis conducted by consultants IHS Global Ltd. London covered 145 countries all over the world which defined different financial model in contracts on the implementation of hydrocarbon exploration and production activities concluded with oil companies. Financial models are generally divided into models based on hydrocarbon production sharing (recovered quantities) and models based on royalties for recovered hydrocarbons. These main financial models can be combined and such combinations are considered to be hybrids of sorts.

Consultants IHS Global Ltd. London has identified as many as 220 different kinds of financial models in 145 countries all over the world. The reason why there are more financial models than the countries where they are used is because different financial models are applied to specific geographic areas (onshore, offshore or deep offshore areas), that is, to specific geographical conditions or for some other reasons.

Out of the specified 220, as many as 116 financial models were based on hydrocarbon production sharing (53% of the total number of all identified financial models), the approach chosen by Croatia as well. Models based on hydrocarbon production sharing include a series of financial components and contractual requirements that will be further explained below.

One-time fees

A signatory bonus is a one-time fee paid at the time of the signing of the production sharing agreement by the host country and the investor. This fee is paid for each individual agreement (per block) and it is usually defined in tender documents. The signatory bonus may be defined as a fixed amount or as a component subject to bidding, in which case, the minimal sum is limited in tender documents.

A discovery of hydrocarbons bonus is a fee paid by the investor to the host country after commercial profitability is confirmed, that is, after the production field development plan is accepted by the host country.

Hydrocarbon production bonuses are fees payable during the production period for specific amounts of production reached. Production is usually measured in a certain period (usually monthly or quarterly) and fees are calculated based on the achieved production; however, it is also possible to choose the cumulative production monitoring variant which means that fees are paid after a set quantity of cumulative production is achieved, regardless of the period of achievement.

One-time fees are the investor's expenses which are not included in the recovery of the investor's costs under the agreement on production sharing, however, they are considered as items of expenditure in income tax, in countries with such tax systems.

Administrative fee

The administrative costs fee is a fee for settling costs of agreement administration, including, and not limited to, costs of monitoring and control of the investor's performance of undertaken obligations in accordance with the license and the agreement, costs of support to the investor and coordination between the investor and competent national authorities regarding the investor's fulfilment of obligations based on issued licenses and concluded agreements, costs of support to the investor for obtaining all the necessary documents and papers required for hydrocarbon exploration and production. The amount of this fee is usually fixed, however, including the inflation rate into the fee to neutralise the effects of money devaluation is recommended.

Royalty for recovered hydrocarbons

Royalty for recovered hydrocarbons secures the host country a monetary flow from the beginning of the commercial production of petroleum projects and is calculated as a specific percentage of the total amount of the total production market value. Oil companies are not in favour of this type of levy, especially as part of models based on production sharing since this specific fee is a production tax of sorts and for the investor, it means that the production quantity available for cost recovery is reduced and the point of time when the oil company achieves return on its initial investment is postponed. The percentage used to calculate this fee is usually fixed and it can be defined in a specific range, depending on certain factors, i.e. the average daily production levels. In Europe and in the Mediterranean, royalties for recovered hydrocarbons are usually calculated using a straightforward procedure, mostly a 5%, 10% or 12.5% rate.

Hydrocarbon production sharing

The agreement on production sharing sets out production sharing in detail and its goal is to enable profit sharing between the host country and the investor (oil company) so the investor could realise cost recovery and get return on investment by sharing the remaining part of the production. Three elements of production sharing (cost recovery, remaining production sharing and profit sharing) are described below.

Recovery of costs

In the model based on hydrocarbon production sharing, the investor recovers the costs from the remaining production, after production used for business operations is deducted and after royalties for recovered hydrocarbons are deducted. There is a number of factors that affect the investor's cost recovery, such as the cost recovery period, annual recovery rate and cost recovery ceiling.

Cost recovery period - eligible costs are compensated to the investor periodically (quarterly or annually), starting from the beginning of production. Costs not compensated in one accounting period are transferred to the next period, until they are full compensated (but only in the duration of the agreement).

Cost recovery rate - defines the percentage of the investor's costs that will be taken into account during recovery calculation. Cost recovery ceiling - max. production quantity is determined, based on which the investor can achieve cost recovery in a specified accounting period. The cost recovery ceiling usually aims at ensuring that a production share is available for distribution, securing the host country a monetary flow from profit sharing. The cost recovery ceiling in a specified accounting period ranges between 50% and 100% of production value minus the royalties for recovered hydrocarbons.

Production left for sharing

Production left for sharing between the host country and the investor is a part of the production obtained by deducting the royalties for recovered hydrocarbon and the investor's costs from the total productions, in accordance with the defined cost recovery ceiling.

Profit sharing

Profit sharing is performed over hydrocarbon production left for sharing. There is a number of methods for sharing profit between the host country and the investor, but most financial models use a specific type of a decreasing scale depending on the calculated R factor, while only a small number of models use a simple calculation with a fixed sharing percentage. The R factor is a project profitability measurement. The R factor value used in a current accounting period, quarterly or annually, is a ratio of the investor's cumulative net revenues based on recovered hydrocarbons until the end of the previous accounting period and cumulative capital expenditures based on recovered hydrocarbons until the end of the previous accounting period. The investor's cumulative net revenues are usually equal to the sum of the investor's cumulative cost recovery and the investor's cumulative share in profit, minus the investor's cumulative operational costs.

Tax system

The usual taxes from the aspect of profit include income tax. Tax systems in certain countries also impose additional income taxes and other types of levy in form of taxation of dividends, profit share payments, etc.

3.9.3 Sociological characteristics

In the period between 29 August 2014 and 29 September 2014 Internet consultation with the public regarding the Decision on the Development of the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic and the Decision on the Implementation of the Procedure for Strategic Assessment of the Environmental Impact of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic was held. During the Internet discussion, comments to the proposals of the Decisions were submitted by the following representatives of the public:

1. Lana Ujdenica
2. Špiro Tičić
3. Dunja Ribarić
4. Tamara Eskić
5. Petra Dizdar
6. Maria R. D'Orsogna, on behalf of 586 signatories, legal and natural persons from 16 World countries
7. "Dignitea", Organisation for Sustainable Development of Hvar
8. WWF Mediterranean Programme Office
9. Koraljka Polaček
10. Zelena Istra (Green Istria) Organisation
11. "Eko – Zadar", Organisation for the promotion of organic food production, environmental protection and sustainable development
12. Zeleni forum (Green Forum) – civil society organization network for environmental protection
13. Sunce, organisation for nature, environment and sustainable development
14. Iva Anzulović
15. Pan, organisation for nature and environment protection
16. Šime Validžić
17. Zelena akcija (Green Action)/FoECroatia
18. Brodsko ekološko društvo (Brod Ecological Society) - BED
19. Vladimir Bajzec
20. PhD Draško Holcer, PhD Nikolina Rako Gospić, PhD Peter Mackelworth, Plavi svijet (Blue World), Institute of Marine Research and Conservation

The representatives of the public who commented on the above specified Decisions consent to their comments' publication. Competent authority representatives replied to all of the comments.

The comments differed in tone and none of them expressed a positive attitude towards the Decisions, and they can be divided into three main groups.

1. Those that unconditionally oppose the exploration and production of hydrocarbons in the Adriatic – comments 1, 2, 3, 4, 5, 6, 7, 9, 14, 16, 19.
2. Those that point to shortcomings of the Decision on the Implementation of the Procedure for Strategic Assessment of the Environmental Impact of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic – comments 8, 10, 20.
3. Those that point to shortcomings of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic and the shortcomings of the Strategic Study - comments 11,12, 13, 15, 17, 18.

Integral comments, together with the replies, have been published on the Ministry of Economy website.
http://www.mingo.hr/public/Savjetovanja/Komentari_13_10_14.pdf

3.10 Economic characteristics

3.10.1 Fisheries

According to available indicators, the overall share of the fisheries sector in the gross domestic product of the Republic of Croatia is between 0.2 and 0.7%.

Croatian fisheries is divided into fish farming, catching and processing. With regard to fishing, according to the classification in 2013, vessels were divided into vessels for commercial fishing and vessels for small-scale coastal fishing. At present, small-scale coastal fishing falls into the category of commercial fishing. In 2013, 4,270 vessels belonged to the category of vessels for commercial fishing, whereas the category of small-scale coastal fishing vessels numbered 9000 vessels (Source: Operational Programme for Maritime Affairs and Fisheries of the Republic of Croatia for the Programming Period 2014-2020, programme starting points and goals (abstract)). Number of vessels that will be entitled to small-scale coastal fishing in 2015 will be 3,500. The most significant part of Croatian fishing fleet by total tonnage are purse seine vessels, and the most significant part of its fishing fleet by total power are multi-purpose vessels. The total catch of the fishing fleet in 2013 was 75,274 tonnes. Surrounding fishing gear (purse seine nets) accounts for, by far, the largest amount of catches (89%). Trawl fishing gear account for about 8% of the catch, while bottom-set gillnets account for little more than 1% of the total catch.

To gain insight into the catch in the Adriatic Sea (Figure 3.74), catches made by the two largest fleets in the Adriatic Sea - Croatian and Italian fishing fleet - are compared. In the total catch, Croatia accounts for only 24%, and the situation is even worse if we consider only the trawl fishing: the Croatian share in this regard accounts for about 8% of the total catch. If we consider only the area ofthe Northern and Central Adriatic (GSA 17), the Croatian share makes up about 30%, and trawl fishing around 12-14% of the total catch. A great discrepancy in the level of exploitation primarily of demersal (trawl) resources is even more apparent if we compare catches of individual fishing fleets with spatial distribution of demersal stock in the Adriatic Sea, obtained on the basis of international scientific research (MEDITS program). According to these data, 58% of the total biomass of demersal resources is located in the Croatian territorial sea, 18% in the ZERP zone *(Ecological and Fisheries Protection Zone* of the Republic of Croatia), and only 24% in the Italian territorial and extraterritorial waters.

Figure 3.74 Division of the Croatian fishing sea

Legend: unutarnje more – internal sea; teritorijalno more – territorial sea

By comparing the annual catch of Croatian and Italian fishermen (Figure 3.75), a massive disproportion is noticed, which results in different level of fishing effort and level of exploitation, which ultimately results in large differences in the state of renewable resources along the east and west coast of the Adriatic.

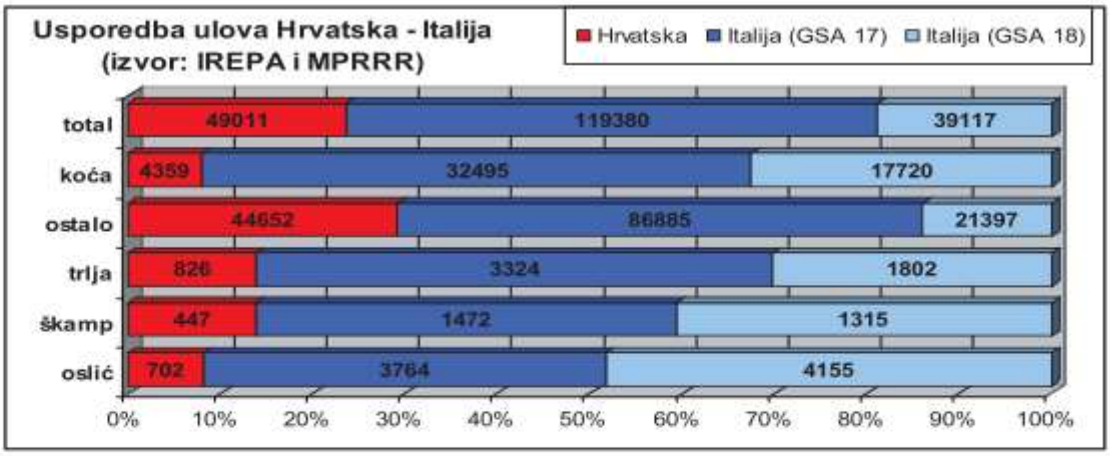


Figure 3.75 Comparison of catches in the Adriatic Sea between Croatia and Italy (Source: Ministry of Agriculture – Fisheries Department)
Legend: Comparison of catches Croatia – Italy (Source: The Institute for Economic Research in Fishery and Acquaculture (IREPA) and Ministry of Agriculture, Fisheries and Rural Development (MPRRR); koća – trawl, ostalo – other, trlja – mullet, škamp – Norway lobster, oslić - hake

3.10.1.1 Fishing zones

The fishing sea ofthe Republic of Croatia is divided into 11 fishing zones with 37 fishing sub-zones. Out of 11 fishing zones, part of Area A and Area E, F and G are located in the inner fishing sea of the Republic of Croatia, and part of Area A and Area B, C, D, H, I, J and K are located in the outer fishing sea of the Republic of Croatia (Figure 3.76).
Administrative classification of the fishing sea has been established for the purpose of management and data collection. Fishing sea is the sea area where the Republic of Croatia exercises its power and certain sovereign rights and jurisdiction relating to fishing, and spatially it includes the territorial seas of Croatia and the ZERP area (or the space over which the Republic of Croatia holds certain sovereign rights and jurisdiction).

Figure 3.76 Fishing zones in the Adriatic

Zona	Srdela	Inćun	Miješana mala plava riba	Trlja od blata	Oslić	Muzgavac	Škamp	Listovi	Ostalo	UKUPNO
A	6.134	489	213	91	5	229	1	244	985	8.391
B	20.780	4.993	1.126	384	56	62	4	9	611	28.025
C	1.823	1.611	141	283	265	74	213	22	927	5.359
D	154	865	44	45	55	5	14	8	287	1.477
E	8.006	4.973	517	38	259	40	45	16	891	14.785
F	3.202	410	110	50	21	10	1	2	418	4.224
G	5.847	759	181	208	103	29	2	3	574	7.706
H	0	0	1	2	0	2	0	14	7	26
I	0	282	0	1	0	1	0	0	140	424
J	0	0	0	0	12	0	3	0	97	112
K	0	0	0	0	1	0	1	0	4	6
UKUPNO	45.946	14.382	2.333	1.102	777	452	284	318	4.941	70.535

Figure 3.77 The catch of some important species of marine organisms per zones in 2011 (t) (Source: Ministry of Agriculture – Fisheries Department)

Legend: Zona – zone, srdela – sardine, inćun – anchovy, miješana mala plava riba – mixed small pelagic, trlja od blata – red mullet, oslić – hake, muzgavac – octopus, škamp – Norway lobster, listovi – soles, ostalo – other, ukupno – total

3.10.1.2 Assessment of stock status

Demersal resources

Taking into account the technical characteristics of the trawl fleet in Croatia (small-size, old and poorly equipped vessels), it is logical that the majority of the catch is realized in the coastal areas, while the trawl catch outside the territorial sea (H, I, J, and K zones) is almost negligible and makes up to only 0.6% of the total catch. The bulk of the catch comes from the open Central Adriatic – the wider area of Jabuka Pit (fishing zone C), and accounts for about 38% of the total catch. The most important commercial species in this area are hake, Norway lobster and white octopus. The second biggest fishing zone by annual catch is the zone A (15%). The structure of the catch depends significantly on the season, but it is dominated by octopodes, squid, whiting, mullet and sole. There is a similar structure of the total catch in the fishing zone B (14.5%), where the most important species are red mullet, hake and octopodes. The catch in channel areas of the Northern Adriatic (zones E and F) constitutes about 11.5%, and the dominant species are hake, mullet, Norway lobster and octopodes. Catches in the Central Adriatic channels (Zone G) account for up to 10% of the total catch, and the dominant species are hake, red mullet and octopodes. The smallest part of the catch comes from the fishing zone D (open Southern Adriatic), because this is a relatively deep area used by a small number of fishing vessels. Its share in the total catch is 8%, and the most important species are hake, mullet and shrimp (Source: Croatian Operational Programme for Fisheries 2007-2013)

Figure 3.78 shows the movements of fishing vessels in the Adriatic in 2013 in relation to the blocks proposed in the FPP.

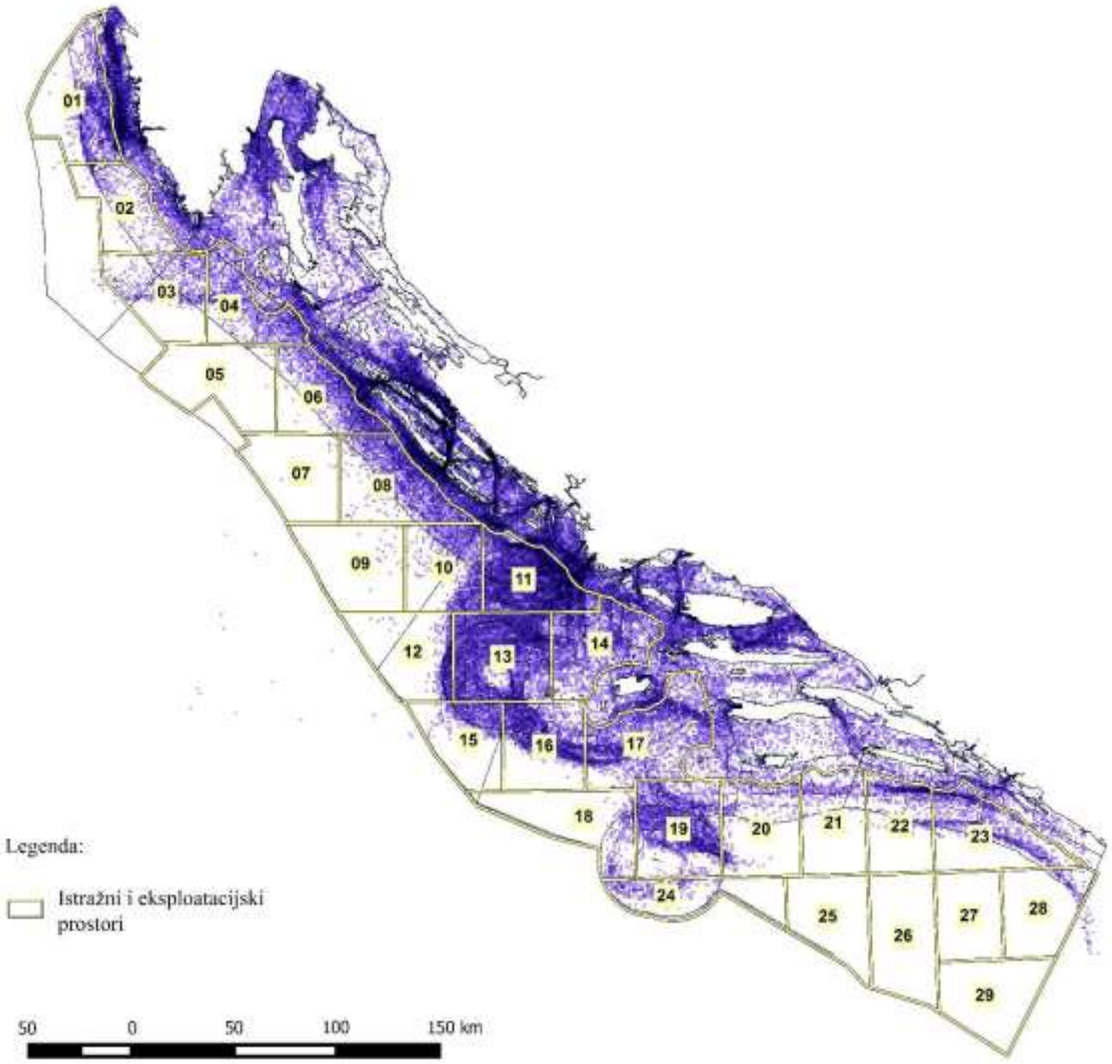


Figure 3.78 shows the movements of fishing vessels in the Adriatic in 2013 in relation to the blocks proposed in the FPP. Ministry of Agriculture – Fisheries Department)

Legend: Istražni i eksploatacijski prostori - blocks

By comparing the total biomass (according to MEDITS expedition) with the catch realised in each fishing zone, results show a disproportionate exploitation of resources. Highest level of exploitation occurs in fishing zones C and A, and the most favourable situation is in channel areas (zones E, F and G). Trawling activities in the Republic of Croatia are highly seasonal; therefore the total catch and catch composition depend on the period when the catch was made. Peak values of the catch occur in the autumn. Decline in the catch occurs during winter months due to poor weather conditions and small number of fishing days. Catch increases during the spring period are due to hake, octopodes and Norway lobster catch.

Croatian fishing sea constitutes about 61% of the GSA 17, but it should be noted that the Croatian fishing fleet exploits mainly the inner and territorial fishing sea (which together account for about 34% of the GSA 17). Of the total number of trawlers in GSA 17, Croatian vessels account for about 40%, of the total kW 31%, and of the GT 27%. Croatian trawl catch accounts for only 14% of the trawl catch in GSA 17. Bearing this in mind, one can see clear differences in the level of fishing effort, exploitation and catch in GSA 17, which results in a different state of the resources. However, due to the fact that the most commercially important stocks of biologically unique populations are subject to migration, over-exploitation in one area will soon be reflected in other parts of the sea.

According to the available results (DemMon Project), most of the trawl catch consists of bony fish (72%), followed by cephalopods (13%), crustaceans (8%), cartilaginous fish (6%), and molluscs (approximately 1%) and the main species in catches in 2011 were red mullet (24%), hake (15%) and octopodes (9%).

As for most demersal stocks in GSA 17, classic assessments of demersal resources were not done, while status assessment of resources in Croatian fishing sea can be made based on the movement of the biomass index calculated according to MEDITS Programme. In fact, MEDITS Programme represents a long series of data on the status of resources in the Adriatic Sea, collected using unified methodology, which as such provides a real picture of the status of resources. Given the fact that almost all commercially important stocks for trawl fishing in the Adriatic Sea are biologically unique populations harvested by fishing

fleets of different states, the correct picture of the situation can be obtained only when the resource status describes the entire area. When describing the status, biomass index, i.e. biomass of species or groups per unit area (kg/km2) has been used, as well as percentage distribution of individual species biomass in the Croatian territorial sea and in the rest of the Adriatic. Biomass index for species harvested during MEDITS expeditions shows extreme fluctuations for the study period, with two periods marked by distinctly negative trends: first in late nineties and second in recent years. Distinct decrease in biomass index in recent years is evident in the Croatian territorial sea, as in the rest of the GSA 17. The mean biomass index for the Croatian territorial sea was 625 kg/km2, and for the rest of the Adriatic it was 386 kg/km2, i.e. the biomass index ratio was 1.62:1. During the study, 50% of the biomass was typically located in the Croatian territorial sea; however, the percentage varied from 40-60% between years (Source: Croatian Operational Programme for Fisheries 2007-2013)
Much better picture of the status of demersal resources can be obtained by studying the MEDITS Programme target species biomass index, i.e. commercially important species biomass index. As in the previous case, pronounced inter-annual variations of biomass index can be noticed, with a marked negative trend in recent years. The mean biomass index for the Croatian territorial sea was 435 kg/km2, and for the rest of the Adriatic it was 169 kg/km2, i.e. the biomass index ratio was 2.57:1. During the research, majority of the total target species biomass was also located in the Croatian territorial sea and averaged about 60%.
So called BOI species – species that live on or close to the seabed, are usually taken as status indicators for demersal settlements. Population density of such species is much higher in the Croatian territorial sea than in the rest of the Adriatic. The mean value in the Croatian territorial sea was 88 kg/km2, and in the rest of the Adriatic 21 kg/km2. Biomass index ratio was 4.13 : 1, and almost 70% of their total biomass was located in the Croatian territorial sea.
In addition to the description of distribution of demersal species, critical areas for certain species in the Adriatic Sea can also be located through joint research that covers the entire area of the GSA 17. One such place is the open middle Adriatic – wider area of Jabučka kotlina (Jabuka Pit), which is a spawning and nursery area for a large number of the most important demersal species (hake, monkfish, octopus, Norway lobster) As the largest part of this area is located in the extraterritorial waters of the Adriatic (ZERP zone and Italian continental shelf), measures to protect resources in this area require significant coordination of actions of states exploiting these resources. Stock status assessments are made for some significant commercial species in trawl (and generally demersal) fishing. Assessment of **red mullet** shows a stable SSB (spawning stock biomass) for the last four years, which is about 6,000 tonnes. Analyses show stable recruitment during this period, with highest values recorded in 2011. The stock can be considered sustainable, with certain limitations. It is important to bear in mind the difference between levels of species exploitation in Croatia and Italy, as well as the fact that the Italian fishing is mainly based on juvenile harvesting and Croatian on harvesting of mature specimens. Assessment of **hake** shows a decline in SSB in recent years. Recruitment has fluctuated during the study period, and it shows a decline in recent years. The current value of fishing mortality is greater than F0.1, which indicates overfishing. Recommendation is to reduce fishing effort, but also in this case one should bear in mind the great differences in the level of exploitation. Preliminary assessment of **Norway lobster** was made for the stock inhabiting the open Central Adriatic (Jabuka Pit). Analyses showed a strong decline in SSB, a strong decrease in recruitment and increased fishing mortality. Present value of fishing mortality is well above F0.1, and the population is overfished. Implementation of urgent measures to reduce fishing mortality is recommended. Assessment of **common pandora** shows SSB increase during the study period. Recruitment in recent years shows a decline. Fishing mortality trend is declining, however, as the current fishing mortality is higher than F0.1, the population is considered overfished, and reduction of fishing mortality is recommended. However, given the stable SSB, the decline in recruitment may be related to environmental factors.
Having regard to the decline in biomass index in recent years of a considerable number of demersal species throughout the Adriatic Sea and in the Croatian territorial sea, as well as the decline in the total catch of commercially important species in the trawl fishing in the Republic of Croatia, the management plan for trawling is aimed at bringing into proportion the intensity of exploitation with the stock status, thus creating conditions for the establishment of long-term sustainable management and protection of renewable resources.
Responsibility for the current state of resources in GSA 17 lies on all the countries involved in fishing, however, their share of responsibility is not equal but proportional to a fishing effort and catch realized by an individual fishing fleet harvesting the unique biological resources.

Rsources of small pelagics

Although "srdelara" purse seine net fishing takes place in all fishing zones of the Republic of Croatia, four fishing zones account for the largest amounts of catches. The greatest catches by these purse seiners were made in fishing **zone B** (outer Northern Adriatic), where catches make up an average of 41% of the total catches of small pelagics made with this type of fishing gear. The average lowest catches of small pelagics by purse seiners have been recorded in fishing zone H (ZERP), whereas in fishing zone K there were almost no catches during a four-year period. In the last four years, the share of pelagics in the total catches of the Republic of Croatia fluctuated from 84.5% (2008) to 91.6% (2011). On the basis of the recorded values, it has been noticed that the catches of these two economically most important species vary both on the multi-annual and annual scale.

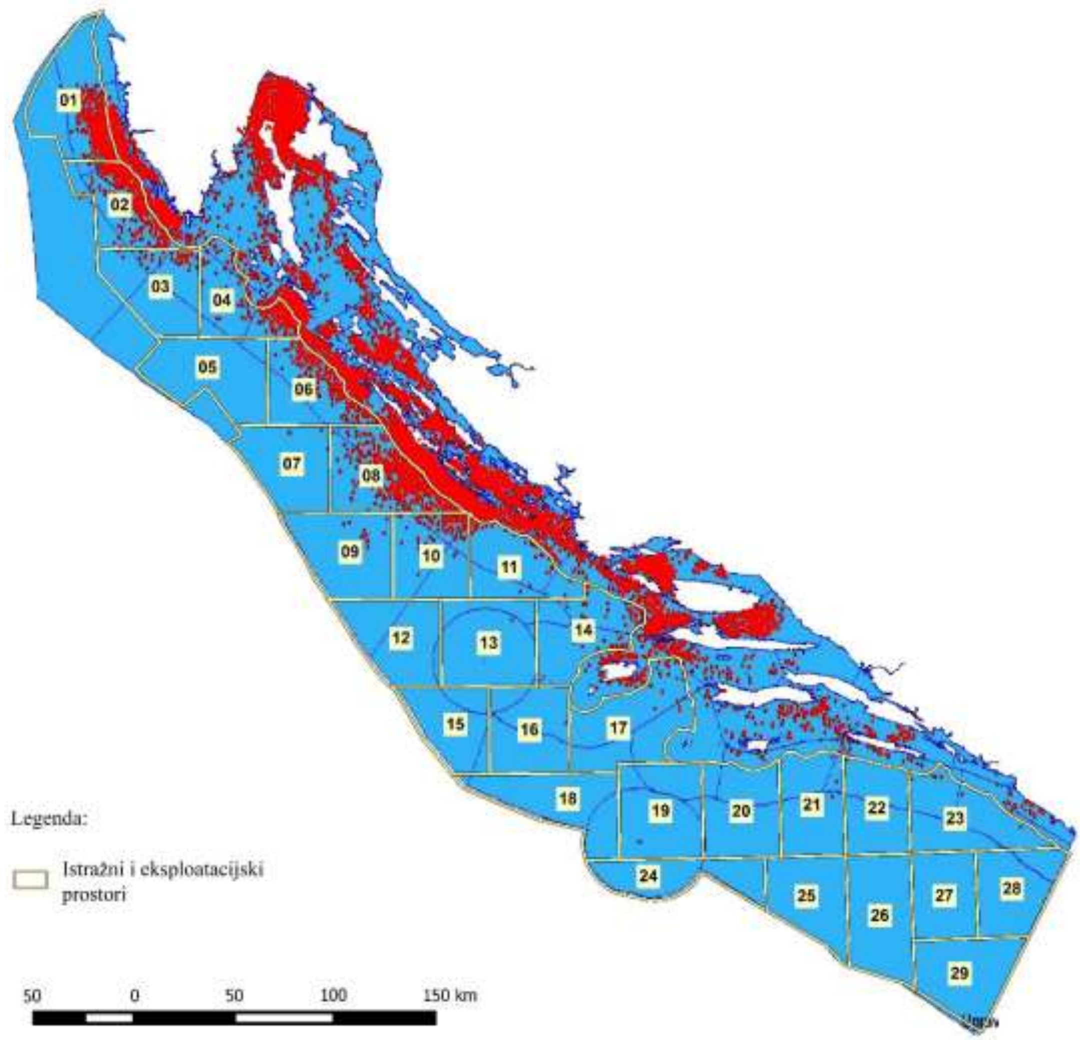


Figure 3.79 Areas of purse seining in the Adriatic in 2013 in relation to the blocks proposed in the FPP.

Legend: Istražni i eksploatacijski prostori - blocks

Models estimating the biomass of small pelagics in the Adriatic Sea include the direct method of using the echo-sounder, statistical data on the catches and the collection of biological parameters of the population, along with the inclusion of these data into indirect estimation methods – Virtual Population Analyses (VPA) and Integrated Catch Analyses (ICA). The VPA and ICA methods are used for reconstructing the biomass of the harvested stock through the data on the catches and biological parameters (length frequency, age structure, first sexual maturity, natural mortality). Estimation of the biomass of both sardines and anchovies includes the data for specific species of all the countries involved in fishing, and the biomass of these two species thus obtained refers to the entire GSA 17 area, that is, to the stock exploited by Italy, Slovenia and Croatia.

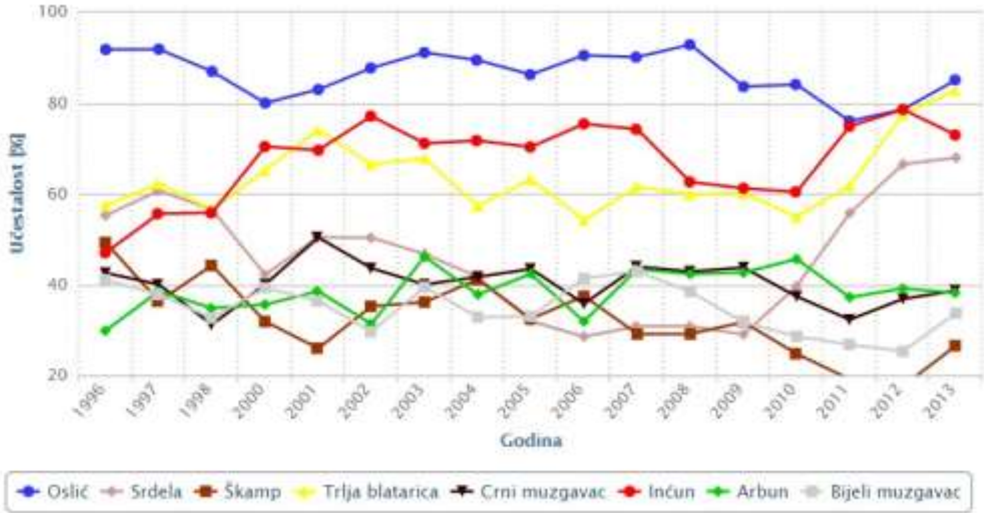
The total sardine biomass in the entire Adriatic varied greatly in the past. Small pelagics biomass is generally expected to fluctuate, since the species in question have short lifespan and relatively high natural mortality coefficients, and their recruitment is extremely dependant on environmental factors. Sardine biomass has constantly grown in the last 10 years, although the size of the biomass is still not at the level of the biomass of the 1980s. However, it should be taken into consideration that the statistical data, as well as the analysis of all collected data, have changed during the collection period. In addition, it is important to note that in 2011 catches on both sides of the Adriatic recorded high values. Taking all of this into consideration, the current biomass of this stock in the Adriatic Sea can be described as intermediate.

The values of the estimated anchovy biomass varied somewhat significantly in the last 10 years. From 2000 to 2005, the anchovy biomass grew substantially, after which the values somewhat decreased, and in the past 3 years they have risen again. Generally speaking, from 2000 to 2011 the anchovy biomass has recorded an increasing trend. Taking all of this into consideration, the status of the anchovy stock in the Adriatic Sea is considered sustainable.

In May 2013, the GFCM (General Fisheries Commission for the Mediterranean) has adopted a multi-annual management plan for fisheries on small pelagic stocks in the GSA 17. The plan stresses that no limit reference points in line with the MSY (maximum sustainable yield) have been identified so far, and that in the absence of such indicators approximate indicators are used. The exploitation rate is projected to be maintained at less than 0.4 per year on appropriate age groups, while the SSB is projected be maintained above 109,000 tonnes for sardine, and 250,600 tonnes for anchovy. The levels of fishing fleet capacity and fishing effort shall be maintained at the levels exerted in the year 2011, with certain limitations. These measures aim to maintain stable state of exploited species populations. Considering the need for ensuring long-term preservation of reference SSB on the agreed levels, and having regard to the socio-economic dimension of this kind of fishery, the measure to reduce fishing effort and fishing fleet capacity in this fishery segment is directly correlated with the achievement of objectives of the International Multiannual Management Plan.

3.10.1.3 Structure of economically important fish populations

The largest part of the catch is represented by small pelagic species (sardine and anchovy) – over 80%, white fish about 16%, cephalopods about 2%, and crustaceans and molluscs about 2%. Since hake, Norway lobster, common pandora, red mullet and octopodes (white and black) are the most common commercial species of trawl fishing, and sardine and anchovy are the most common species of commercial purse seine catches, these 8 species are described in more detail in the next section.



Legend: (from left to right) hake, sardine, Norway lobster, red mullet, black octopus, anchovy, common Pandora, white octopus. učestalost – frequency, godina - year

Figure 3.80 The frequency of appearance of commercial species of marine organisms in the Adriatic (Source: Croatian Institute of Oceanography and Fisheries – Split)

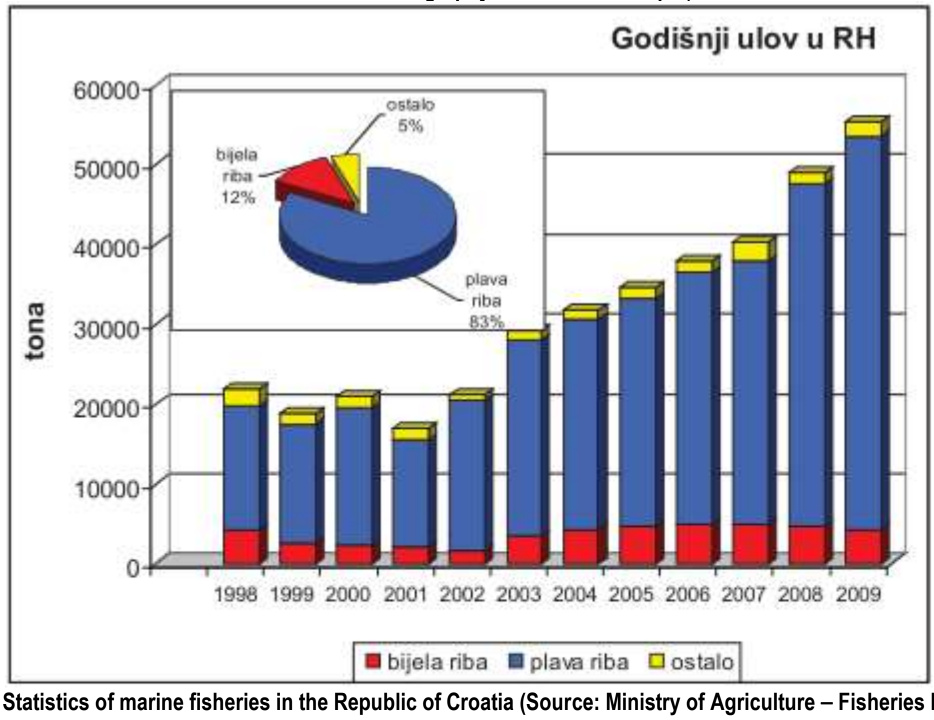


Figure 3.81 Statistics of marine fisheries in the Republic of Croatia (Source: Ministry of Agriculture – Fisheries Department)
Legend: Godišnji ulov u RH - Annual catch in the Republic of Croatia, tona – tonnes, bijela riba – white fish, plava riba – pelagic, ostalo – other

During 2013, total annual catch of marine fishing in Croatia increased from 63,000 tonnes in 2012 to 75,269 tonnes. This is primarily a result of growth of the catch of pelagics (the catch amounted to 68,392 tonnes), while the catch of white fish remained almost unchanged in the previous year (4,314 tonnes). The catch of cephalopods grew (1,363 tonnes), as well as the catch of cartilaginous fish (124 tonnes) and crustaceans (685 tonnes). A slight increase was recorded in the catch of anchovy (from 8,109 to 8,904 tonnes), and a significantly higher one in sardines (from 43,527 to 53,085 tonnes). Compared to the previous year, the catch of hake (1,138 tonnes) increased, and the catch of red mullet (1,104 tonnes) decreased.

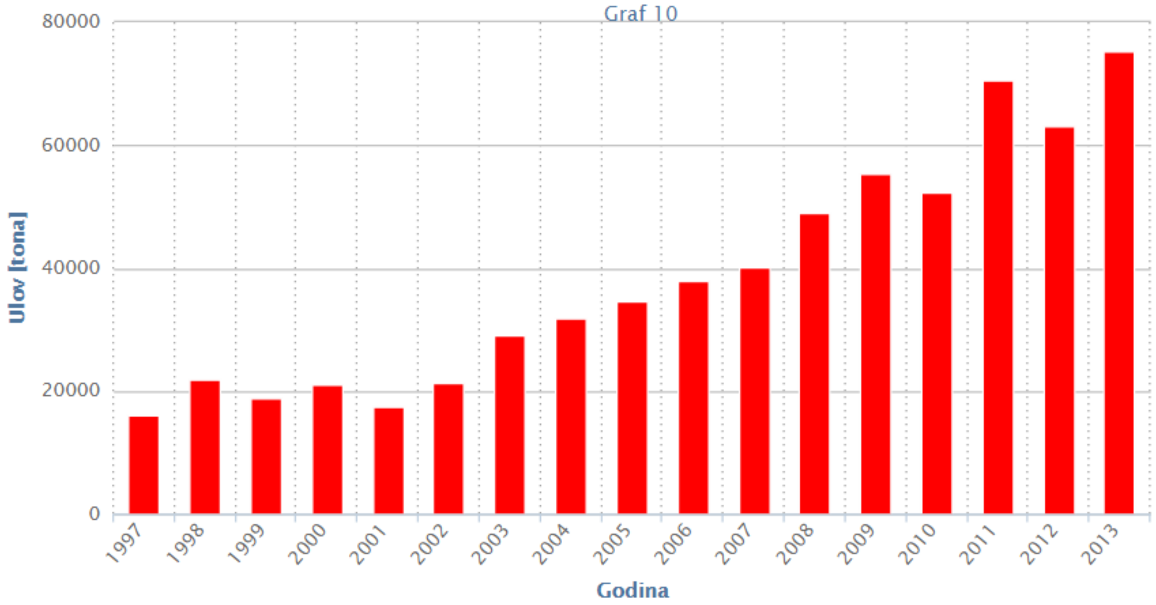


Figure 3.82 Total annual catch of marine organisms in the Adriatic (Source: Croatian Institute of Oceanography and Fisheries – Split)
Legend: ulov – catch, tona – tonnes, godina – year

The most important landing places in 2010 for small pelagic species were Kali, Zadar, Biograd na moru and Pula, while for the demersal catches these were Mali Lošinj, Tribunj and Zadar. In addition to the commercial fisheries at sea, sport and recreational fishery represent an important segment of the fishery in Croatia. (http://www.mps.hr).
In the Adriatic Sea, the intensity and the methodology of monitoring various types of fishery and related communities that are exploited are different. As a consequence, the view of the status of individual communities and the status of individual types of fishery can not be equally described in detail and with equal precision.

3.10.1.3.1 Status of demersal communities

Monitoring of demersal settlements is performed continuously since 1996 through scientific expeditions (EU MEDITS (spring), FAO AdriaMed Trawl Survey (autumn period), "DemMon" (demersal monitoring), PHARE Project and others. The distribution of the most important demersal species in the Adriatic Sea is made based on MEDITS expeditions, where the distribution of individual species and the distribution of juvenile specimens was shown separately, with the aim of locating critical areas for individual species (i.e. spawning areas and nurseries) requiring special attention, because these are places of species repopulation.
Hake *(Merluccius merluccius)* is widespread throughout the Adriatic Sea, except in its most northern and shallowest parts (around the mouth of the Po River). Population is densest in the area ofthe open Central Adriatic and canal areas along the Croatian coast (Figure 3.83). The highest concentration of juvenile specimen (main spawning and nursery areas) is located in the open middle Adriatic (Jabuka Pit) and canal areas of the Northern Adriatic.

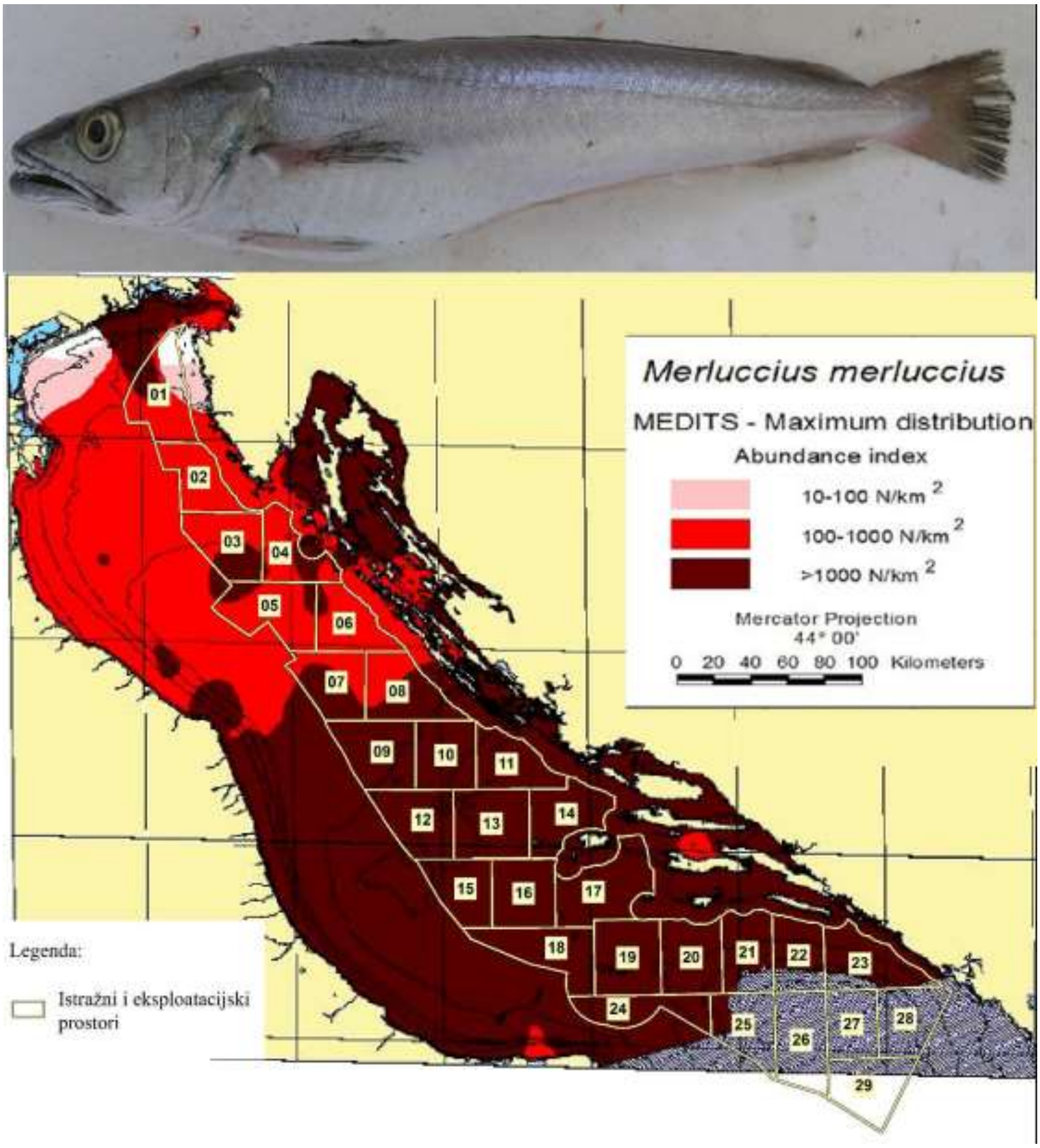


Figure 3.83 Distribution of hake in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of Oceanography and Fisheries – Split) Norway lobster *(Nephrops norvegicus)* is found in the open Central Adriatic and in canal areas, primarily in areas with silty type of sediment. The highest population density is in the open Central Adriatic and in canal areas of the Northern Adriatic. As this is a non-migratory species, juvenile specimen are mostly located in the same areas as adults.

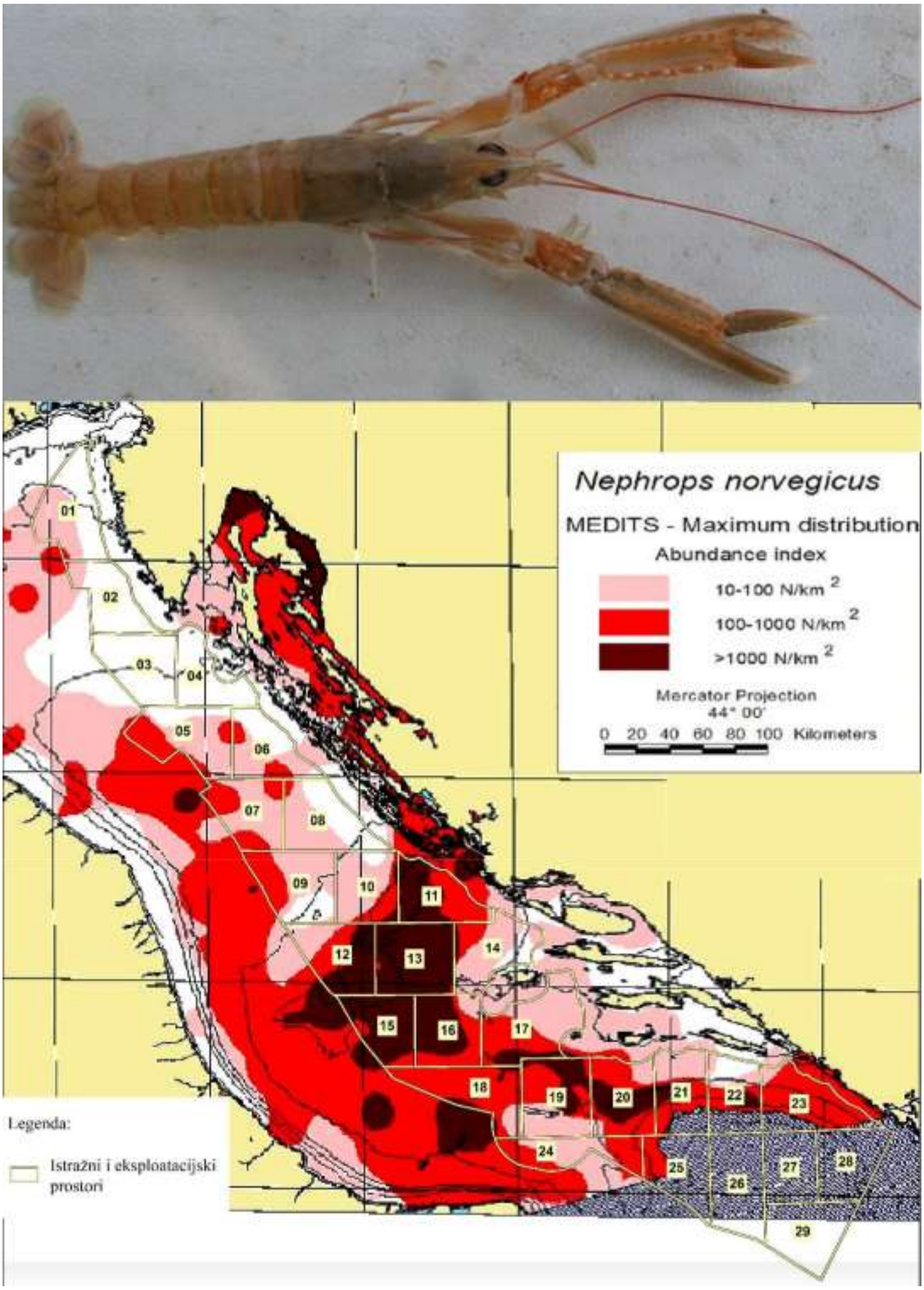


Figure 3.84 Distribution of Norway lobster in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of Oceanography and Fisheries – Split) Common pandora *(Pagellus erythrinus)* is a typical circalittoral species in the Adriatic Sea which is widespread in coastal areas, especially along the eastern coast, at depths up to between 120 and 150 meters. The highest population density is in canal areas of the eastern Adriatic, while main areas with a high concentration of juvenile specimens are situated along the western coast of Istria and in channels of the Central Adriatic.

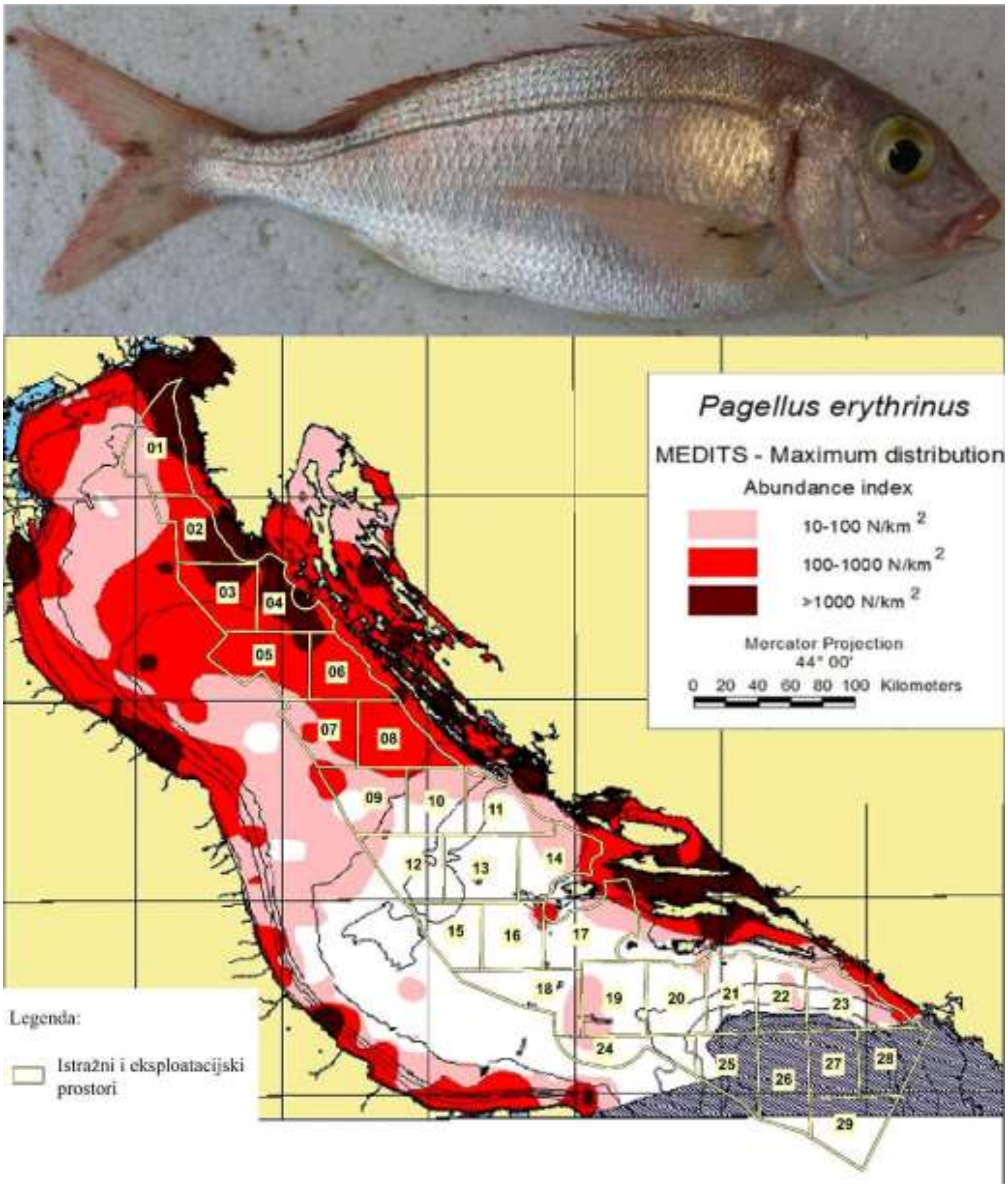


Figure 3.85 Distribution of common pandora in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of Oceanography and Fisheries – Split) Red mullet *(Mullus barbatus)* also inhabits the entire Adriatic Sea, but the population density is low at depths greater than 150 meters. Population density is much higher along the eastern coast of the Adriatic than along the western coast, but this information should be taken with reserve, since red mullet migrates extensively in the Adriatic Sea, and in the studied period (spring-summer period) the majority of the population was located along the east coast. In the rest of the year the population is more or less uniformly distributed across the Adriatic Sea.

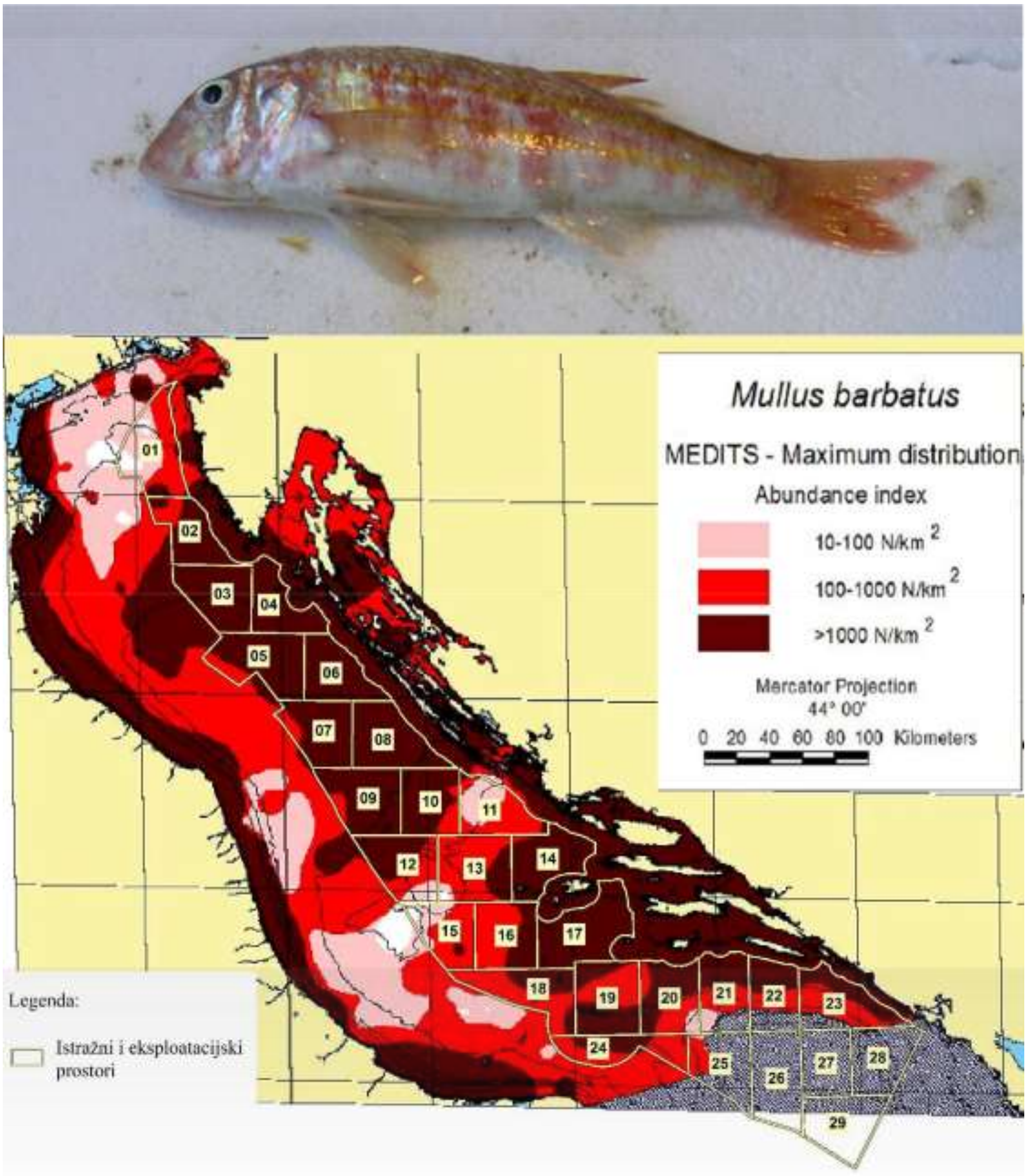


Figure 3.86 Distribution of red mullet in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of Oceanography and Fisheries – Split)

White octopodus inhabits parts of the Adriatic Sea deeper than 100 meters (primarily the Central Adriatic), with almost no difference in the prevalence of juvenile and adult specimens.

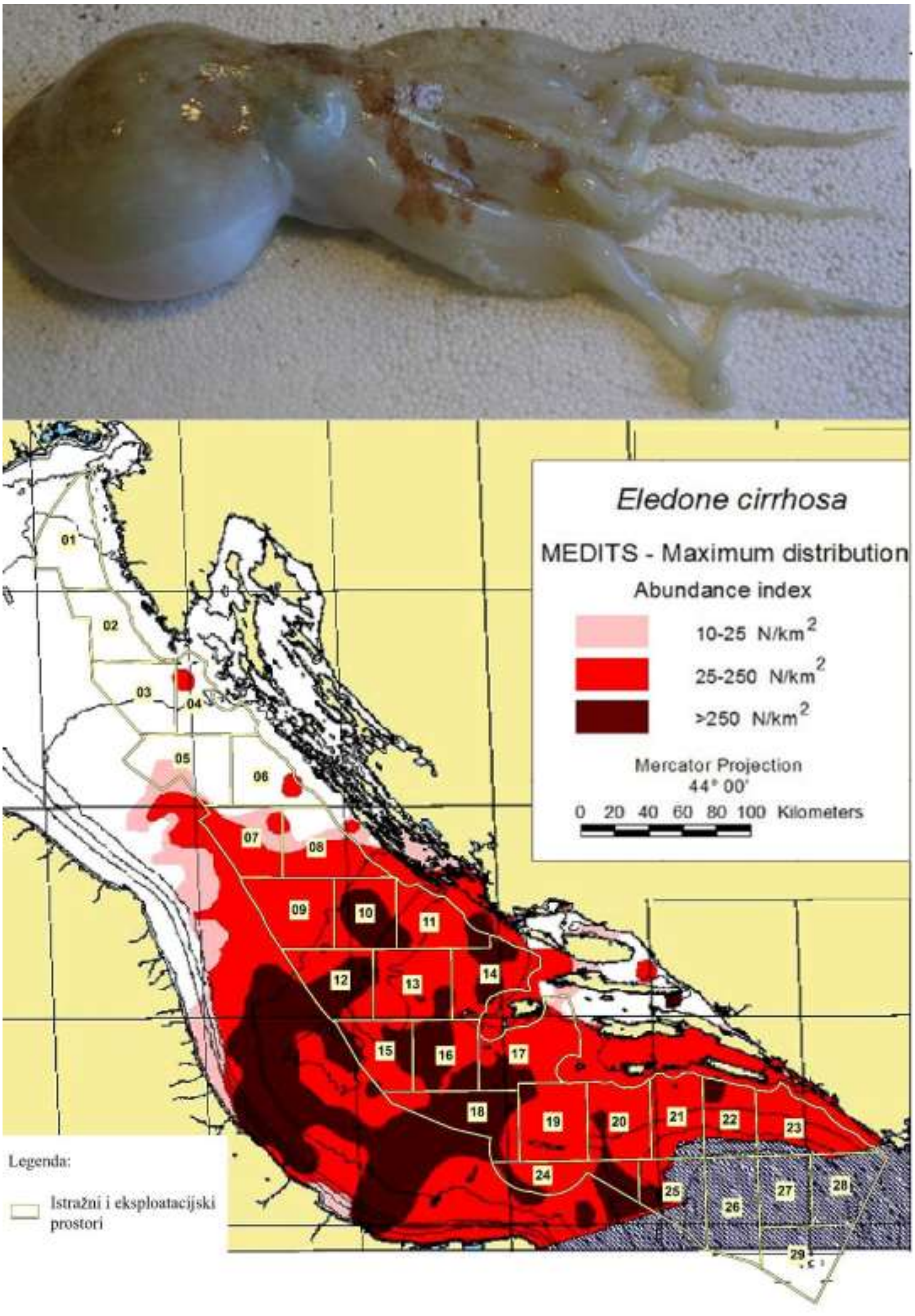


Figure 3.87 Distribution of white octopus in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of Oceanography and Fisheries – Split) Unlike white octopus, that inhabits deeper parts of the Adriatic Sea, black octopus inhabits mostly shallower parts of the Adriatic Sea, mainly in its northern part, and the eastern coast of the Adriatic Sea. The highest population density is along the western coast of Istria, where also the largest quantities of juvenile specimens are located.

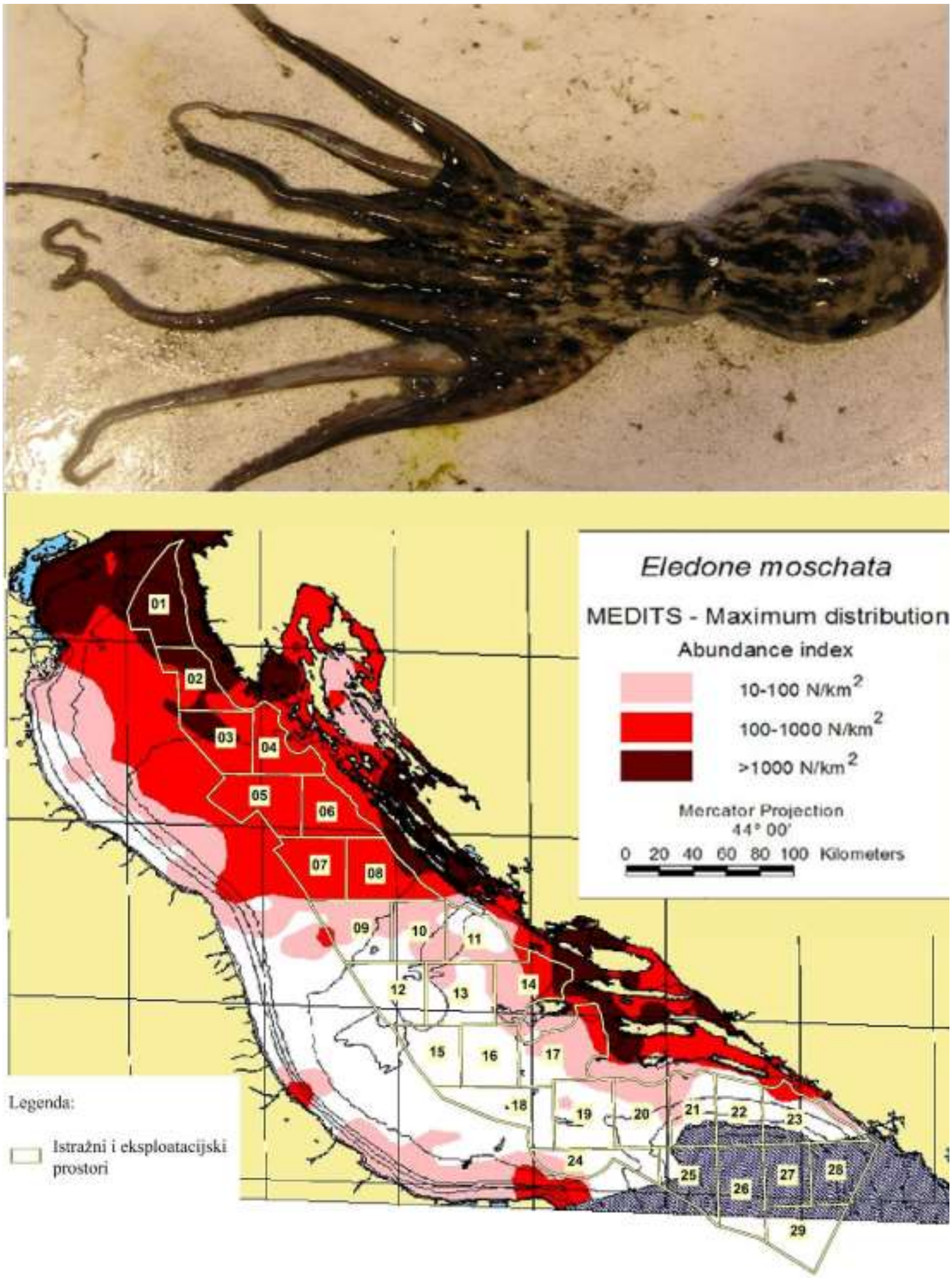


Figure 3.88 Distribution of black octopus in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of Oceanography and Fisheries – Split)

The trawl catches in the Jabuka Pit area have a very high concentration of juvenile specimens of a large number of economically important species. This points to the fact that this part of the open Central Adriatic is one of the most important nurseries in the Adriatic for many demersal species, including hake and Norway lobster. Jabuka Pit is also reproduction area of a large number of species, it is an important spawning area for commercially important species such as hake, Norway lobster and white octopus. In addition to the abovementioned species, in the open Central Adriatic area there are large concentrations of juvenile specimens of other, less economically important species. Such is the case with whiting, Atlantic horse mackerel, Mediterranean scaldfish, European flying squid and other species. All this shows the great importance of the open Central Adriatic and the Jabuka Pit in restoring demersal resources of the Adriatic Sea. Therefore, this part of the Adriatic is considered an extremely sensitive and critical area that requires special protection measures.

3.10.1.3.2 Status of demersal communities

Monitoring of pelagic communities and pelagic ecosystem was established through the PELMON Project from 2003, and includes stock assessment of small pelagics by echo-monitoring and collection of biological and oceanographic data needed for the explanation of changes occurring in stocks. Monitoring of commercial pelagic fishing took place under the project.
Under the VPA, which in 2011 grew into the PERIMON Project, data on the composition of catches and fishing effort in the pelagic fishing (mainly of small pelagic fish) are collected.
Sardine *(Sardina pilchardus)* and anchovy *(Engraulis encrasicolus)* are oceanodromous, epipelagic and neritic species that live in shoals. In the Adriatic Sea, both species are found widely distributed. It was noticed that sardine is slightly more densely distributed along the eastern coast of the Adriatic (Sinovčić et al., 1991), while the anchovy is more prevalent along its western coast. Sardines and anchovy, as well as other species of pelagic fish: Atlantic mackerel, chub mackerel, Atlantic bonito, tuna and garfish are migratory species. During their life they gradually migrate from the coastal towards the open areas of the Adriatic Sea. For the purpose of spawning, sardines migrate towards the coast during the colder part of the year (Sinovčić et al., 2003, 2008), while the anchovy spawning migration takes place during warmer months (Sinovčić et al., 2007).

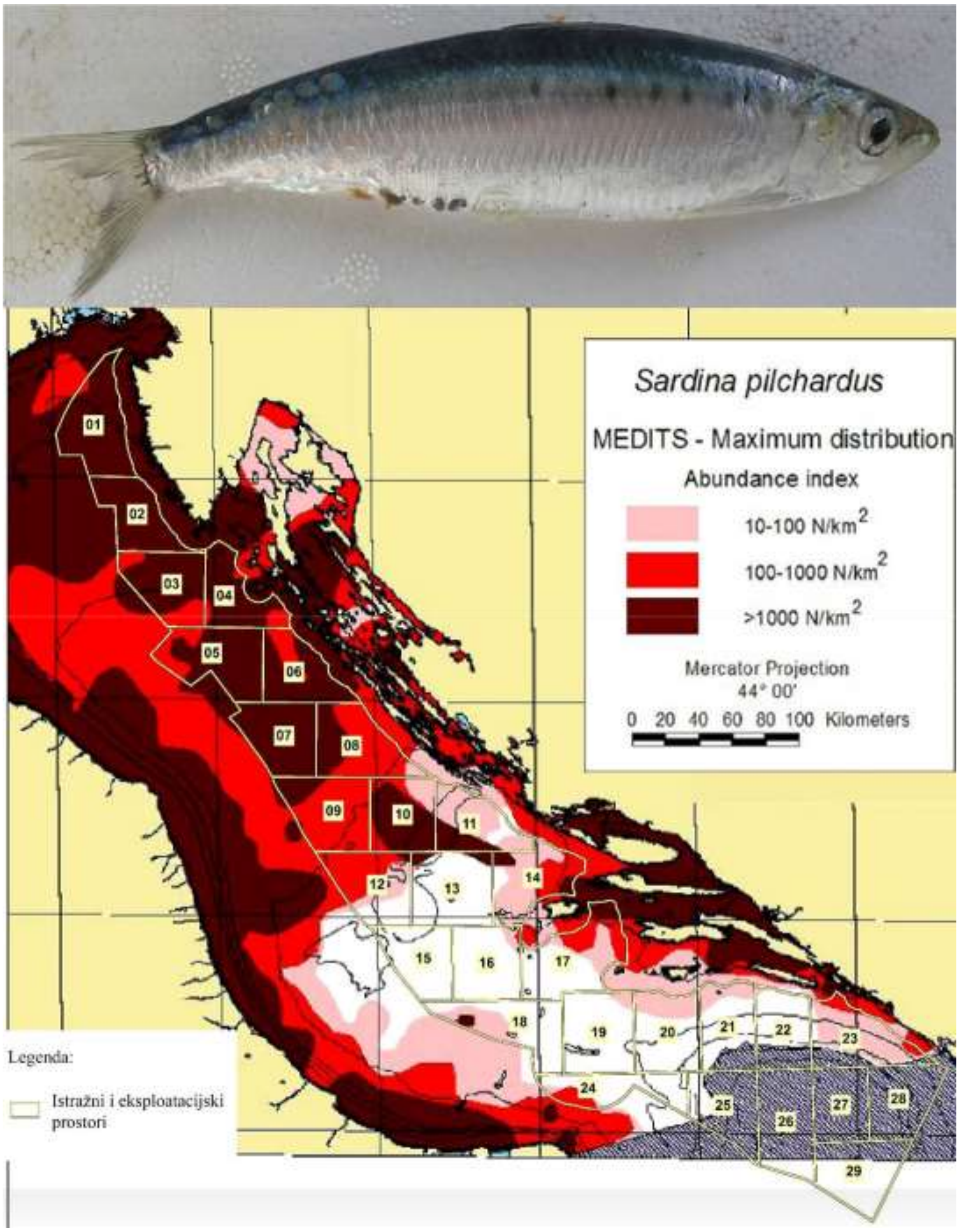


Figure 3.89 Distribution of sardine in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of

Oceanography and Fisheries – Split)

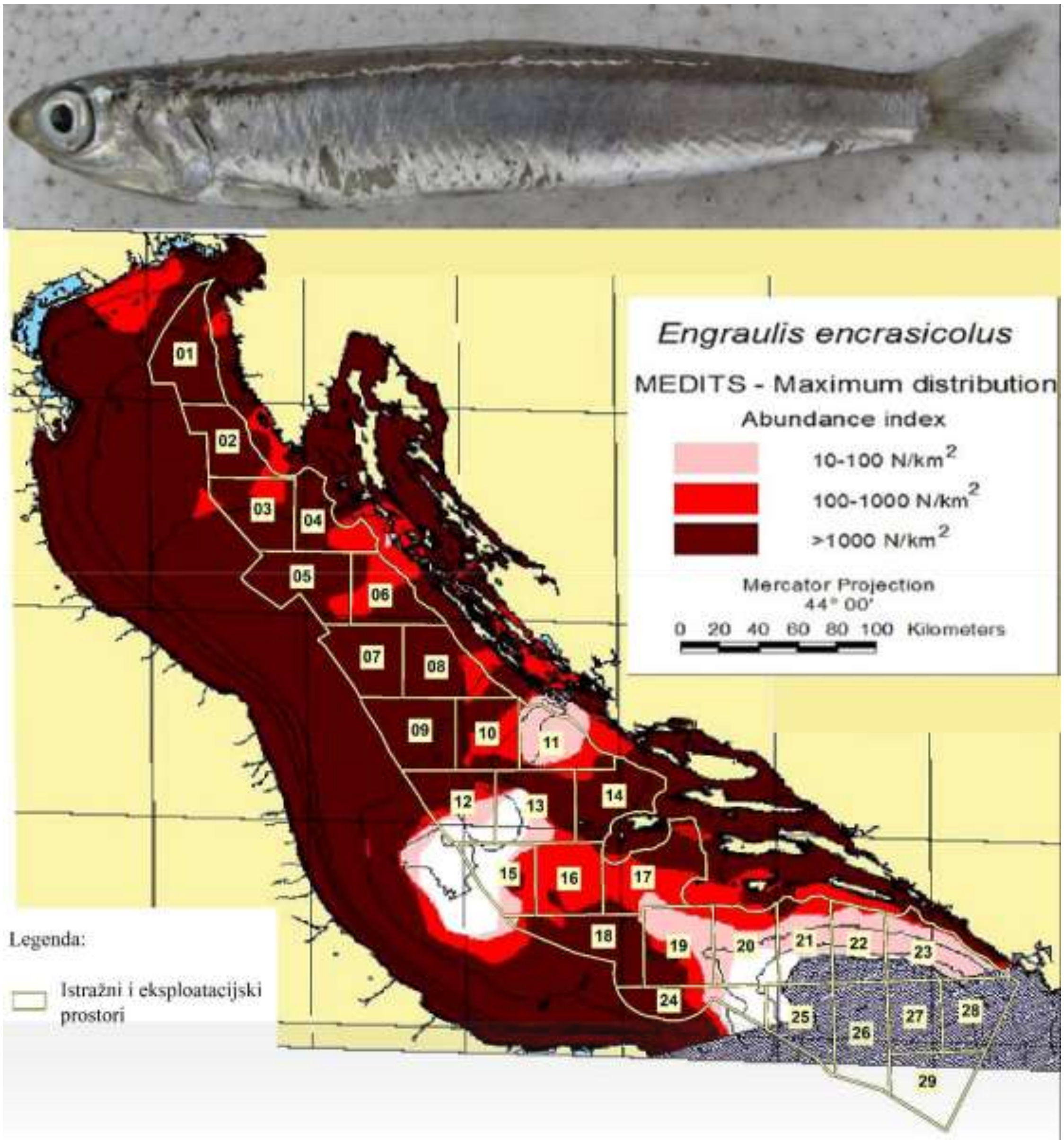


Figure 3.90 Distribution of anchovy in the Adriatic Sea in relation to blocks provided for in the FPP (Source: Croatian Institute of Oceanography and Fisheries – Split)

Apart from small pelagic species, more significant commercial pelagic species in the Adriatic include the widespread bluefin tuna *(Thunnus thynnus)* which is found distributed throughout the Adriatic, but whose peak density is in the Jabuka Pit area where tuna is commercially harvested in May and June to the fulfilment of quotas laid down by law.

3.10.1.3.3 Status of coastal communities

Monitoring of status of coastal communities is done in part through projects of the Ministry of Science (basic scientific project of the Laboratory) and PRIMO Monitoring of coastal fisheries (since 2008).

3.10.1.3.3.1 Bottom longlines

Today the main areas of bottom longline fishing are located from the southern border of the Croatian territorial sea all the way to the parts of the open Northern Adriatic area (almost to the island of Sušac). In recent years, the exploitation began also in canal areas of the Northern Adriatic, primarily in Kvarnerić. In the open sea area, the exploitation, as a general rule, extends to the ZERP border, but is also done in the Italian continental shelf.

During the year, longline fishing areas vary, and typically depend on migrations and availability of species that are harvested. However, the temporal dynamics of longline fishing is significantly influenced by bottom trawl fishing. In fact, this gear directly competes with the bottom longline, both because of the areas in which they are used, and because of a part of the target species that are exploited (primarily hake). This competitive relationship is particularly visible in the ZERP zone, where the large Italian trawl fleet operates. Because of this problem, exploitation in the area of the ZERP zone is possible only two to

three days a week, i.e. during weekends, when the Italian fleet is in the ports. Despite such relative temporal separation of these two types of fishing, often happens that trawlers, while they operate, damage bottom longlines.
Catches with bottom longline contain a greater number of fish species, so this gear can be classified in the category of multispecies fishery. However, the bulk of the catch consists of three species: tub gurnard *(Trigla alfalfa),* hake *(Merluccius merluccius)* and turbot *(Psetta maxima),* while all other species in the longline catches can be regarded as secondary species.
The figure below shows the percentage composition of the catch by fishermen who fish with bottom longlines north of Jabuka Pit. The three main species in the catches account for 87% of the total catch (tub gurnard 42.3%; turbot 31.7% and hake 12.9%). Other species with a percentage in the catches of over 1% are: little tunny *(Euthynnus alletteratus)* 4.7%, common pandora *(Pagellus erythrinus)* 3.0%, picked dogfish *(Squalus acanthias)* 2.3% and European conger *(Conger conger)* 1.6%. The other nine species account for 1.6% of the total catch.
The composition of the analyzed catches of Komiža fishermen for a five-year period gives a similar picture. The three main species account for 84% of the total catch (tub gurnard 49.9%; hake 30.7% and turbot 2.8%). Unlike Zadar longline catches, here the ratios of secondary species in the catch differ: picked dogfish (6.2%), European conger (3.0%), thornback ray (2.7%), little tunny (2.0%) and common eagle ray (1.5%).

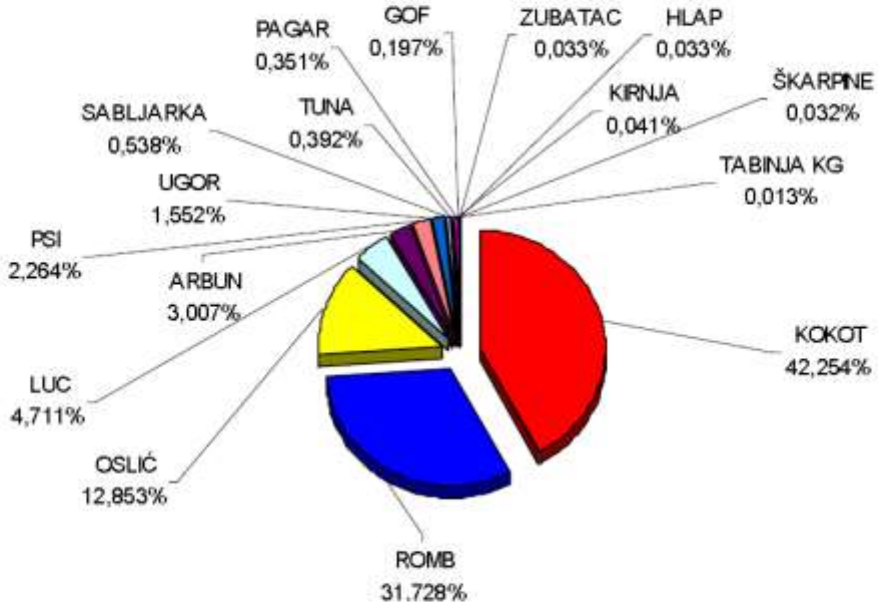


Figure 3.90 Average composition of the longline catch (Zadar area) for the period 1997–2006
Legend: romb - turbot, oslić – hake, luc – thornback ray, arbun – common Pandora, psi – dogfishes, ugor – European conger, sabljarka – swordfish, tuna – tuna, pagar – porgy, gof – greater amberjack, zubatac – sea bream, hlap – European lobster, kirnja – grouper, škarpine – scorpion fish, tabinja kg – forkbeard, kokot - tub gurnard

3.10.1.3.3.1.1 Analysis of the population structure of the most important species in catches

3.10.1.3.3.1.1 Tub gurnard *(Trigla lucerna)*

Tub gurnard inhabits the Mediterranean, Black Sea and the eastern Atlantic from Norway to Senegal (Bini, 1973; Tortonese, 1975), and in the Adriatic Sea this species is spread everywhere, but is not numerous (Jardas, 1996). It remains at depths up to 100 (130) meters, and in some places up to 200 meters. Typically this species inhabits different seabeds, but prefers seabeds of finer and more coarse sediment (Županović and Jardas, 1989).
Tub gurnard is a long living species that can live up to 13-14 years (Relini et al., 1999), and reach a length of 75 cm (about 6 kg) (Jardas, 1996). It spawns in early winter to late spring, and both genders attain sexual maturity at 3-4 years of age (Relini et al., 1999). Recruitment takes place in late winter and early spring in shallow areas, and in the summer juvenile specimens are already 15-20 cm long.
This species is exploited with different fishing gear: trawl nets, longlines and bottom-set gillnets. Trawlers mainly catch juvenile specimens, while adult specimens are harvested with deep longlines.

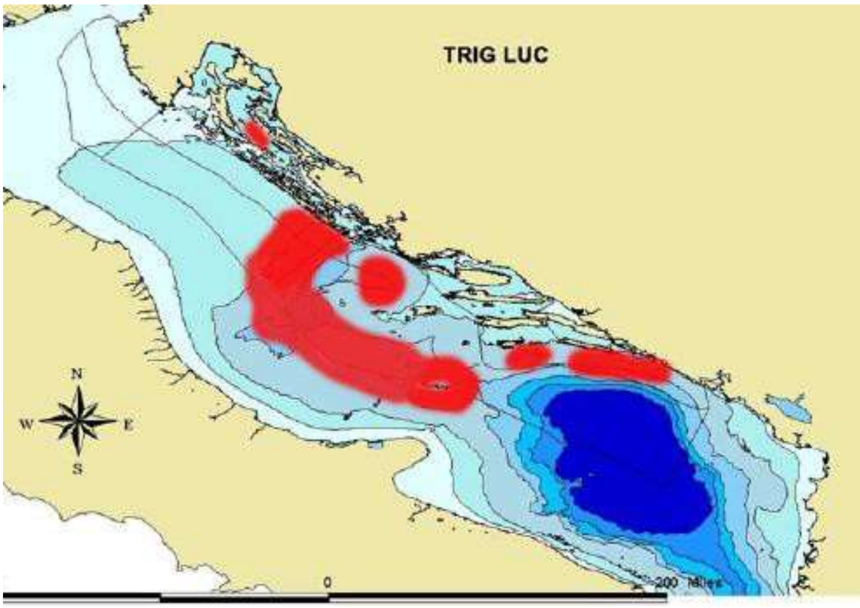


Figure 3.93 Main areas of tub gurnard exploitation

3.10.1.3.3.1.2 Turbot *(Psetta maxima)*

Turbot inhabits the north-east Atlantic from Iceland and Norway to Morocco, the entire Mediterranean and the Adriatic and Black Sea. It is widespread throughout the Adriatic Sea, but in the Northern Adriatic it is significantly more abundant (Jardas, 1996). It grows to a length of 1 meter (12 kg) and can live up to the maximum of 25 years.

This is a typical demersal species inhabiting rocky, sandy and muddy sediments to the depths of hundreds of meters, but preferring the depths of 20-70 meters. Harvesting is done with bottom-set gillnets and longlines, and this species can be found also in the trawler's catch.

Reproduction occurs in late winter and early spring (Caputo et al., 2001), and the males and females are sexually mature in the third and the fourth year of life respectively (Jardas, 1996).

Experiments of distribution and migration monitoring of this species by marking (Aneer et al., 1990) have shown that this species does not significantly alter their habitat throughout life. In fact, after the marking and release into the sea, the specimens were again harvested averagely 6 km away from the place of release into the sea. 90% of the specimens were caught within a radius of 20 km from the place of release, and 79% within a radius of less than 10 km, within a time interval from 22 months to 12 years.

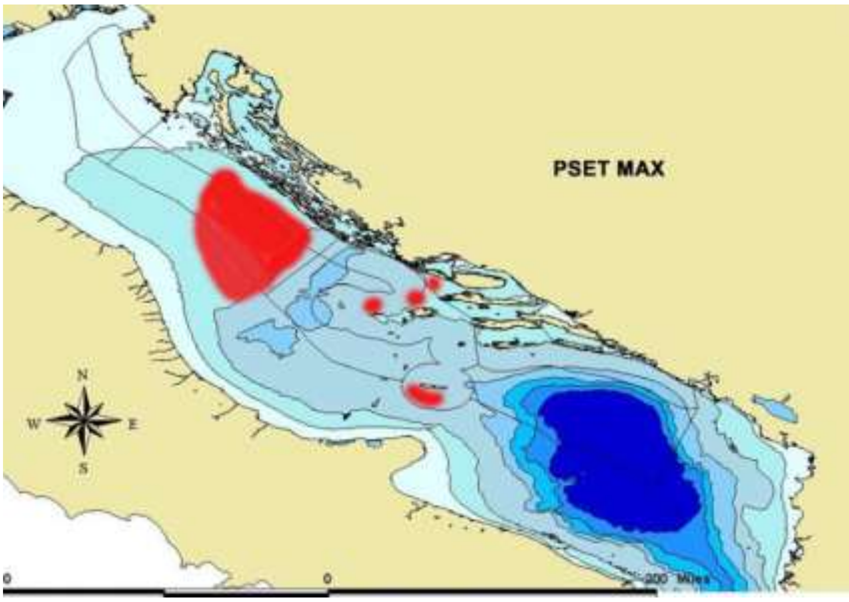


Figure 3.92 Main areas of turbot exploitation

3.10.1.3.3.1.3 Hake (Merluccius merluccius)

Hake is one of the most important species of Croatian bottom fishery, both of trawl and longline fishery.

This species is widespread in the north-east Atlantic, the Mediterranean, the Adriatic Sea and part of the Black Sea (Jardas, 1996, Relini et al., 1999). It is widespread throughout the Adriatic Sea, except in areas north of the river Po. This is a nektobenthic species living at depths from 10 to 1000 meters, and the population in the Adriatic Sea is densest at depths between 100-200 meters (Ungaro et al., 2004).

It prefers muddy seabeds, and during the day it remains near the seabed, and at night it rises to the upper layers. It spawns throughout the year, but spawning is most intense in winter and spring. Sexual maturity occurs at lengths of 20-28 cm. It is a long living species (can live over 20 years), and can grow over 1 meter.

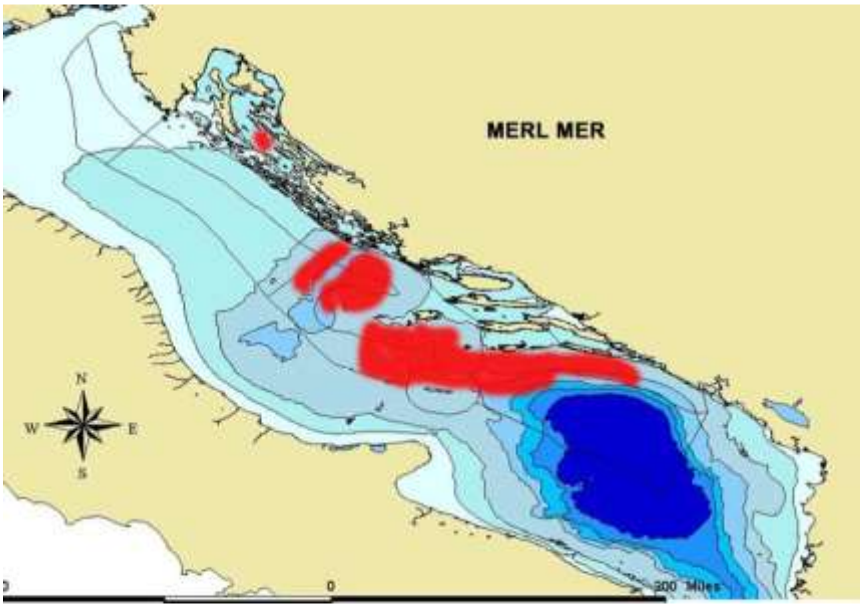


Figure 3.93 Main areas of hake exploitation

3.10.1.3.3.1.4 Thornback ray *(Raja clavata)*

Thornback ray inhabits the eastern Atlantic from Norway to South Africa, the south-west Indian Ocean, the Mediterranean and the Black Sea (Jardas 1996; Reline et al., 1999). This is a benthic species living up to the depth of 700 meters (Fischer et al., 1987), and in the Mediterranean its population is densest at depths of 100-200 meters.

This species can grow to a length of about 1 meter (Županović and Jardas, 1989) and reach a weight of 20 kg (Relini et al., 1999). Reproduction is oviparous. Females lay up to 150 egg capsules in shallow water during winter and spring. Reproductive maturity occurs at approximately 75 cm (males) and 85 cm length (females) (Jardas, 1996).

3.10.1.3.3.1.5 Picked dogfish *(Squalus acanthias)*

Picked dogfish can grow to a length of about one meter, but the usual length is 60-90 cm. It remains along the seabed and rarely comes to the surface. It lives in depths of only a few meters up to 900 meters, usually 20 to 200 meters (Fisher et al., 1987; Jardas, 1996).

It inhabits boreal and warm waters, but is not present in tropical areas. In the Adriatic, it mainly inhabits its northern and central part, and is more numerous in canal areas than in the open sea.

Males are sexually mature at lengths of 60-70 cm and females between 70 and 100 cm (i.e. at the age of over 10 years). Females give birth to 2-20 young of 20-30 cm length. It feeds mainly on fish, and less on cephalopods, crustaceans and polychaetes.

3.10.1.3.3.1.6 European conger *(Conger conger)*

European conger is widespread in the Eastern Atlantic from Norway to Senegal, in the Mediterranean and in the western part of the Black Sea, and throughout the Adriatic Sea (although the population is denser in the Northern Adriatic). It inhabits rocky and sandy shore at depths up to 100 meters (Jardas, 1996 Relini et al., 1999).

This species can grow up to 3 meters (68 kg) (Jardas 1996). It spawns in summer, and is sexually mature at the age between 5 and 15 years. It feeds on fish, crustaceans and cephalopods.

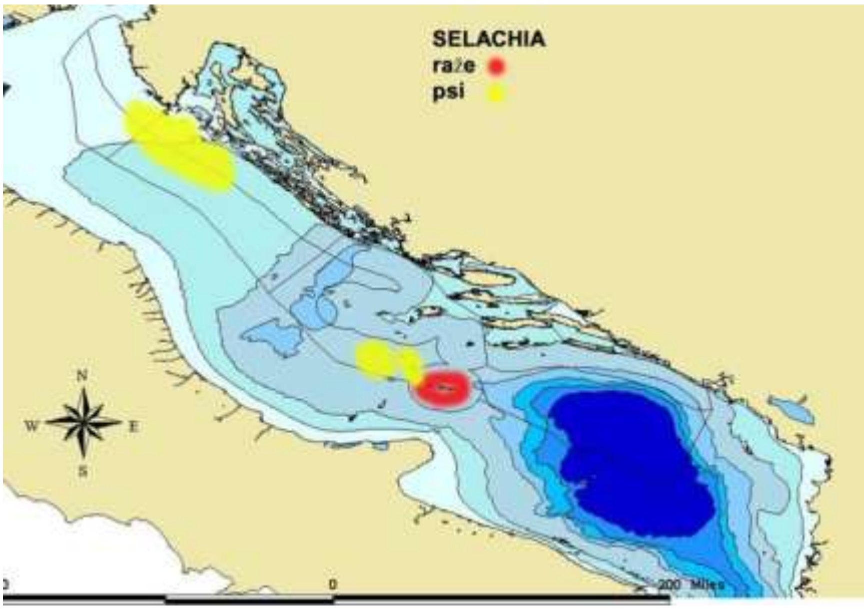
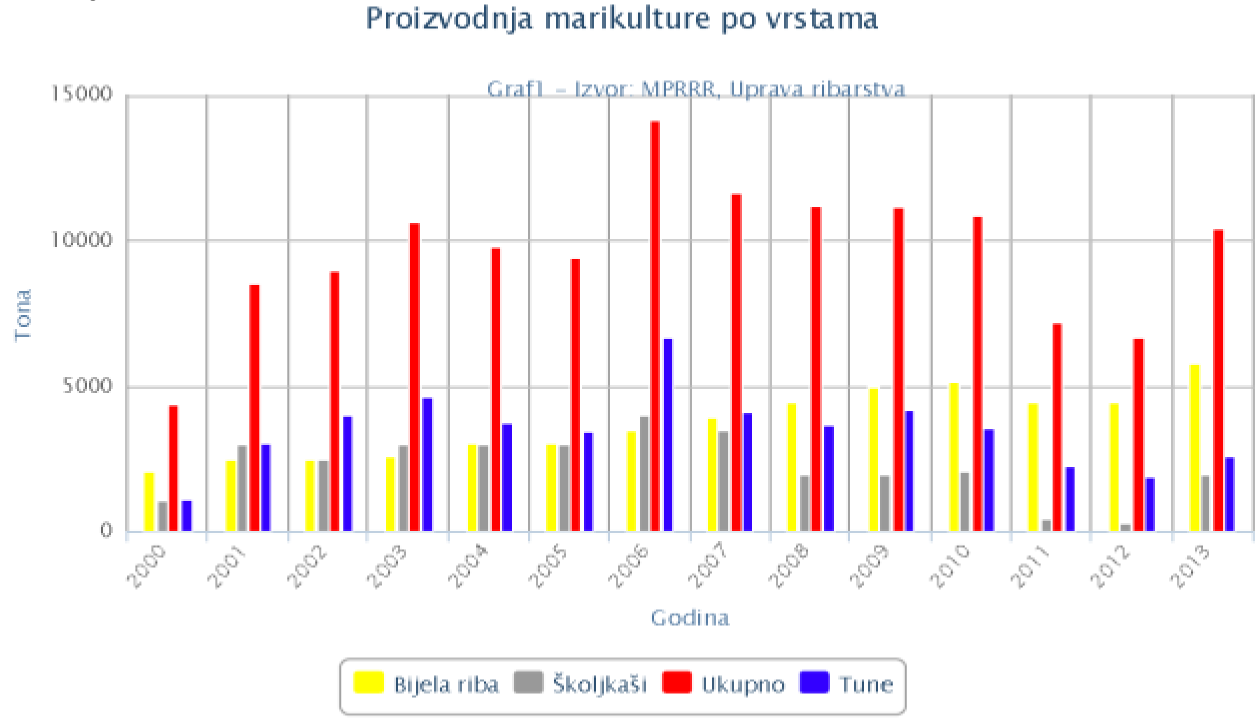


Figure 3.94 Main areas of cartilaginous fish exploitation

3.10.1.4 Mariculture

After a significant decline in production in the past two years, Croatian aquaculture increased in 2013, but only because of the significant growth in production in mariculture. Cromaris, a leading company in this sector, exercised considerable investment to consolidate production with a new zootechnical farming approach in offshore cages which are positioned in the open sea. At the same time, the project of hatchery modernization in Nin is ongoing, that will produce fry for the Croatian mariculture. We are talking about an increase in production of European seabass and gilthead sea bream, and the introduction of some new native species, which is also officially encouraged. Another significant growth (statistically) was recorded in the production of molluscs. However, these numbers are mainly a result of establishing better way of data collection on the production volumes of many manufacturers. Statistical indicator of growth in tuna production in 2013, compared to previous years, is defective due to the fact that the size of production has been limited by the quota system and the length of the breeding cycle. The difference in tuna farming between 2012 and 2013 may be due to greater harvesting of farmed tuna in January 2013 in relation to its harvesting in December 2012.



Legend: Production in mariculture per species, Source: Ministry of Agriculture, Fisheries and Rural Development (MPRRR), Fisheries Department; bijela riba – white fish, školjkaši – molluscs, ukupno – total, tune - tuna

Pelagic fish farming implies tuna breeding *(Thunnus thynnus)* in floating cages in semi-open and open areas of the Central

Adriatic, or in the areas of Zadar and Split-Dalmatia County. Cultivation is based on catch of small-size tuna from the nature (8-10 kg) and their further breeding to the market size (30 and more kg). Production is almost entirely placed on the Japanese market. In the past few years a stagnation of production was recorded due to restrictive measures for tuna catches, and does not exceed 2,000 tonnes per year. Starting from 2015, an increase in catch quotas is expected, which should contribute to the revival of breeding. Total installed breeding capacity of the existing aquaculture farms exceeds 7,000 tonnes per year, which means there is a huge untapped potential. In areas covered by blocks, no spaces and equipment for growing mariculture species are located, nor it is planned to set up fish and shellfish cages in the open sea until 2020. Locations of planned offshore farms are not known (Source: National Strategic Plan for the Development of Aquaculture for the Period 2014-2020, Programme starting points and goals (abstract); Ministry of Agriculture – Fisheries Department)

At present, the open sea farming is at the limit of acceptability. Once the above mentioned solution shows satisfactory efficacy, it will be easy to implement it, because it is not a source of competition in the coastal zone and should be encouraged by providing cheaper concessions and simplifying the process of obtaining the necessary permits. Although the optimum distance can not be calculated precisely, indicatively it is clear that larger farms are to be set away from the most stressed parts of the coastal zone, at the same time trying to stay in an area that is protected from the extreme weather conditions, but close enough in terms of logistics, without causing the price of running the farm to become uncompetitively high (Study on the use and protection of the sea and the underworld in Split-Dalmatia County, with an emphasis on mariculture activities, in the multi-sectoral context of Integrated Coastal Zone Management (ICZM), Oikon 2012).

3.10.2 Tourism

The market position of Croatia, compared to its competitors, is to a certain extent a reflection of market readiness of its main tourist products. For the macro-region North Adriatic these products are sun and beach holiday, cycling and diving tourism. For the Central and Southern Adriatic especially prominent are *yachting* tourism and sun and beach holiday, while for the macro-region Continental Croatia the fittest market products are cultural tourism, holidays in rural areas and cycling tourism.

Tourism linked to the sun and the sea and nautical tourism are the most important tourism branches in the area in which the activities of the FPP are planned.

Nautical tourism is a special type of tourism, which, in addition to privately organized boating - cruising with one's own or rented vessels with accommodation and/or overnight stay of tourists on them, includes cruises organized by the owners of vessels and by travel agencies with accommodation and/or overnight stays of tourists on vessels, and tourist navigation on vessels for the purpose of other types of leisure and recreation (fishing, diving). The essential difference between nautical tourism and other forms of tourism is navigation, i.e. a considerable mobility of tourists–boaters, which involves frequent, and often daily changes of the place of stay. Boaters find most attractive areas under different categories of protection on account of their high natural value and specific landscape and biological diversity: strict reserves, national parks, special reserves, nature parks, regional parks, nature monuments, significant landscapes, forest parks, monuments of park architecture. Especially attractive are the national parks of Brijuni, Kornati, Krka and Mljet and the nature parks of Telaščica and Lastovo Islands, and the largest number of nautical tourists' visits is realised in the national park of Kornati.

The greatest advantage of Croatia over other Mediterranean countries for the development of nautical tourism are the so-called general and social factors of the nautical offer – the purity of the sea, the beauty of the landscape, environmentally preserved coastline and the feeling of safety in the country.

Total tourism expenditure on the territory of Croatia in 2010, realized on a total of 51.6 million travels, amounted to HRK 53 billion or EUR 7.3 billion. Realized tourist expenditure according to the experimental satellite account of the tourism directly generates 8.5% of direct gross value-added, or 8.3% of direct gross domestic product of Croatia.

Economic effects of nautical tourism are defined on the basis of the estimated total revenue from the overall tourism, which in 2007 amounted to EUR 7 billion. In the total revenue from tourism, marine tourism is estimated to account for 10%, which means that in 2007, with a total of 811,000 arrivals of boaters, tourism earned about EUR 700 million.

According to the Nautical Tourism Development Strategy of the Republic of Croatia for the period 2009-2019, two priorities for the development of nautical tourism are the protection of extremely valuable areas (uninhabited, non-urbanized coasts, islands, islets, bays and coves), which motivate the arrival of domestic and foreign boaters, and planning of the construction of new ports of nautical tourism of the highest standards of environmental protection on less valuable areas.

With physical plans (in the planning period from 2007 to 2015), a construction of a new capacity of 33,655 berths in total is planned, of which 25,755 berths in the sea, and 7,900 dry berths on the mainland. In the future, according to the Counties' Spatial Plans, with the construction of the newly planned capacities and in addition to the existing ones, total capacity of nautical tourism would be 54,675 berths, of which 41,589 in the sea and 13,086 on the mainland.

The biggest threat to long-term development of nautical tourism is the uncontrolled use of naturally formed space and natural resources. Therefore, the concepts of responsible management of natural space and resources, i.e. the protection of nature and the environment for the purpose of their preservation, is contained in the principle of sustainable development, which is an imperative for economic development makers and land-use planning at all levels.

Environmental issues and environmental responsibility are among the hottest global challenges of the future in the development of tourism. As an activity which at the same time rests on the environmental quality and effects it intensively, tourism will adhere significantly more intensively to the application of environmentally responsible, "green" concepts, both at the level of individual service providers and the entire destinations. Integrated Coastal Zone Management, in which tourism is an important sector of

the economy, is a framework for a balanced development of coastal areas and an incentive for the development of sustainable tourism, seeking to preserve coastal ecosystems and landscapes and natural and cultural resources.
Starting from the global trends in the tourism market and the quality of the tourism key points in terms of resources and attractiveness, i.e. development potential of individual products, for the development of Croatian tourism by 2020, in addition to the sun and the sea tourism, especially important are the following product groups: nautical tourism (yachting and cruising), health tourism, cultural tourism, business tourism, cycling (biking), and enology and gastronomy tourism, rural and mountain tourism, and adventurous and sports tourism. In addition to these product groups, Croatia sees its opportunity also in the development of several specific product groups, dominated by the eco-tourism and by the youth and social tourism.
One of the market opportunities for Croatia, identified in the Tourism Development Strategy of the Republic of Croatia by 2020, is taking an environmentally responsible position. This implies a proactive attitude towards the preservation of space, biodiversity and natural and social resources. Implementation of "green" concepts on all organizational and business levels opens up opportunities for genuine sustainable development of tourism and compliant market positioning.
What is expected in the trend movement by 2020 is that the further global growth of yachting will significantly be a result of development of new markets of the Middle East and the BRIC countries (Brazil, Russia, India, China) and the economic recovery of traditionally the main source markets for Western Europe and North America. It is anticipated that the main trend beneficiaries will be the customer segment of the 55+ age group, whose active lifestyle, health and available income enable them to engage in yachting. Innovative offer of "Stay & Sail" arrangements and yachting skills learning will target precisely the above older segment. Growing demand for larger vessels will result in expanding marinas and training them to accept large (12+ meters) and mega (20+ meters) yachts, including in the Mediterranean. An important new aspect in the development of yachting are initiatives oriented towards environmentally responsible management. The forecasts also point to a further strong growth *of* cruising, supported by the perception of high value for money of this product and by the still low market penetration. Cruising companies will continue to invest significantly in attracting new market segments, particularly young people, families with children, but also MICE cruises by introducing new routes, thematic trips and new contents and services on ships. Environmental responsibility and "green" practices will become increasingly important topics for the cruising industry.
Investments in ports of nautical tourism, in accordance with the provisions of the Nautical Tourism Development Strategy of the Republic of Croatia 2009-2019 provide for investment potential related to the improvement of offer of nautical tourism ports, and are estimated to approximately EUR 552 million, of which EUR 475 million relates to the construction of new berths in new marinas, existing marinas and ports, and EUR 77 million to raising the quality of the offer of existing ports and marinas. Investments project that the construction of a number of marinas equipped to handle mega yachts will take place, primarily in attractive destinations with year-round offer.
Desired Position of the Croatian nautical tourism in 2020 is:
Croatia is the most desirable yachting destination in the Mediterranean. Its position is based on indentation, preservation, and culture of life on the coast and islands, quality of nautical infrastructure, security of stay and themed itineraries. The offer is adapted also to the demand of luxury mega yachts, and charter offer is based on high-quality, licensed service.
International cruising at sea takes place in stronger cooperation with shipping companies and protects interests of Croatian destinations, which includes the definition of departure ports for big and medium-sized ships and ports for ships up to 1000 passengers. Croatia is a mecca for smaller-sized yachts, but also for the most luxurious ones.
Domestic cruising in Croatia is one of the most desirable tourist products in Europe. Product quality is improved, and there are new ships scheduled for year-round business.
The main destinations of international cruise tourism are Dubrovnik and Split. In 2014, Dubrovnik recorded arrivals of 571 cruise ships, with a total of 770,000 passengers, which is 17% less than in 2013, when Dubrovnik serviced more than 680 calls of cruise ships with more than one million passengers.
Since 2006, a significant increase in the number of tourists arriving on cruise ships can be noted in the port of Split (Figure 3.91).

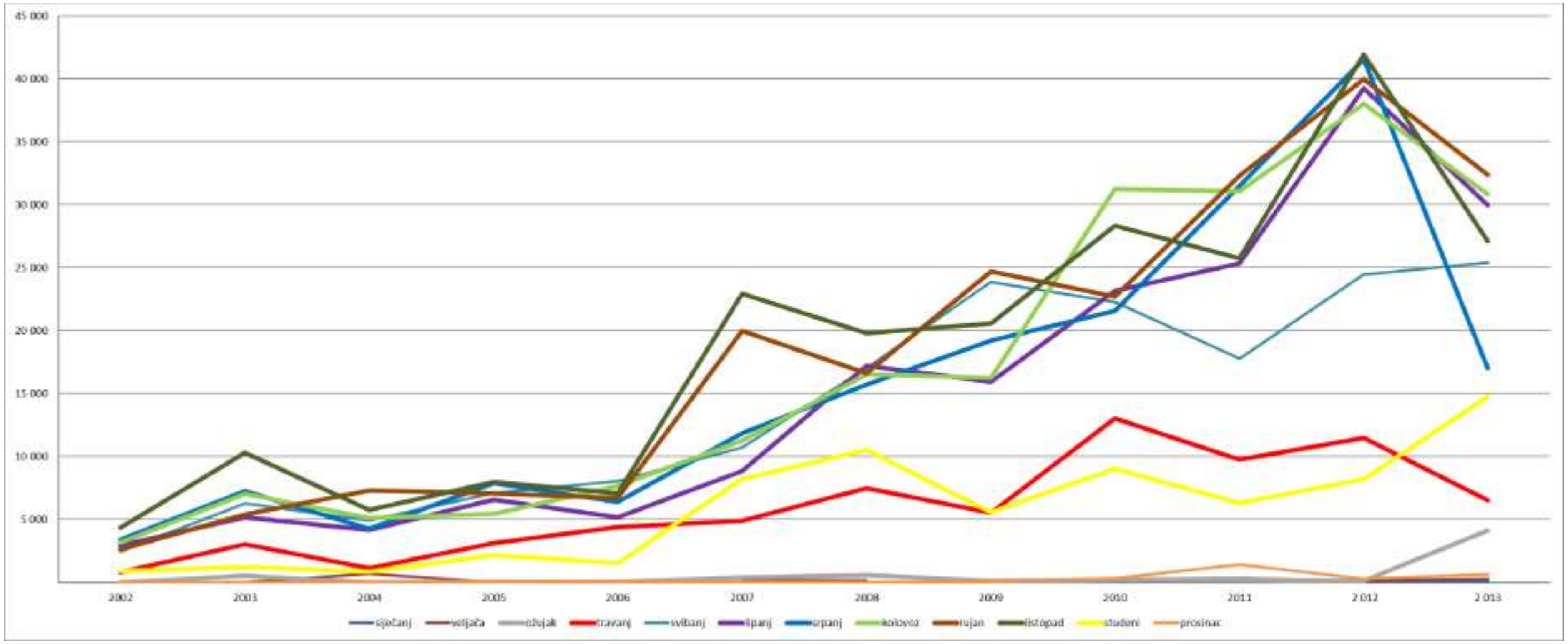


Figure 3.91 Number of tourists per month from the cruise ships in the port of Split from 2002 to 2013 (Source: Split Port Authority http://portsplit.com/cruising/statistika/)
Legend (from left to right): January, February, March, April, May, June, July, August, September, October, November, December

3.10.3 Maritime shipping, maritime traffic and waterways

3.10.3.1 Introduction

The study is based on the existing positive law of the Republic of Croatia, and in this respect it is based on the following assumptions:

- characteristics of ships that are under consideration meet the requirements for such vessels laid down by the provisions of the International Convention for the Safety of Life at Sea, 1974 (SOLAS 74), International Convention for the Prevention of Pollution from Ships 1973/78 (MARPOL 73 / 78th), International Convention on Load Lines, 1966 (LOADLINE 1966), International Convention on Tonnage Measurement, 1969 (TONNAGE 1969), as amended, or by the requirements of the relevant and applicable Technical Rules of the Croatian Register of Shipping;
- characteristics of offshore facilities for the exploration and production of the subsea correspond to the conditions laid down by the MODU regulations of the International Maritime Organization, as amended;
- characteristics of ships to which the international conventions do not apply and of yachts and boats meet the conditions prescribed by the competent administration of states whose flags such ships, boats or yachts fly;
- masters and crews of ships, yachts and boats meet the requirements of the international conventions, the relevant national legislation and/or regulations, especially with regard to education and training, and conditions regarding safe safety management and environmental protection, as set out in Chapter IX of the SOLAS Convention, where applicable;
- masters and crews of ships, yachts and boats act reasonably, in a way an average skilled sailor would act; acting which is significantly contrary to the rules of the profession or which is indented to injure people or cause damage to the environment or property is not examined in this study;
- properties of means of communication among ships, yachts and boats as well as other means of surveillance or data collection correspond to the nominal effective range, i.e. reliability declared.

The text follows the labor, management and technological assumptions of the relevant and valid documents and recommendations of the International Maritime Organization and of other international professional bodies engaged in safety of navigation and environmental protection, as well as the applicable national regulations, in particular those laid down by:

- The International Convention on Salvage of Life at Sea (SOLAS) 1974,
- The International Convention on the Prevention of Marine Pollution (MARPOL) 1973/78,
- circulars and recommendations of the International Maritime Organization concerning the safety of navigation, pollution prevention measures and technical soundness of ships and offshore structures,
- recommendations of the The International Association of Authorities for the maintenance of waterways (IALA), where applicable,
- Maritime Code (Croatian Official Gazette 112/04, 76/07, 146/08, 61/11, 56/13),
- Regulation on the safety of maritime navigation in internal waters and territorial sea of the Republic of Croatia and the manner and conditions of the supervision and management of maritime transport, Croatian Official Gazette 79/13,
- Regulation on the conditions and methods of maintaining order in ports and other parts of internal waters and territorial sea of the Republic of Croatia, as amended, Croatian Official Gazette 90/05, 10/08, 155/08, 80/12.

The text of the impact assessment section refers to the entire Adriatic. The area covered by the FPP is hereinafter referred to as block.

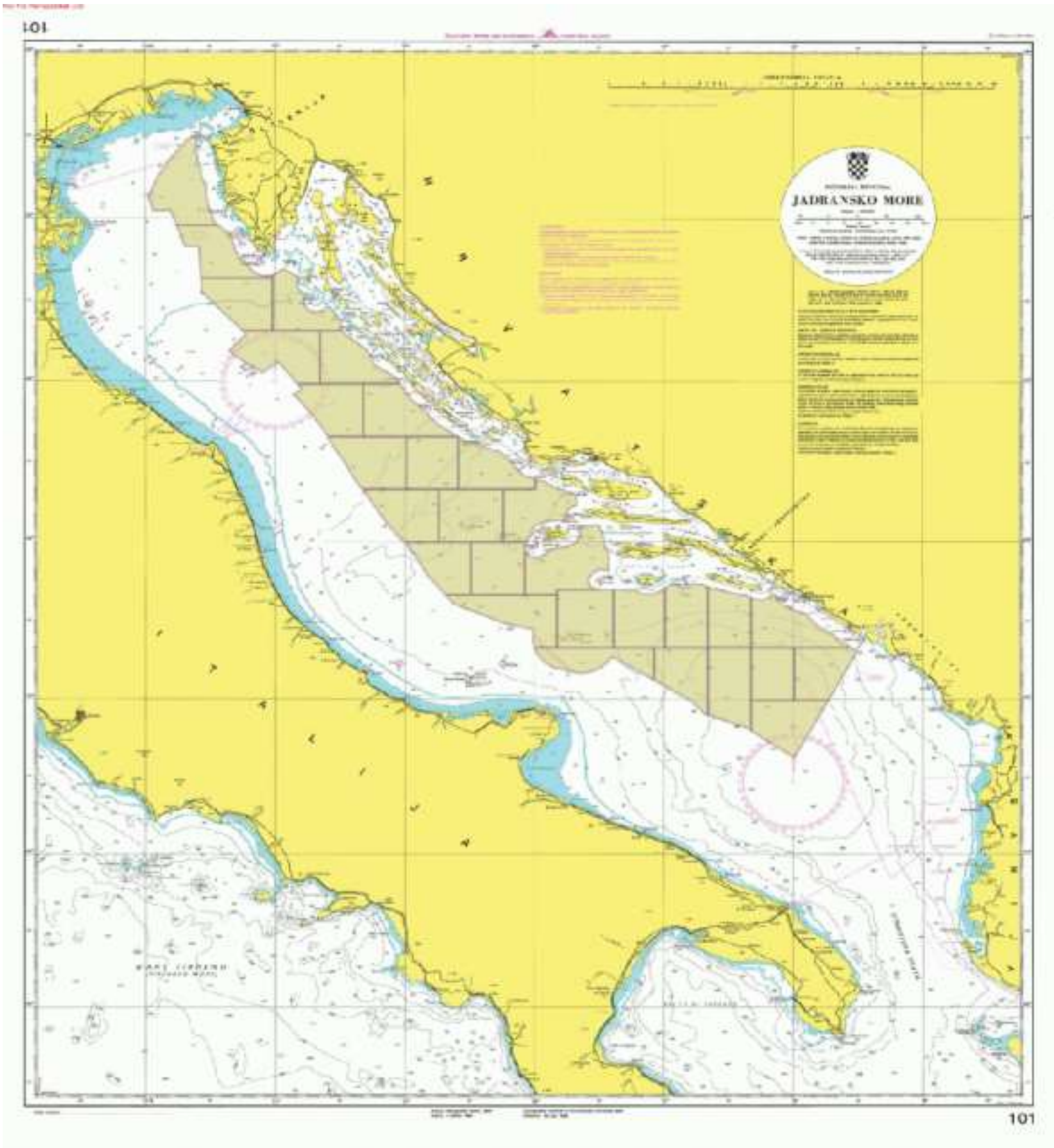


Figure 3.92 Blocks

3.10.3.2 Navigation conditions in the Adriatic

3.10.3.2.1 Winds

Prevailing winds in the Adriatic are bora (NNE to ENE), sirocco (ESE to SSE), maestral (WNW to NW) and westerly winds, which, in terms of the total number of days, account only for a small part of the winds. The impact of the mainland, as well as the distribution of islands and channels significantly change the direction and strength of wind in the coastal and interinsular area. Along the coast, the wind of Force 6 Bf or more blows averagely 25-40 days a year, but in exposed places it can blow over 100 days a year. Gale force wind (Force 8 Bf and more) blows more rarely, usually 2-10 days a year and usually appears as bora, and less frequently as sirocco, especially in the Southern Adriatic. Frequent is the appearance of the tramontana, especially over the open sea, while the maestral usually blows in the summer; the appearance of the sirocco and bora is considerably lower in the summer than in the winter months.

Table 3.28 Annual distribution of wind (%) by speed and direction on the Adriatic

Bf	<1	1 – 2	3	4	5	6	7	8	> 9	Σ
N	1.3	1.4	2.4	4.1	1.4	0.3	0.5	0.2	0.0	**11.6**
NE	0.5	0.5	1.7	1.5	3.4	2.2	1.4	0.2	0.0	**11.4**
E	0.6	0.6	1.7	2.6	1.4	0.7	0.5	0.0	0.0	**8.1**
SE	0.4	0.5	1.2	2.4	2.9	3.6	1.7	1.0	0.0	**13.7**
S	1.3	1.4	2.2	2.6	3.4	1.2	0.3	0.2	0.0	**12.6**
SW	1.8	1.8	1.5	1.4	0.9	0.3	0.3	0.0	0.0	**8.0**
W	1.8	1.8	2.2	2.9	0.7	0.3	0.2	0.0	0.0	**10.4**
NW	2.5	2.6	8.0	6.2	3.9	0.7	0.3	0.0	0.0	**24.2**
Σ	**10.2**	**10.6**	**20.9**	**23.7**	**18.0**	**9.3**	**5.2**	**1.6**	**0.3**	**100**

The dominant wind is the bora - usually cold, very gusty wind blowing throughout our coast from the land towards the sea or, in geographical terms, from directions NNE to ENE. Basic characteristics of the bora are sudden and very strong strokes (up to 69 m/s in Maslenica, 59 m/s in Makarska, 54 m/s on the mainland-Krk bridge). It should be noted that the bora, because it blows from the land so its fetch is relatively short, does not create any waves (up to 2.5 m), but at a speed of 6.5 m/s it creates a substantial amount of sea foam.

In terms of its influence on the safety of navigation (given its top speed and frequency), the bora is followed by the sirocco that mainly blows from ESE to SSE in the Adriatic. Extremely high wind speeds during the sirocco were measured on Palagruža (57 m/s). Because of the extreme long fetch, especially from the direction of SE, the sirocco can create extremely high waves (over 70 m in length and over 10 meters high), so if the sirocco blows longer, one should expect weather conditions that will significantly affect the way of navigation, and security of work and stay on the open sea in general.

Significant wind is also the libeccio, which generally blows from the SE, and can also be gale force. Its strength and created waves will generally be larger than waves caused by the bora, but significantly less than waves caused by the sirocco. It should be expected that the wind from SW direction will only on rare occasions endanger the safety of ships and maritime traffic in general.

3.10.3.2.2 Waves

Basic characteristic of waves in the Adriatic is their exceptional repeatability, as up to 80% (at the Ocean ≈ 42%, in the Mediterranean ≈ 66%) for waves up to 1.5 m height. Characteristic of waves caused by gale force winds is their considerable steepness ($H/\lambda = 1/10$), i.e. their average period of 4.6 sec, for which the navigation on the Adriatic coast, especially of smaller ships, is considered more dangerous at approximately the same wave height at the oceans.
Gale force waves 2.4 to 3.6 m high can be observed, with variable probability, practically in the entire Adriatic. Waves 3.7-6.9 m high
have the same spatial distribution with approximately half the frequency. The highest waves, of 6 m and more, can be encountered only in the wider area of Kvarner when the sirocco blows (SE), and in the Otranto area when the sirocco or ostro blow (S).
Characteristics of waves generated by wind generally depend on the direction, speed and duration of the prevailing winds. In the Adriatic, wind blowing direction is very much dependent on the local relief and the area over which the winds blow (fetch), and the relief of the seafloor (sea depth).
In general, the strongest storms can create waves up to 10 m high on the open sea, with significant wave height as over 6 m and a mean wavelength of up to 80 m.

3.10.3.2.3 Sea currents

Surface sea currents in the Adriatic have no significant impact on the safety of navigation in the open sea. The global system of water circulation in the Adriatic is such that the currents along the eastern coast and the western coast are directed towards NW and SE respectively, with several places where they stray from the east to the west coast of the Adriatic (Lastovo and Lošinj).
General characteristic of currents in the Adriatic is their inconstancy in terms of speed and direction. Velocities of currents differ in certain areas and time periods, and the mean velocity of currents is about 0.5 knots. In certain circumstances, especially in narrow passages and channels, it is expected that the values of flow velocity must increase significantly. During the course of the year, surface sea currents of the coastal parts of the east coast of the Central and Southern Adriatic, as well as in area of interinsular channels significantly change per season both in terms of speed and the direction.

3.10.3.2.4 Tides

Tides of the Adriatic Sea are of mixed type with extreme inequality in height. Tidal amplitudes increase from south to north. Mean amplitudes range from 0.22 m (Bar) to 0.68 m (Trieste). Increase of air pressure and the strong, long-lasting northern winds (bora and tramontana wind) can cause lowering of the sea level up to 0.50 m, and the strong and long-lasting southern winds (sirocco, libecchio) can cause a rise in sea level to 0.80 m in the Central and Southern Adriatic.

3.10.3.2.5 Fog

On the Adriatic Sea, fog is more common in its northern than in the southern part, and usually occurs in the area of the Venetian plain. In other areas of the Adriatic, probability of fog is very small and occurs on average less than 5 days in a year, except in the area of Northern Dalmatia and the islands of Palagruža, and in the area of Dubrovnik, for example, it occurs on average one day a year.

3.10.3.2.6 Orientation

The Adriatic coast is high and steep and provides good radar contours, so the the position of the vessel can be determined timely and with certainty in all weather conditions either by visual observation or by using radar devices. In addition, relief landforms on all the islands allow fast and accurate orientation.

Consequently, methods for radar navigation can be continuously used in the Adriatic area, because of a very good reflection of the configuration of the coastline (sufficient radar antenna height ensures satisfactory accuracy of the radar position at a distance as over 30 M).

In addition to a sufficient number of visible objects on the coast that allow safe navigation and orientation in space at a relatively good horizontal visibility in the Southern Adriatic area, a developed network of lighthouses, shore lights, light buoys and other marks additionally ensure safe navigation and orientation, and exclude the possibility of confusion. In this regard, the equipment of the eastern Adriatic coast with navigation means meets the highest standards encountered in areas where natural conditions are not nearly as good as they are on the Adriatic coast in general.

3.10.3.2.7 Satellite navigation

Satellite navigation, i.e. the Global Positioning System (GPS) and GLONASS can be used in the entire area of the Adriatic. Accuracy, availability, reliability, time interval between two successive positions of the ship and system capacity are common and fully meet international standards. There is no system providing improved GPS signal accuracy in the Adriatic.

3.10.3.2.8 Communication coverage

In the eastern part of the Adriatic Sea, ships can use radio traffic services of coastal radio stations (CRS) of the Republic of Croatia. Adriatic sea watchkeeping service is broadcasted on VHF channel 16, and for vessels equipped with DSC VHF DSC devices, on VHF channel 70. If there are no urgent requests for the radio link, all communications can be transmitted via the working channels of the coastal radio stations of the Republic of Croatia. On the waterway to the ports on the eastern Adriatic coast, boats can transmit all messages via the coastal radio stations:

- RIJEKA radio with the call sign (9AR), VHF radiotelephony on the channels 04, 16, 20, 24, and MF radiotelephony,
- SPLIT radio with the call sign (9AS), VHF radiotelephony on the channels 07, 16, 21, 23, 81 and
- DUBROVNIK radio with the call sign (9AD), VHF radiotelephony on the channels 04, 07, 16.

Navigation information, i.e. information relevant to the safety of navigation along the Croatian coast of the Adriatic and the associated waters is issued and published by the Croatian Hydrographic Institute in Split as the national coordinator, and broadcasted and repeated by the coastal radio stations in English and Croatian language, as long as they are effective or until they have not been published in Notices to Mariners.

Weather reports for the Adriatic Sea are issued daily by the Maritime Meteorological Centre Split, which provides a general description of the weather, the weather forecast for 24 hours and warnings. These types of reports on Croatian CRS of Rijeka, Split and Dubrovnik are usually broadcasted together with the navigation notices on appropriate working channels in English and Croatian language. Daily weather reports with weather maps and the development of weather conditions for the next three days can be obtained in all Croatian port authorities.

3.10.3.2.9 Magnetic conditions

Magnetic variation in the Adriatic Sea (2012) oscillates, ranging from approximately 2.5 °E in the area of Venice to 3.5 °E in the Strait of Otranto area. Annual change in magnetic variation is very small and is approximately 7.1 'E in the northern part up to 6.2' W in the southern part of the Adriatic.

In the Adriatic Sea area, magnetic anomalies were observed in the area of Lošinj - Rijeka, and in the southern part of the Adriatic Sea on the territory of Jabuka - Svetac - Vis.

3.10.3.3 Traffic flows in the eastern part of the Adriatic

Waterway is a sea belt where normally traffic between two points on the sea is maintained. Waterway is in a certain maritime area the result of compromise between the shortest and safest connection between the two points at sea (or land, in case of a port as the final destination).

With respect to the safety of navigation, waterways can be divided into mandatory, recommended and prohibited and, in the legal sense, on national and international. In the internal waters and in the territorial waters of the Republic of Croatia, waterways are marked according to the IALA A, i.e. the combined 4 lateral (side) marks system. The following is marked in the Croatian national waters:

- lateral limits of navigable canals,
- natural navigational hazards and other obstacles to navigation (wrecks, etc.),
- areas and objects important for navigation,
- new dangers to navigation,
- prohibited anchorages,
- ports and ports access ways.

In principle, with respect to the safety of navigation, waterways in the Adriatic sea are satisfactory, of sufficient width and depth, and for the most part do not require demanding maneuvers of high complexity and/or risk. Even when the concentration of traffic on the waterway is highest, the level of navigational safety in the Adriatic Sea is high or moderate.
Waterways are used with different intensity by various segments of maritime transport.
Waterways in the Adriatic Sea are divided into:

- longitudinal Adriatic waterway,
- coastal waterways,
- navigable areas of low traffic,
- areas of restricted or prohibited navigation.

Navigable areas of low traffic and areas of restricted or prohibited navigation are not discussed below, because of the negligible impact the exploration and production of hydrocarbons in the Adriatic have on them, i.e. negligible impact of areas of low traffic on activities related to hydrocarbons.

3.10.3.3.1 Longitudinal Adriatic waterway

Longitudinal Adriatic waterway is the main waterway of the Adriatic Sea and it connects Otranto passage and largest ports of the Northern Adriatic. The total length of the road is just over 400 km. This waterway (in its central part) extends west of the island of Palagruža, while in the northern part it branches out in two directions, one towards Venice and the surrounding ports, and second towards Trieste and Koper. The northern part of the path is substantially defined by the internationally approved measures of maritime navigation routing.

In its central part it runs between the island of Palagruža and the island of Pianosa, i.e. through the area of the triangle formed by the island Sušac, island Pianosa and Gargano Promontory. Its backbone is the traffic separation scheme. The traffic separation scheme has been established unilaterally by the Republic of Croatia and does not exceed the boundaries of the Croatian territorial sea.

Most of the longitudinal waterway runs through the open sea, i.e. through the area of sufficient width and depth free of any significant navigational hazards, except of the risk of collision with the opposite or cross traffic, possible adverse bypassing of ships in the uttermost parts of the way, possible adverse effect of hydro-meteorological conditions and the like.

The greatest densities of traffic are realized in the area of traffic separation west of Palagruza, and in the traffic separation scheme on the Northern Adriatic. These increased densities are a consequence of a relatively small width of the navigation lanes of each scheme, due to which the traffic is concentrated in a relatively small area, whereas the density of traffic in the surrounding areas is much lower.

[4] There are two waterway marking systems: IALA A system and IALA B system. In Croatia, the accepted system of marking is IALA A.

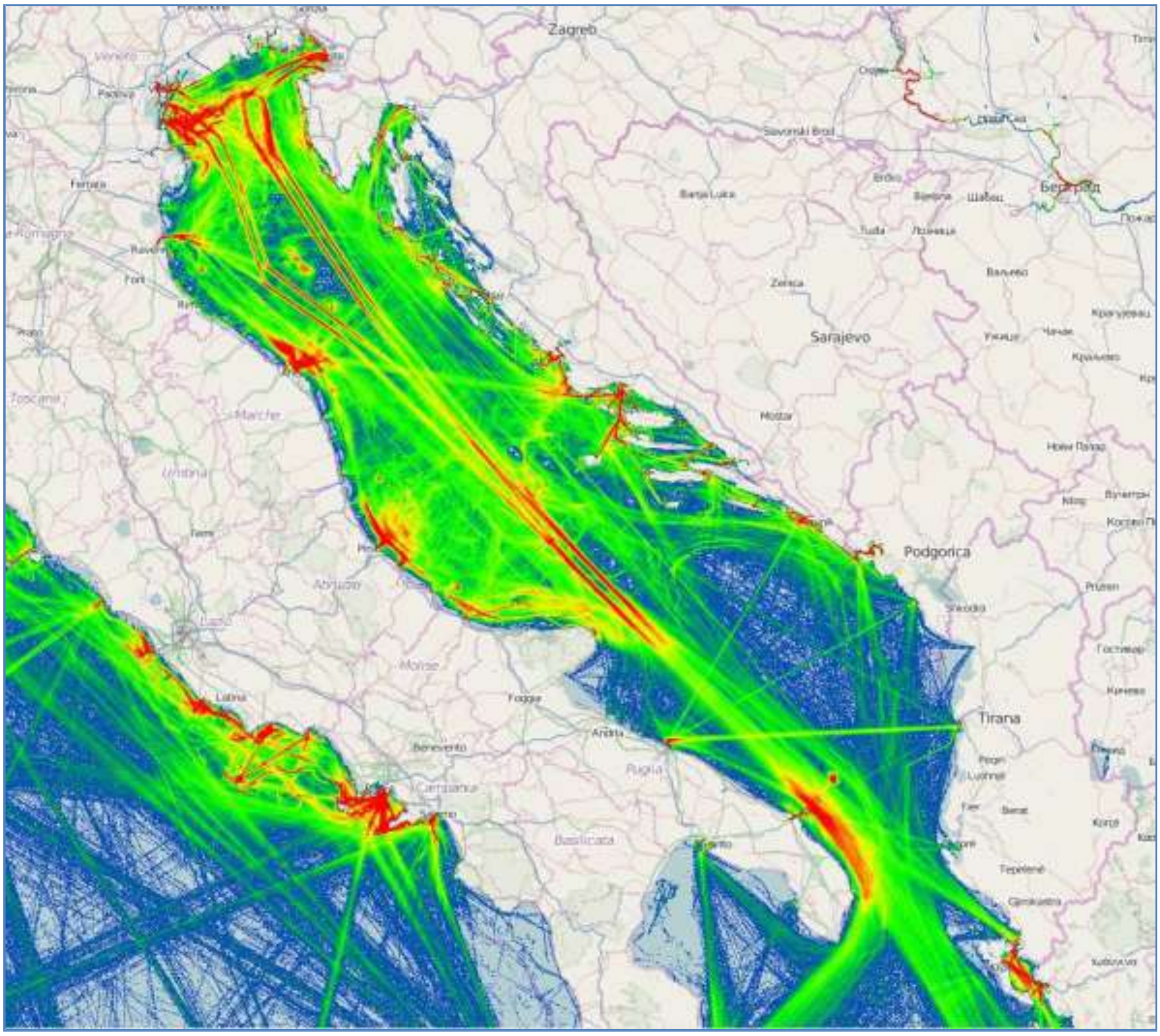


Figure 3.93 Adriatic waterway (according to data for the second half of 2013)

Longitudinal waterway is the path used primarily by merchant ships on international voyages. According to available data, approximately 22,000 ships a year sail into the most important ports of the northern Adriatic using this waterway. It should be noted that this is the waterway used by the largest number of tankers, container ships and other ships with dangerous cargo. In its southern part it runs through the edge portion of the block or partly even outside of it. In its northern part, the arm of the traffic separation scheme that stretches along the coast of Istria passes approximately throught the mid of the block.

3.10.3.3.2 Coastal waterways

Coastal waterways are ways that generally connect ports on the mainland with the island centres or ports in other Adriatic countries. In the Adriatic these are the transversal waterways and the coastal waterways.

The most important transversal waterways are:

- Split – Ancona,
- Zadar – Ancona,
- Dubrovnik – Bari,

Traffic through the transversal waterways is primarily traffic of ro-ro passenger ships and is characterized by high seasonality: traffic in the summer period is several times higher than the traffic in the winter half-year. The turnover is on a yearly basis relatively modest. With respect to the impact on the exploration and production of hydrocarbons, it is important to emphasize that these boats always follow the same waterways that are arranged in a specific way with the search and rescue services of the coastal states (pursuant to the provisions of Chapter V of the SPLAS Convention). In other words, in case of need it is possible to eliminate the cross-influences by establishing waterways which prevent adverse impacts.

Coastal waterways are navigable waterways between major ports on the mainland and the islands' centres. These waterways are mainly used throughout the year by the ro-ro passenger ships ("ferries"), with a slight increase in frequency during the summer period. It should be noted that all coastal waterways are in the area of the internal sea waters, i.e. outside the block, and therefore the impact of this part of the traffic is very modest, to the point where it interferes with the traffic to facilities for the exploration and production of hydrocarbons.

3.10.3.3.3 Other segments of maritime traffic

Merchant ships on international voyages and ships on regular lines, mainly ro-ro passenger ships and HSC ships, generally use the longitudinal waterway, i.e. the coastal waterways. For those types of ships waterways are clearly identifiable, they change seldom, and traffic characteristics are well known.

However, certain segments of maritime transport are not characterized by such high regularity. This group includes mainly fishing boats, yachts, cruise ships and smaller cargo ships in the local transports.

Fishing vessels largely remain in the internal waters, and to a much lesser extent in the territorial waters. In the category of vessels whose influence is noticeable fall primarily seiners and tuna fishing vessels. When operating, these boats can interfere with activities on the boundary parts of the blocks that lie along the coastal edge, and this to a greater extent in the Central Adriatic, less in the Northern and modestly in the Southern Adriatic. The greatest pressure of fishing vessels should be expected near the island of Jabuka, i.e. in blocks 11, 12 and 13, and then to a lesser extent in the blocks 8 and 10. Other blocks will suffer considerably less pressure.

It should be noted that fishing activities may have a significant impact on exploration procedures and in particular on production procedures. The impact is seen primarily in mechanical entanglement of fishing gear in underwater installations. It is therefore necessary to perform underwater installation in a way to maximally prevent entanglement, or establish maritime transport so as to minimize the operation of fishing vessels in the vicinity of the installations for the production of hydrocarbons.

Yachts are vessels greater than 12 m in lenght and typically appear in the summer months, mostly in the internal sea waters. Therefore, despite their large number, their impact on exploration and production is very modest or even negligible.

Ships for multi-day cruises are divided into two very large and significantly different groups: ships on international voyages and smaller, mainly nationally operating ships.

The ships on international voyages realize almost 900 port entries a year. Approximately 2/3 of entries are in the port of Dubrovnik, approximately ¼ in the port of Split while other ports have a negligible number of entries. The vast majority of these ships arrives from or goes towards Venice, so their navigation is intersected by numerous blocks, especially 18-23. In navigating the middle and northern Adriatic they follow the longitudinal waterway. Consequently, there is a certain impact on the safety of exploration and production because of great kinetic energy of these ships, which is why there is a possibility of significant damage.

Cruise ships on domestic lines are ships usually navigating up to 7 days the internal sea waters and very rarely go out in the block area. Therefore, their impact on the exploration and production is negligible.

Smaller cargo ships are ships that connect ports of the eastern coast and considerably less often ports on the west coast of the Adriatic as well. Largely they navigate the internal sea waters, unless they are prohibited to do so by special regulations, and the territorial sea, generally in the area adjacent to the coast. Therefore, even when they are part of international navigation, their impact is not great and can be ignored. The only area in which there is a possibility of interference is the area of the west coast of Istria, but even here the incidence is relatively rare.

3.10.3.4 Traffic separation scheme

Traffic separation schemes are established in areas where there is an increased risk of collision or grounding of ships. The schemes consist of a series of measures that are established and are not equally mandatory. Definitions of the individual measures, principles the states should adhere to when they establish these measures, and declaration of measures when these partly or fully cover international waters (outside the territorial waters of a given state) are established by the International Maritime Organization under the provisions of COLREG 72 Convention. If a given measure or the whole traffic separation scheme lies within the territorial waters of a particular country, then its declaration can be done by such State or the latter may ask the International Maritime Organization to confirm the so declared scheme.

At present, the internationally established traffic separation scheme is established in the Nothern Adriatic. The scheme was introduced in 2001 and amended in 2006. For now, no changes of established measures of traffic separation in the Northern Adriatic or the establishment of new traffic separation measures are foreseen. The existing measures are considered satisfactory. In this respect, no establishment of additional areas of restriction or prohibition of navigation (or expansion of existing), as implemented on the northern Adriatic, is foreseen. This is because such a measure, especially on such a large area, is not common and, in case of its application in other parts of the Adriatic, it would significantly and adversely impact other aspects of maritime transport. Exceptionally, if on the basis of the explorations the need of setting a number of facilities on a smaller, limited area is determined, then the establishment of ATBA in cooperation with other countries on the Adriatic can be considered.

In the territorial waters of the Republic of Croatia, two schemes have been established, one near the island of Palagruza, and one in the Vela Vrata area.

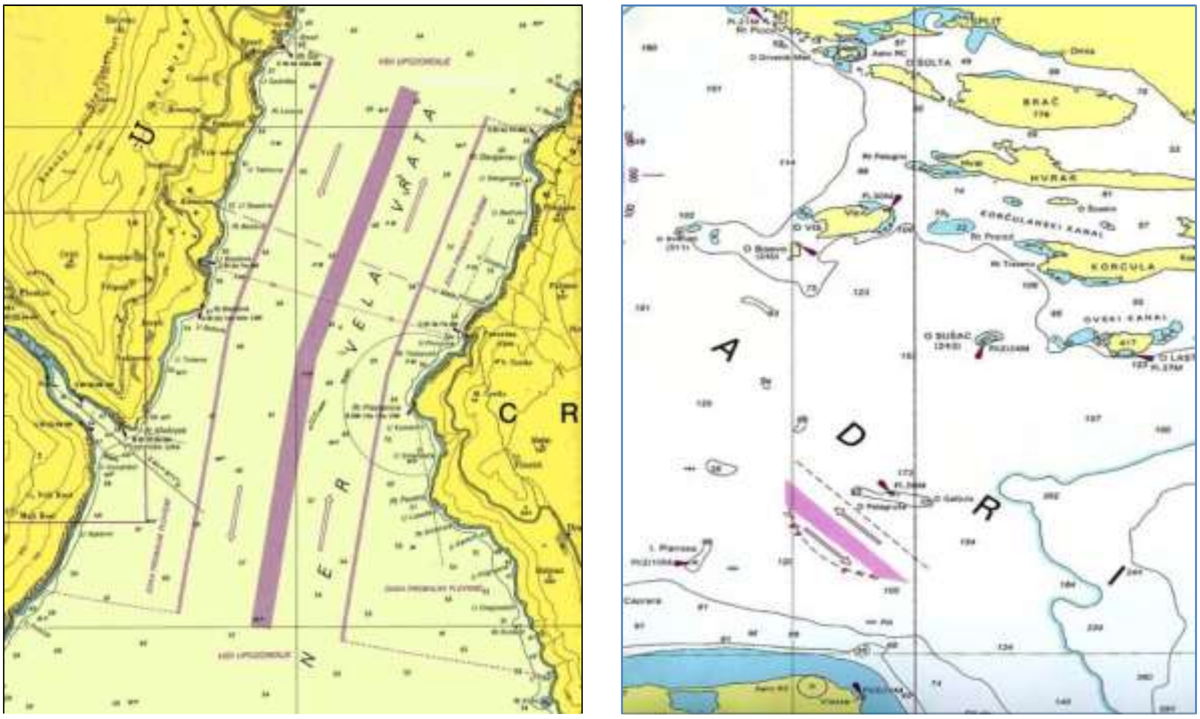


Figure 3.93 Traffic separation scheme in the Vela Vrata area and near Palagruža

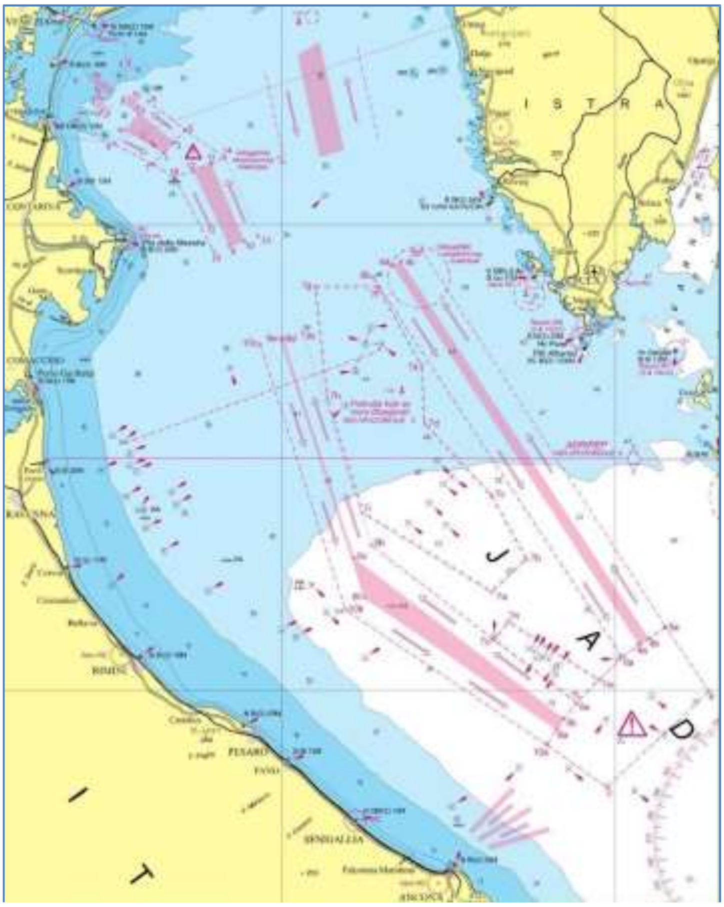


Figure 3.94 "Nothern Adriatic" Traffic Separation Scheme

The mandatory ship reporting system in the Adriatic

In the whole area of the Adriatic Sea the mandatory ship reporting system - ADRIATIC TRAFFIC, abbreviately called ADRIREP, is established. This system of reporting covers the entire Adriatic Sea area north of width 40°20'N and is mandatory for all tankers over 150 GT and for all ships over 300 GT, if carrying dangerous or noxious cargo in bulk or in containers. The said system includes Albania, Croatia, Italy, Slovenia, Serbia and Montenegro.
The basic function of the established system is to obtain information about the traffic of hazardous and noxious substances transported by seagoing vessels to all coastal states of the Adriatic Sea. The data are obtained directly from ships at sea. The system enables the established search and rescue coordination centers and other data users to have dynamic knowledge of the number and characteristics of the ships in the Adriatic, which enables the users take significantly more effective action in case of threats or actual pollution.
The primary stations of the ADRIREP system are head offices of the competent maritime authorities: Brindisi, Bari, Rijeka, Venice, Trieste and Koper. Secondary stations are all Adriatic ports in their areas of competence, with the exception of the primary stations. The system is divided into 5 areas. Each area "belongs" to the respective authorized center and creates connection by using a specific VHF channel.

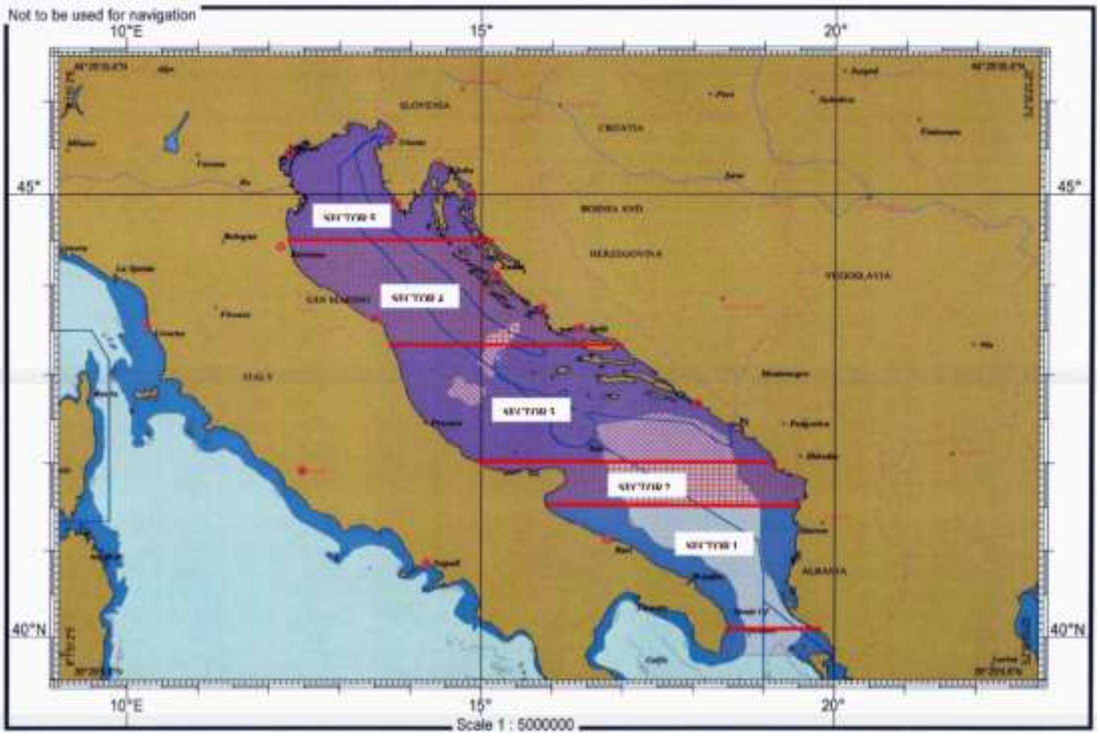


Figure 3.95 The boundaries of the sector of mandatory reporting system from ships in the Adriatic

3.10.3.4.1 The AIS system

Direct monitoring of the open sea navigation is achieved using long-range radar systems or automatic identification system - AIS.
Long-range radar systems are intended for the control of the high seas. The advantage of such systems is reflected in the ability to monitor relatively large areas of sea from one place and collect data on the movement of ships without the need for ships to be equipped with dedicated equipment. The disadvantage of such systems is the high cost of installation and maintenance, and limited area coverage in the event of a large number of islands and islets in the area of supervision.
The AIS System enables the identification of ships at sea, monitoring of their movements, and collection of a number of other data that are mostly related to the safety of navigation. The AIS System automatically transmits information about the vessel on which it is installed (static and dynamic data and information about the ship route) by using standard VHF channels 88A and 88B. The transmission is repeated every 10 seconds or more often, depending upon the set operating conditions. Data can be read on radar devices of surrounding ships or coastal stations, i.e. on designated land device.
The AIS System was established by the former Ministry of Maritime Affairs, Transport and Communications (now Ministry of Maritime Affairs, Transport and Infrastructure) and unified within the VTS System of the Republic of Croatia. Monitoring and management of maritime traffic is carried out in order to increase maritime navigation safety, efficiency of maritime traffic and protection of the marine environment and includes:

- collection of data on marine facilities and maritime traffic,
- provision of data to maritime vessels,
- provision of navigational advices and support in navigation to maritime vessels,
- organization of navigation and management of maritime traffic.

Monitoring and management of maritime traffic is carried out through the cooperation of the competent services of the Ministry and port authorities with maritime vessels that navigate or are located in the monitoring and management area. Maritime traffic monitoring and management area comprises the internal sea, the territorial sea and the ecological and fisheries protection zone of the Republic of Croatia (ZERP).
The VTS Service is, together with the port authorities, responsible for the monitoring of navigation, whereby the port authorities directly monitor the navigation, and the VTS Service indirectly (by radar and by other means) monitors and manages the maritime traffic and provides support to other services engaged in maritime navigation management.
The VTS Service is responsible for communication with ships from the moment of entering the ZERP to mooring and vice versa (it receives the necessary information and provides them to the Port Authority and to "associated participants"), and provides guidance to ships in the VTS area regarding entrance/departure from the port/anchorage and, finally, supports the MRCC in search and rescue operations.

3.10.3.5 The CleanSeaNet

The CleanSeaNet is a European satellite system for the detection of oil spill into the sea. The system has enabled:

- identification and tracking of sea surface contamination with oils,
- determination of accidental pollution,
- better identification of ships or objects that have caused contamination.

The CleanSeaNet service is based on radar images from satellites. Coverage area includes all the sea surface area of the EU countries. When a potential oil spill is detected in the national waters of a state, a warning message is transmitted to all potentially interested states. The images are available at contact points within 30 minutes after the passage of the satellite. About 2000 images are processed annually.
This service, if integrated into national and regional systems, enables rapid response in the event of contamination, both of accidental and intentional discharges from ships. Finally, when paired with the vessel monitoring system (SafeSeaNet), the system allows the identification of vessels which have caused pollution, enabling the taking of appropriate steps for claiming damages from pollution.
The Republic of Croatia, under an agreement with the European Maritime Safety Agency in 2008, has the right of access to the system, which means not only to satellite images, but also to additional services, such as oil spill trajectory models, images in the visible spectrum and oceanographic and meteorological data to determine the movement and behavior of oil on the sea surface.

3.11 Waste management

Waste management in the marine environment means treatment of waste resulting from exploration and exploitation of the seabed and its subsoil, the dumping of wastes from vessels and aircrafts, and the marine litter management (Act on Sustainable Waste Management, OG 94/13). It is required by Croatian and international regulations to have a waste management plan in place for all activities performed in the marine environment. Such plans regulate the manner in which waste is managed at sea which is safe for the marine environment, and define its final disposal as permitted by the law.

Currently there is no systematic collecting of data on marine litter in the Republic of Croatia, which makes it difficult to talk about volume of waste generated at sea and in the sea (including potential exploration and production of hydrocarbons). However, there are data, given below, and owned by the Croatian Environment Agency, on waste generated from petroleum refining, natural gas purification, and pyrolytic treatment of coal.

Out of the volume of hazardous waste reported in 2007 in the Republic of Croatia, the waste generated from petroleum refining, natural gas purification, and pyrolytic treatment of coal makes around 10 % of the reported volume of hazardous waste (The State of the Environment Report of the Republic of Croatia, 2005 – 2008).

In 2004, there were 42,419 tonnes of hazardous industrial waste generated. The biggest portion in the total volume generated makes hazardous waste, reported under the following categories (The State of the Environment Report of the Republic of Croatia, 2007):

- oil wastes – except edible oil,
- wastes from petroleum refining, natural gas purification and pyrolytic treatment of coal. There were 8,134 tonnes of sludge from tanks reported under this group. Approximately 84 % of such waste is handed to a waste collector, i.e. a processor, and around 16 % is processed on the site of generation.

3.11.1 Waste in the process of exploration and production of hydrocarbons

All of the activities in the process of exploration and production of hydrocarbons are, practically, accompanied by generation of various types of waste, which is in various physical states (solid, liquid, and gas). Solid waste, resulting during exploration and production of

hydrocarbons, includes metal, wood, plastic, packaging waste, clinical waste, sand, other construction waste, biodegradable waste, EE waste, waste waters, etc. In addition to solid waste, there is also liquid waste generated in the process of exploration and production of hydrocarbons, consisting of water which passes through the drainage system, of water-based mud, clinical waste water, formation water, and of other fluids used for drilling. Other waste waters are discharges from vessel's decks (drainage), and consist of all the waste waters resulting from rainfall, rig washing, decks washing, tanks cleaning, and runoff curbs and gutters, including from drip pans and work areas.
The matter at issue is the ship-generated waste (utility, clinical, biodegradable, EE waste, sanitary wastewater, drainage), and the waste generated directly from the activities of exploration and production of hydrocarbons (construction waste, formation water, various fluids).

In these phases gas leakage may occur, and certain quantities of gas get to atmosphere at the exploration phase when smaller quantities of hydrocarbons are flared.

Types of waste generated in the course of particular activities of exploration and production of hydrocarbons are given below.

3.11.1.1 Exploration phase

In initial drilling of an exploration wellbore, there are collapsed rocks cuttings, formation waters, water-based muds, and surplus of cement slurry (at the end of cementation of a series of casings – drive pipes) released to the seabed. Cement slurries consist of water, cement mixture and additives, some of which are also used in water-based muds. Most of this material is settled around the well within the area of few meters to several tens of metres of diameter (Neff, 2005).

If a hydrocarbon reservoir is discovered in the course of exploratory drilling, a survey of rocks (testing) must be undertaken. Such survey lasts only as long as it is takes to obtain the necessary data (1 to 2 days). The extracted hydrocarbons are flared during the survey, and so the pollutant emissions in atmosphere occur.

If oil-based and synthetic-based muds are used, they are returned onshore, recycled and reused. Pursuant to international and Croatian regulations, rock cuttings coming from the use of oil-based muds must not be returned to the sea. As regards releasing of rock cuttings from synthetic-based muds, the percentage of the retained synthetic-based muds on cuttings is limited by international regulations.

3.11.1.2 Production phase

The same type of waste is produced both from drilling a development well, and an exploration well.

Side waste is also inevitable during assembling activities: it is similar to utility waste consisting of glass bottles, paper and plastic packaging, leather gloves, other clothes and shoes, etc.

All solid waste generated during the production of hydrocarbons will be transported to the shore and delivered to a legal entity authorised for disposal, pursuant to international regulations (the MARPOL Convention, the Barcelona Convention).

When erecting a fixed platform, the discharge of waste waters and the emission of pollutants into the air may occur. The well treatment fluids and well maintenance fluids are used in this process, and they also get released into the sea. There may also occur the release of formation water. Produced sands will also appear as waste in the production phase. The produced sand are the suspended solid particles, raised to the surface after hydraulic fracturing, the accumulated produced sand, and other particles, including limestone from the production. This waste includes also sludge generated in the formation water processing system, like solid particles removed from the slug during filtration. The produced sand is transported to the shore, and disposed as non-hazardous waste.

Platform plants are usually powered by diesel or gas engines emitting air pollutants: CO, NOx, SOx, particulate matters, volatile organic compounds – VOC, and greenhouse gases, like CO_2 and CH_4.

Supply ships and helicopters also emit pollutants into the air due to diesel (ships) and jet fuel combustion.

Judging from historical data about a typical drillship, there is to be expected a generation of about 40,000 kg of waste monthly per ship (including household waste, oil waste, oil/fuel filters, absorbents, oily water, cardboard, plastic, paper, batteries, wood, etc.).

3.11.2 Waste management during exploration and production of hydrocarbons

The treatment of waste generated during exploration and production of hydrocarbons is regulated by international and Croatian regulations, as follows: the MARPOL Convention 73/78, the Barcelona Convention, the Marine Strategy Framework Directive (2008/56/EC), the Waste Management Strategy in the Republic of Croatia (OG no. 130/05), the Act on Sustainable Waste Management (OG 94/13), Ordinance on key technical requirements on safety and security of offshore exploration and production of hydrocarbons in the Republic of Croatia (OG no. 52/10).

The document titled "A Set of Characteristics of Good Environmental Status (GES) for marine waters over which the Republic of Croatia exercises its sovereign rights and jurisdiction, and a set of objectives in the marine environment protection, and therewith related indicators – Draft" defines descriptors (descriptive surveys of good environmental status) recommended to be respected to ensure the implementation of the Marine Strategy Framework Directive. The following descriptor is defined to monitor the status in the area of waste management: **Properties and quantities of marine litter do not cause harm to the coastal and marine environment (Descriptor 10).**

Since the understanding of the status, quantities and characteristics, and impact of waste on marine environment is currently insufficient, it is not possible to determine the current status and trends for this descriptor in the Croatian part of the Adriatic Sea. Namely, there is no systematic collecting and recording of data on marine litter, nor is there a strategic document/a legal act which exclusively covers the problems of such waste. The activities regarding the prevention of marine litter generation are undertaken through the implementation of the current legislative framework and strategic documents on waste management.

3.11.3 Treatment of waste in accordance with international and Croatian legislation in force

3.11.3.1 International conventions

There should be organised collection and on-shore disposal of waste from vessels, pursuant to the MARPOL 73/78 International Convention. The Convention defines the permitted concentrations of oil that may get into the sea (discharge of muds and water passing through the drainage system).

The MARPOL Convention also stipulates the obligatory establishment of a waste management plan, as well as an emergency plan (in case of oil spill).

The Barcelona Convention, among others requires a chemical use plan showing chemicals which the operator intends to use in the operations, then the purposes for which the chemicals are intended to be used, the maximum concentrations of the chemicals which the operator intends to use, etc.

The use and storage of chemicals must be approved by the competent authority, which may regulate, limit or prohibit the use of chemicals. The disposal of such hazardous chemicals requires a special permit. Also, there are standards formulated for the disposal of oily mixtures determining maximum oil content in water passing through the drainage system and in the mud. Prior cleaning of these mixtures is necessary until the permitted concentration of oil is reached. Oily waste and sledges are disposed of on the shore. The above regulations regulate also the issue of non-hazardous waste (biodegradable, utility and other waste), i.e. its final disposal on the shore, while on board/platform it must be temporarily safely stored.

3.11.3.2 Legislation of the Republic of Croatia

Pursuant to the Waste Management Strategy of the Republic of Croatia (OG no. 130/05), producers and importers of products and waste, i.e. legal and natural entities whose activities generate waste, participate in the waste management system at the level of the state, of regional and local units of self-government, by adopting waste management plans and delivering data to the authorities in charge.

Pursuant to the Act on Sustainable Waste Management (OG no. 94/13), the handling of waste resulting from exploration and exploitation of the resources of the continental shelf, the seabed and its subsoil is performed on the basis of a permit, laid down by the minister.

Pursuant to the Ordinance on key technical requirements on safety and security of offshore exploration and production of hydrocarbons in the Republic of Croatia (OG no. 52/10), it is forbidden to store or emit unburned hydrocarbons into the atmosphere or the sea.

3.12 Infrastructure

Most of the underwater infrastructure in the territory of the Republic of Croatia was set up for the purposes of connecting islands in the aspect of telecommunications and energetics and is located in the coastal waters. There are currently two underwater telecommunications cables of a total length of around 123 kilometres and around 57 kilometres of underwater pipelines for the purposes of hydrocarbon production platforms located in the territorial waters and the continental shelf of the Croatian sea (Figure 3.94). The northern of two telecommunication cables connects Umag and Mestre (Italy), while the southern cable connects Dubrovnik with Durres (Albania) and Corfu (Greece). The installation and labelling of underwater cables and pipelines is stipulated in the Maritime Code (OG 181/04, 76/07, 146/08, 61/11 and 56/13), Ordinance on requirements for the granting of licences for pipeline installation and maintenance of underwater cables and pipelines in the continental shelf of the Republic of Croatia (OG 126/07) and the Ordinance on the manner and conditions of the designation of an electronic communication infrastructure zone and other related equipment, protection zone and radio corridor and the commitments of the construction or building investor (OG 75/13).

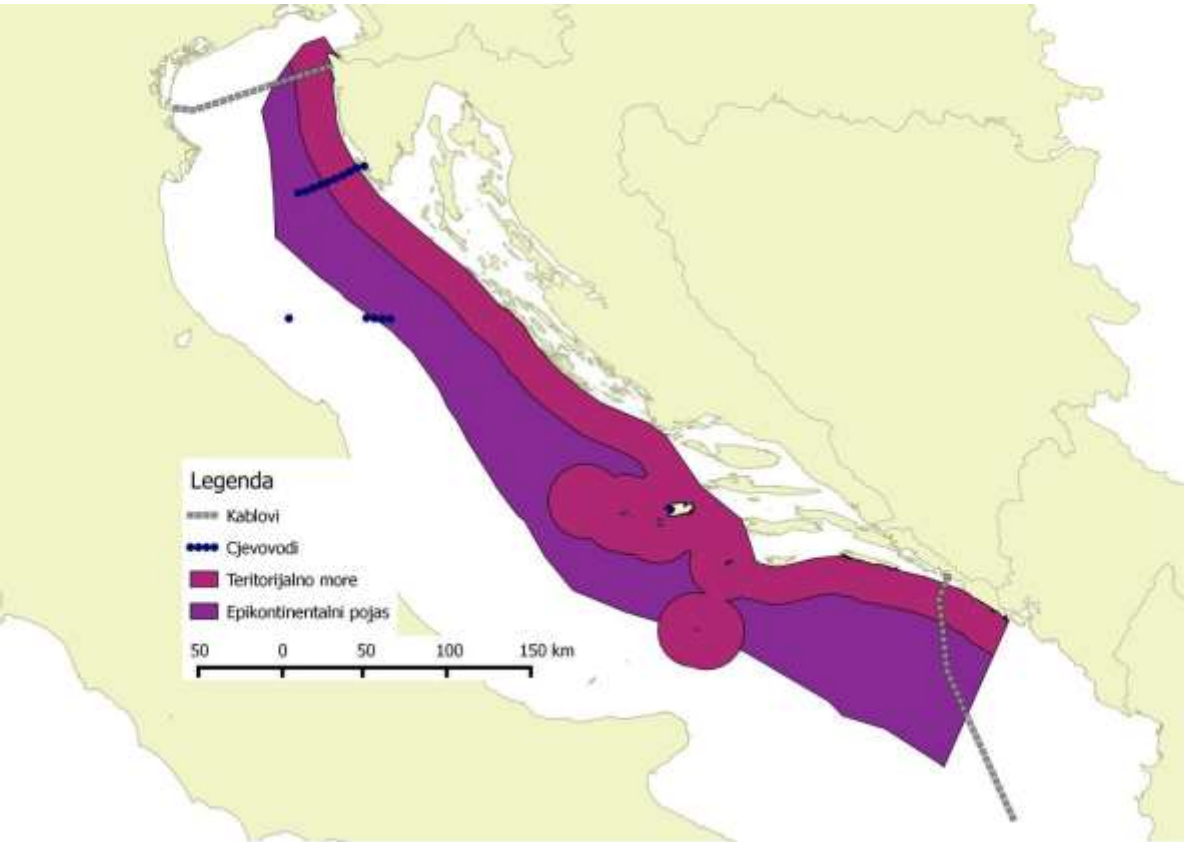


Figure 3.94 Map of existing underwater cables and pipelines in the sea of the Republic of Croatia (Source: Croatian Hydrocarbon Agency)

Legend: Kablovi – cables; cjevovodi – pipelines; teritorijalno more – territorial waters, epikontitentalni pojas – continental shelf

Due to the fact that the Ordinance on requirements for the granting of licences for pipeline installation and maintenance of underwater cables and pipelines in the continental shelf of the Republic of Croatia and the Ordinance on the manner and conditions of the designation of an electronic communication infrastructure zone and other related equipment, protection zone and radio corridor and the commitments of the construction or building investor, and that the Strategic Study respects the fact that these regulations will be respected, it is estimated that, expect in the case of accidents, it is unlikely that during the installation of the new production platform infrastructure there will be a negative impact on the existing underwater infrastructure.

It is therefore acknowledged that the implementation of the FPP could have a negative impact on infrastructural elements, but since exact locations of wells and supporting infrastructure are not determined within the framework of exploration and production blocks, that is, spatial locations of individual projects and structures are unknown, the evaluation will be processed (in accordance with applicable law and practice) through the mechanism of the Assessment of the project impact on the environment/Appropriate assessment of the project impact on the ecological network. Due to the above reasons, the infrastructure won't be analysed by all chapters in the subsequent steps of the Strategic Study preparation, but the impacts on this environment component are acknowledged only in the sense of accidents.

3.13 Possible environmental development without the implementation of the Framework Plan and Programme

Environmental characteristics should continue to develop without the implementation of the FPP, according to the patterns settled so far, with existing driving forces and limitations.

Natural processes of changes in the physical and chemical characteristics of the sea and the underground are slow and their influence is hard to measure within the time period of FPP implementation. Anthropogenic processes causing changes to these characteristics, such as industry, tourism and others in the Adriatic region are constantly increasing, but given the sea volume and the weak intensity of these changes, it is not expected that, without implementing the FPP, these processes could cause changes to the physical and chemical parameters beyond permissible limits.

Climate change intensity in the Adriatic depends on the global patterns, and without implementing FPP it would continue as it did until today. Natural level of noise in the Adriatic is caused by natural processes and its level changes depending primarily on environmental conditions. The quantity of noise caused by human activity in the Adriatic is increasing primarily with the increase in quantity and intensity of economic and other human activities (ships for transport of various cargos, cruise ships, fishing boats, vessels used for tourism purposes, etc.). As an increase is foreseen in most of these activities, it can be expected that the level of noise caused by human activities will also increase. Exact estimates of noise levels in the Adriatic will remain unknown until noise mapping is carried out.

The number of marine organisms is influenced by complex environmental and anthropogenic processes. The estimates of number and patterns are not possible for many Adriatic species due to data deficiency and insufficient knowledge of ecology. Without the implementation of FPP, the monitoring of these species' status would most probably continue in the same direction as it did until now.

Speaking of economically significant fish species, the assessment of red mullet shows a stable SSB (spawning stock biomass) for the last four years, which is about 6,000 tonnes. Analyses show stable recruitment during this period, with highest values recorded in 2011. The stock can be considered sustainable, with certain limitations. Assessment of hake shows a decline in SSB in recent years. Recruitment has fluctuated during the study period, and it shows a decline in recent years. The current value of fishing mortality is greater than F0.1, which indicates overfishing. Preliminary assessment of Norway lobster was made for the stock inhabiting the open Central Adriatic (Jabuka Pit). Analyses showed a strong decline in SSB, a strong decrease in recruitment and increased fishing mortality. Present value of fishing mortality is well above F0.1, and the population is overfished. Assessment of common pandora shows SSB increase during the study period. Recruitment in recent years shows a decline. Fishing mortality trend is declining, however, as the current fishing mortality is higher than F0.1, the population is considered overfished, and reduction of fishing mortality is recommended. However, considering the stable SSB, the decline in recruitment may be related to environmental factors.

The total sardine biomass in the entire Adriatic varied greatly in the past. Small pelagics biomass is generally expected to fluctuate, since the species in question have short lifespan and relatively high natural mortality coefficients, and their recruitment is extremely dependant on environmental factors. Sardine biomass has constantly grown in the last 10 years, although the size of the biomass is still not at the level of the biomass of the 1980s. However, it should be taken into consideration that the statistical data, as well as the analysis of all collected data, have changed during the collection period. In addition, it is important to note that in 2011 catches on both sides of the Adriatic recorded high values. Taking all of this into consideration, the current biomass of this stock in the Adriatic Sea can be described as intermediate.

The values of the estimated anchovy biomass varied somewhat significantly in the last 10 years. From 2000 to 2005, the anchovy biomass grew substantially, after which the values somewhat decreased, and in the past 3 years they have risen again. Generally speaking, from 2000 to 2011 the anchovy biomass has recorded an increasing trend. Taking all of this into consideration, the status of the anchovy stock in the Adriatic Sea is considered sustainable.

Based on the trends described, we can estimate that without the implementation of FPP, the status of the described economically significant fish species would continue in the same direction as it did until now.

Ecotoxic metals are introduced in the marine environment naturally and anthropogenically, through river inflow, rock erosion, or they are carried through the atmosphere and, without FPP implementation, current trends regarding the movement of their concentrations in marine environment are expected to continue.

In the case that FPP is not to be implemented, the principal threats to subsea culture heritage would still be anchoring, tourism development, commercial fishing (trawling), and communication and energy infrastructure.

The tourism development trend until 2020 is expected to involve further global growth in yachting as a result of the development of new markets in the Middle East and the BRIC countries, as well as the economic recovery of the main traditionally emitting markets of western Europe and Northern America. The main beneficiaries will most probably be from the segment of buyers older than 55, whose active lifestyle, health and available income enable them to pursue yachting. Innovative offer, Stay & Sail arrangements and yachting skills training will be aimed specifically at this mature segment. The growth in demand for larger vessels will result in the expansion of marinas and their adjustments so as to be able to take in larger (12 m and more) and mega (20 m and more) yachts, including the area of the Mediterranean as well. A significant new aspect in the development of yachting are the initiatives aimed at environmentally responsible business operations. Forecasts indicate there will also be further powerful growth in cruising, supported by the perception of high value for money of this product and an as of yet low market penetration. Cruising companies will continue to invest significantly in new market segments, especially youth, families with children, but also in MICE cruises by introducing new routes, themed trips and new amenities and services on ships. Ecological responsibility and the "green" practice will become increasingly important topics for the cruising industry.

Investments in nautical tourism ports, in accordance with the guidelines from the Development Strategy of Nautical Tourism in the Republic of Croatia for 2009 – 2019, provide for investment potential in connection with the improvement of the offer in nautical tourism ports, and are estimated at around 552 million EUR, 475 million EUR of which is related to the new construction of berths in new marinas, existing marinas and ports, and 77 million EUR to increasing the quality level of the offer in the existing marinas and ports. The construction of a certain number of marinas to take in mega-vessels is expected, primarily in attractive destinations offering services throughout the year.

In the case that FPP is not to be implemented, new platforms for the exploration and production of hydrocarbons would not become a part of the landscape, and the existing marine views would remain unaltered.

In the case that FPP is not to be implemented, marine waterways and navigation conditions in the Adriatic will remain unchanged and their development will be preconditioned by certain other activities.

In the case that FPP is not implemented, the number of infrastructure elements for hydrocarbon production in the Adriatic will remain the same since there will be no need for new pipelines, while the increase in waste quantities will be preconditioned by other activities. Given that the activities connected to the exploration and production of hydrocarbons are high income activities, failure to implement FPP will cause the income from existing economic activities to remain the only source of income affecting the GDP.

4

This chapter provides an overview of the environmental characteristics that may be affected by the implementation of the Framework Plan and Programme (FPP). Environmental characteristics considered from the perspective of potential impact are the following: chemical properties, climate characteristics, noise, biodiversity, ecological network, marine and seabed pollution, cultural and historical heritage, fisheries, tourism, maritime shipping, maritime transport and waterways, waste management, infrastructure, socioeconomic characteristics, landscape features as well as human health and quality of life.
Potential impacts on environmental characteristics are listed for each activity conducted in the course of hydrocarbon exploration and production. A detailed description of each impact on the respective environmental characteristic is provided in the chapter regarding the „Impact of Framework Plan and Programme on the Environment".

Table 4.1 Overview of the environmental characteristics that may be affected by the FPP implementation

Environmental characteristic that may be affected by an activity	**Operations**	**Impacts resulting from operations**	**Documents, permits and authorizations to be conducted/obtained**
OPERATIONS FORESEEN DURING THE EXPLORATION PERIOD			
Noise Biodiversity Ecological network Fisheries Maritime shipping, maritime transport and waterways	2D and 3D seismic survey	Use of a part of the water area Increase in maritime transport Airgun noise	Appropriate assessment of the project impact on the ecological network. Appropriate assessment for the ecological network area consists of the following: screening assessment, main appropriate assessment, determination of the overriding public interest and approval of the project with compensatory measures. Appropriate assessment of the project impact is conducted as part of the preparation of the planned project, prior to obtaining a location permit or other authorization required for the project implementation. Where no appropriate assessment, that is assessment of the need for an EIA is required, the project developer shall submit an application for screening to the competent authority
/	Other operations carried out during exploration (gravity, geochemical, magnetic, magneto-telluric, transient electromagnetic, and bathymetric surveys, seabed sampling, satellite gravity survey, environmental baseline survey)	No significant impact established. Prior to the FPP implementation, the Licensee´s Activity and exploration programme requires an appropriate assessment for the ecological network/environment as provided for in the regulations; potential impacts will be assessed subsequently once activity details for respective blocks are known.	
Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Waste management Fisheries Maritime shipping, maritime transport and waterways	Installation of an exploratory drilling platform	Increase in maritime transport Air pollutant emissions Seabed disturbance Noise pollution Partial use of habitats Landscape disturbance	Environmental impact assessment (Assessment of the need for an EIA, optional Study of the project impact on the environment) Assessment of the project impact on the environment is conducted as part of the preparation of the planned project, prior to obtaining a location permit or other authorization required for the project.

Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Landscape features Waste management Fisheries Maritime shipping, maritime transport and waterways	Exploratory drilling	Discharge of mud and well cuttings Wastewater discharge Hydrocarbon spill Waste material – ship-generated waste Air pollutant emissions Noise pollution Well testing (hydrocarbon flaring) Formation water discharge Light pollution Partial use of habitats	Where the assessment of the project impact on the environment also includes the appropriate assessment for the ecological network in accordance with *leges speciales*, the appropriate assessment of the project impact on the ecological network shall be conducted within the environmental impact assessment. Mining operations (all operations conducted for the purpose of exploration and production of minerals, as well as rehabilitation of the area) require mining projects. Based on the proposed scope and type of mining works, the mining authority shall establish the need for a mining project as well as the type of the appropriate mining project: *a preliminary mining project or a simplified mining project.* *Development of the Mining project regarding the drilling rig on a drilling platform* *Floating installation safety certificate (Croatian register of shipping)* *Entry into the Register of floating installations and fixed offshore facilities (competent port authority)* *Minimum safe manning certificate (competent port authority; confirmed by the Committee)* *Certificate of class*
Climate characteristics Chemical properties Noise Biodiversity Ecological network Marine and seabed pollution Fisheries Maritime shipping, maritime transport and waterways	Accompanying activities – logistics	Increased traffic of vessels and helicopters Air pollutant emissions Hydrocarbon spill	
Chemical properties Climate characteristics Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Landscape features Human health and quality of life Socioeconomic characteristics Waste management Fisheries Tourism Maritime shipping, maritime transport and waterways Infrastructure	Accidents	Mud spill Formation water spill Oil spill Ship accidents Release of hydrogen sulfide from wells	
OPERATIONS FORESEEN DURING THE PRODUCTION PERIOD			
Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Waste management Fisheries Tourism Maritime shipping, maritime transport and waterways Landscape features	Installation of a production platform and pipelines	Increase in maritime transport Seabed disturbance Air pollutant emissions Noise pollution Partial use of habitats Landscape disturbance	A Study of the project impact on the environment is developed as part of the Environmental impact assessment. The Study addresses the production and decommissioning stages. Before developing a study of the project impact on the environment and considering the planned project, the project developer may request an instruction on the study
Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution	Production drilling (presence of a production drilling platform)	Discharge of mud and well cuttings Wastewater discharge Hydrocarbon spill Waste material – ship-generated waste	

Cultural and historical heritage Landscape features Waste management Socioeconomic characteristics Tourism Fisheries Maritime shipping, maritime transport and waterways		Air pollutant emissions Well testing (hydrocarbon flaring) Formation water discharge	content from the Ministry of Environmental and Nature Protection in writing. For the execution of mining activities and construction of mining facilities and plants a main mining project, an additional mining project and a simplified mining project shall be drawn up. The execution of the main mining project requires an executive location permit and a valid decision certifying the quantity and quality of mineral raw materials. Development of the Mining project regarding the drilling rig on a drilling platform *Floating installation safety certificate (Croatian register of shipping)* *Entry into the Register of floating installations and fixed offshore facilities (competent port authority)* *Minimum safe manning certificate (competent port authority; confirmed by the commission)* *Certificate of class*
Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Fisheries Maritime shipping, maritime transport and waterways	Accompanying activities – logistics	Increased traffic of vessels (including ballast water) and helicopters Air pollutant emissions Hydrocarbon spill	
Noise Biodiversity Ecological network Fisheries Maritime shipping, maritime transport and waterways	2D and 3D seismic survey	Increase in maritime transport Air pollutant emissions Airgun noise	
Chemical properties Climate characteristics Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Landscape features Human health and quality of life Socioeconomic characteristics Waste management Infrastructure Tourism Fisheries Maritime shipping, maritime transport and waterways	Accidents	Mud spill Formation water spill Oil spill Ship accidents Release of hydrogen sulfide from wells	
OPERATIONS FORESEEN DURING THE REMOVAL OF MINING FACILITIES AND PLANTS			
Climate characteristics Noise Biodiversity Ecological network Fisheries Waste management Marine and seabed pollution Fisheries Maritime shipping, maritime transport and waterways	Removal of (exploration and production) mining facilities and plants	Use of explosives Noise pollution Removal of “artificial reefs”	
Chemical properties Climate characteristics Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Landscape features Human health and quality of life	Accidents	Oil spill Ship accidents Release of hydrogen sulfide from wells Other accidents	

Socioeconomic characteristics Waste management Fisheries Tourism Maritime shipping, maritime transport and waterways Infrastructure			

5 Existing environmental issues pertinent to the Framework Plan and Programme

Significant environmental protection issues, as well as issues concerning the sustainable development of the coastal area and the sea, include excessive construction in the coastal area which is often accompanied by bad utility facilities, as well as spatial planning dominated by urbanisation of ownership lots without performing land consolidation. In the period from 1960 to 2000, a multiple increase (around five times) of urbanised coastal areas was recorded, from 150 km to 837 km. An increase in the urbanisation of the coastal area (actually constructed or planned for construction) is largely the consequence of construction in coastal towns (residential buildings used in tourism, holiday apartments and homes) as well as outside urban areas (complex tourist zones, manufacturing and business zones, infrastructural facilities and networks etc.). Certain areas are particularly affected by illegal construction.

Construction in coastal areas is probably what affects the biological and landscape diversity of the Adriatic coast the most. Another issue is the fact that these activities are irreversible since piled beaches almost never return to their previous state.

Construction, therefore, has both a direct and indirect effect on the marine ecosystem and the environment:

- The direct effect arises from the filling which directly destroys immobile or poorly mobile organisms. The filling often leads to a change in the types of substrate (e.g. gravelly sediment is replaced by a hard concrete one), leading in turn to a change in landscape diversity, type of community and organisms in such habitats.
- The indirect effect is evident from the irrigation of the piled material from the coast, which may lead to an increase in the sedimentation of the surrounding area, burying sedentary organisms, disabling filtration and breathing processes or preventing the acceptance of early development stages of organisms in the need of a hard substrate at that development stage. In this way, sedimentation can cover a vastly larger area than the one covered by direct piling.
- The construction of ports and piers also leads to changes in the physical and chemical properties of the area, increasing sedimentation, decreasing clarity and hydrodynamics in the mediolittoral and supralittoral zones, and can lead to an increase in the concentration levels of nutrient salts and unwanted contaminants in the antifouling protective paint coats.

The measures for the protection of the coastal and island area from unsuitable urbanisation are not being implemented in the necessary scope and dynamics. Construction is still concentrated on a contact line between the coast and the sea, and the marine area is privatised, showing the importance of a more efficient control of the implementation of spatial and urban planning. For instance, it is possible to achieve a significant level of natural coast conservation through a more rational use of the existing 300 or so tourist zones and a more deliberate activation of a part of around 350 tourist zones planned.

Tourism is the main driver of economic activities in the coastal area and has many favourable economic impacts for certain coastal and island communities. However, in addition to positive impacts, tourism also highly burdens marine environment and the coastal area. Each of these problems entails environmental risks with possible significant economic and social consequences. Due to the length of duration of unwanted patterns, the Croatian government has adopted the Regulation on the development and conservation of the protected sea coastal area, intensifying the control and protection of the coastal and island area from unsuitable construction. The aforementioned regulation has been integrated in the Physical Planning and Building Act from 2007, with specific provisions regarding the protected sea coastal area. The Croatian Physical Planning Council adopted the criteria for the planning of coastal tourist areas in 2009, and their implementation assessment is still pending.

The impact of fisheries on ecosystems can be viewed through:

- the physical damage of fisheries to habitats. It is more pronounced in towed fishing tools (shore seines, rampons, trawlers etc.) used in the infralittoral area (coastal fisheries) than in bottom trawlers whereby exploitation is carried out in deeper sections of the sea where sediment is muddy or sandy, without the presence of marine flora.
- Due to the impact on biodiversity in bottom trawling fisheries, a negative impact arises for the benthic fauna of invertebrates (sea cucumbers, ascidiacea, sea urchins, bivalvia, starfish, crabs, etc.) caught as bycatch. Highest quantities of bycatch are found along the western coast of Istria (bivalvia), but also in the open Central Adriatic (sea cucumbers, ascidiacea, starfish, sea urchins) and in the internal territorial waters. However, since these are organisms of no economic value, they are tossed back into the water, mostly alive and without damage.
- Another important impact is created by fishing tools lost in sea and their parts (nets, traps etc.) confining/trapping the organisms, causing them to die.
- Negative impact is also evident in the accidental catches of turtles and dolphins during fishery activities.

The principal burdens arising from mariculture activities which have been recorded for the Adriatic subregion area are the following:

- Physical destruction of Neptune grass (*Posidonia oceanica*) due to anchor chains in marine farms.
- Changes in the oxygen content and nutrient salt concentrations in the area of farming, and consequential changes in the Phytoplankton population biomass.
- Increased sedimentation of a particular organic substance onto the seabed, a change in the granulometric composition, reduction potential, and nutrient salt content in the sediment, as well as changes in benthic organism populations.

Sailing, i.e. passenger and goods transportation, is a significant branch of economy in Croatia. Principle burdens arising from these activities are the careless and illegal disposal of solid waste (mostly packaging and food) and liquid waste (oily water) into marine environment, transfer of invasive organisms from other areas, and physical mixing of water masses in shallow ports, disrupting the seabed structure and, consequently, benthic populations.

Burdens on marine environment arising from harmful substance pollution can be divided into the following:

- the introduction of substances for the protection of agricultural crops (pesticides, antivegetative substances),
- the introduction of heavy metals and
- the introduction of radionuclides.

Estimations show that today there are over 650 different chemical compounds used for the protection of crops and plantations from weeds and various pests, but also for the prevention of human diseases carried by insects, especially in wet and swamp areas. The estimated amount of overall annual consumption of protective substances is 2.5 million tonnes. According to the data from the State of Environment Report (Croatian Environment Agency, 2007), a total of 3840 tonnes of plant protection substances was produced in Croatia in 2004. The same source provides no reliable data regarding the consumption of these substances, but their estimated consumption is 2.5 – 3 kg of active substances per hectare of arable land. Among these compounds a group of organochlorine compounds, whose application has already been prohibited in multiple countries, is particularly evident due to its toxicity, environmental persistence, and its bioaccumulation characteristics. Although these compounds are mentioned in several acts, regulations and ordinances in the Republic of Croatia, a systematical monitoring of the pollution created by plant protection substances does not exist, which is why the conclusions regarding the use of these substances in agriculture and their biogeochemical cycles in the hydrosphere can be reached only indirectly, based on the results of the existing monitoring of the watercourse and the bivalves from the area of transitional and coastal waters. All analysed data regarding organochlorine pesticides in the watercourses of the Primorje-Istria and Dalmatia basins indicate that their concentrations are very low or below detection level. The bivalve monitoring results also indicate that the existing introduction of these compounds is not intense enough so as to endanger the fair chemical state of the coastal water and open sea water areas. Multi-annual patterns regarding the changes in organochlorine pesticide contents in bivalves support this assumption.

The available data regarding the introduction of heavy metals into marine environment of the Republic of Croatia concern the introduction through point sources (process water and municipal waste waters) and through watercourses. Data regarding the introduction from diffuse sources of pollution or from the atmosphere are not available. Heavy metal quantities carried by rivers into transitional and coastal waters range from 801 kg (Cd) to 33817 kg (Zn). If we compare these values with heavy metal quantities carried to the Croatian territorial sea area through waste waters (Baseline Budget for year 2008, Republic of Croatia, Ministry of environmental protection, physical planning and construction, 2009) it is evident that the introduction of heavy metals into the coastal waters of the Republic of Croatia is mostly done through watercourses, and less through waste water.

The concentrations of 90Sr and 137Cs fission radionuclide activity in marine waters exponentially dropped in the 1990s, and their values have been very low in the past 10 years, in a range from 2 to 4 Bq/m3. Top levels of 137Cs activity concentrations measured in indicative organisms: the European pilchard (*Sardina pilchardus*), the musky octopus (*Ozaena moschata*) and the Mediterranean mussel (*Mytilus galloprovincialis*) amounted to 0.25 Bq/kg, 0.1 Bq/kg and 0.5 Bq/kg. Activity concentrations of natural radionuclides, ^{232}Th (^{228}Ra), ^{238}U and ^{226}Ra, measured during 2008, 2009 and 2010 in the Mediterranean mussel are extremely low and almost always below detection levels.

Nutrient salt contents are introduced into the marine environment from the atmosphere, diffusely from the land irrigation process, through river flow and subsea fresh water sources, as well as through point sources carrying process water and municipal waste water. There is no data regarding the absorption of nitrogen compounds from the atmosphere in the Adriatic region, but atmospheric deposition is certainly a significant entryway for nitrogen into the marine environment of the Adriatic since research has shown that nitrogen deposition in the northern hemisphere has increased ten-fold in the last century.

The origin of diffuse pollution is mostly connected to the irrigation of various land types (agricultural, botanical and forest cover etc.) and artificial surfaces (cities, towns, industrial zones). The impact of this type of diffuse pollution on the ecological and chemical state of transitional and coastal waters as well as open sea waters of the Republic of Croatia has been assessed as relatively unpronounced, supported by certain facts:

- The available data regarding agricultural land in coastal counties indicates that the area used for agricultural purposes, even though the percentage (44 %) is high in overall continental area of Croatia, is very small. More significant parts of the agricultural lands in the coastal area are located only in Ravni kotari in the Zadar county, and on the Istrian peninsula.
- A very small portion in the production of more important crops and plantations, with the exception of olive and grape production which are included in extensive agriculture.

According to the data from Croatian Environment Agency (www/jadran/izor/azo), the annual inflow of overall nitrogen and phosphorus through watercourses amounted to 11.250 tonnes of overall nitrogen and 397 tonnes of overall phosphorus for 2009. If we compare these values to the quantities from waste water, we can conclude that the larger part (around 77 %) of overall nitrogen is introduced via watercourses into the coastal waters of Croatia, while the larger part of phosphorus (66 %) is introduced via waste waters.

The trophic state in the southern Adriatic areas can be described as oligotrophic, i.e. a state marked by low primary production, good clarity, low nutrient salt and chlorophyll *a* concentrations, and the absence of hypoxia. Particularly important for this area is the very good status also established on a station located in front of the Neretva delta (third river by flow rate in the Adriatic area) and the Port of Ploče, indicating that the anthropogenic pressure on this area is currently acceptable. The ecological status on stations in the Central Adriatic can also be evaluated as very good, except for the stations in Vranjic (Kaštela Bay) and the Port of Šibenik, where the status is periodically good.

The bathing water quality along the Croatian coast is very high, indicating that there are no issues regarding the presence of pathogens in the coastal waters of Croatia. A ten-year analysis of the bathing water quality indicates that there is a clear pattern in the reduction of the percentage of beaches which do not meet the existing regulatory criteria in all of the counties. Such a positive trend is the result of an increase in the number of constructed discharges for waste water of faecal origin along the Croatian coastline.

An alien species is a species which is not native to a specific ecosystem, but it was introduced into it either deliberately or by accident. If its reproduction threatens the viability of domestic species, it is considered invasive. Such species threaten the biodiversity of the specific ecosystem and can negatively affect the lives and health of humans, and cause serious damage to economic growth.
In the last two decades, the Croatian part of the Adriatic records the presence of allochthonous organisms, including algae, invertebrates and fish. Certain taxa of algae are often highly invasive. These taxa reproduce quickly and successfully for many reasons. Some, such as the *Caulerpa* algae, have no natural or effective predators that would control their population sizes. Others, such as the *Womersleyella setacea*, create extremely thick coating on the seabed and expand rapidly through vegetative growth which puts them at an advantage following environmental disturbances. All of the so far recorded invasive taxa of marine algae show a substantial negative impact to natural communities and habitats in the Adriatic.
During the last decade the frequency of appearance of "exotic" fish species in the Croatian part of the Adriatic has increased. Most of these species originate from the Red Sea (so-called Lessepsian migrants); first they arrived in the Eastern Mediterranean through the Suez Canal, then they arrived in the Adriatic. *Fistularia commersonii* has been seen multiple times in various locations, which can indicate an establishment of a population of this species with a potentially invasive character. A rise in abundance of thermophilic species (organisms) in the Adriatic refers to a possible rise in sea temperature, which could be linked to climate change. This way recently, for the first time, some species of groupers, such as *Mycteroperca rubra* and *Epinephelus aeneus* have been recorded in the Adriatic. On the other hand, the presence of some fish species, such as *Cyclopterus lumpus*, *Pagrus major* and the invasive crab *Callinectes sapidus*, cannot be linked to climate change because they probably appeared in the Adriatic through anthropogenic interference. Special attention needs to be given to potentially invasive species from the Tetraodontidae family: *Lagocephalus lagocephalus* and *Sphoeroides pachygaster* due to the toxin tetrodotoxin in their tissue which causes poisoning to its consumers.

Species	English name	Year of finding	Area of finding	Origin
Caranx crysos	blue runner	2008	west coast of Istria	Mediterranean
Cyclopterus lumpus	lumpsucker	2004	Southern Adriatic – Molunat	North Sea
*Epinephelus aeneus**	white grouper	1998	Southern Adriatic – Dubrovnik	Mediterranean
Epinephelus coioides	orange-spotted grouper	1998	Northern Adriatic – Trieste	Red Sea
*Fistularia commersonii**	bluespotted cornetfish	2006	Southern Adriatic – Sveti Andrija	Red Sea
L. Lagocephalus lagocephalus	oceanic puffer	2004	Southern Adriatic	Mediterranean
Leiognathus klunzingeri	slipmouth	2002	Southern Adriatic	Red Sea
*Mycteroperca rubrum**	mottled grouper	2001	Southern Adriatic – Dubrovnik	Mediterranean
Pagrus major	red seabream	2004	Zadar archipelago	Aquaculture (Pacific Ocean)
*Saurida undosquamis**	brushtooth lizardfish	1996	Albanian coast	Red Sea
*Siganus rivulatus**	marbled spinefoot	2002	Southern Adriatic – Cavtat	Red Sea
*Sphyranea chrysotaenia**	yellowstripe barracuda	2000	Southern Adriatic	Red Sea
*Sphyranea viridensis**	yellowmouth barracuda	2003	Southern Adriatic	Mediterranean
*Stephanolepis diaspros**	reticulated leatherjacket	2002	Southern Adriatic – Montenegrin coast	Red Sea
Terapon theraps	largescaled terapon	2008	Northern Adriatic	Red Sea
*Invasive species				

Dana source: Croatian Ministry of AGriculture, Croatian Bureau of Statistics

Figure 5.1 Allochthonous species in the Adriatic (source: Croatian Environment Agency)

In 2013 the fish species *Lagocephalus sceleratus* (Silver-cheeked toadfish), an Indo-Pacific species which arrived in the Mediterranean through the Suez Canal (Lessepsian migrant), was recorded in the Adriatic for the second time. It was caught near Tribunj on 17 March 2013. The fish was 492 mm long. This species belongs to the Tetraodontidae (pufferfish) family and represents a potential risk for human health, because its skin and internal organs contain the toxin tetrodotoxin which can paralyse the nervous and respiratory systems and eventually cause death due to consuming incorrectly prepared meat of this fish. This species represents one of the most invasive species in the Mediterranean. Besides the potential danger to human health, this species causes damage to fishermen along the Eastern Mediterranean coast by destroying fishing tools and prey (swallowing the prey together with the hook). An individual of the *Lobotes surinamensis* or tripletail species was caught (12 May 2013) (LT=342 mm, W=845,32 g) in the Northern Adriatic (Raša bay). This is the most northern area in the Adriatic and the Mediterranean in which this species has ever been found. In the last few years a rise in numbers and range of this species was noticed in the Mediterranean, especially around

Malta.

Due to the lack of comprehensive studies and monitoring programmes there currently is not enough data based on which the current status and trends of underwater noise in the Adriatic could be quantitatively determined. Within the framework of the "Consulting Services For The Definition Of The Monitoring And Observation System For Ongoing Assessment Of The Adriatic Sea Under The Adriatic Sea Monitoring Programme, Phase II" project, initial measurements of underground noise have been undertaken on three locations in two periods of time. The capacities of existing measurement equipment and methodology and the obtained useful initial data have been tested. It was found that the increase of impulse noise level is probably caused by construction work on the marine area and by seismic surveys, whereas the increase of continuous underwater noise is caused by the increase in maritime traffic, especially seasonal traffic of tourist ships (Institute for Oceanography and Fisheries).

Due to insufficient data on the status of Adriatic macrofauna and seabirds populations, it is impossible to define all the impacts on them at the moment. It can, however, be assumed that all of the anthropogenic pressure described above influences their dynamics.

6 The Main Assessment of the acceptability of the impact of the Framework Plan and Programme for the Ecological Network

Since the plan and programme foresees activities in the area of the Croatian territorial sea and continental shelf, the Main Assessment elaborates target species and habitats within the blocks foreseen by the FPP. These target species include bird species which are the conservation objective for the ecological network area HR1000039 Pučinski otoci and Audoin's gull (*Larus audouinii*) as well as the common bottlenose dolphin (*Tursiops truncatus*) as the only regularly present species in the FPP water area. Even though it is not on the list of the Croatian target species, the loggerhead sea turtle (*Caretta caretta*) is included in Annexes II and IV of the Habitats Directive (EEC 92/43/EEC) and it was elaborated as such. Besides the loggerhead sea turtles, there are two more turtles which can be found in the Adriatic and which are listed in the Annex of the Habitats Directive (Table 6.1), but they are rare and the information about them is very scarce, and therefore, they were not elaborated in this document (see chapter 3.6.1.2). The Main Assessment recognized the potential impacts of the implementation of the plan and programme on passage migrants (Russel 2005). However, the information on the passage migrants is not familiar enough, and therefore, the species which can be affected will be analysed during the assessment of the impact of the project on the ecological network, when the species and the scope of the planned operations in the individual blocks will be precisely known. The common crane (*Grus grus*) was elaborated as a passage migrant which can be affected by the FPP implementation, and the potential impacts on the Main Assessment level can be applied to all other passage migrants which are conservation objectives. The potential negative impacts to Natura 2000 areas of the neighbouring countries of the EU member states have been elaborated under 13.5. Cross-border impacts.

Table 6.1. The list of turtle species which could be negatively affected by the FPP implementation, and which are listed in the Habitats Directive

Latin name	English name	Countries where the species is protected	Habitats Directive (Council Directive 92/43/EEC)
Caretta caretta	Loggerhead sea turtle	Cyprus, Spain, France, Italy, Portugal, Great Britain	Annex II* and IV
Chelonia mydas	Green sea turtle	Cyprus, Spain, Italy	Annex IV
Dermochelys coriacea	Leatherback sea turtle	Spain, France, Italy, Great Britain	Annex IV

* Priority species

6.1 Characteristics of the ecological network areas

6.1.1 Description of the ecological network areas

Based on a GIS analysis, special areas of the ecological network were declared, which are either fully or partially located within the field limits. The declared ten special areas of the ecological network, important for the preservation of species and habitat types (SAC) and a single area important for conservation of birds (SPA) (Table 6.2):

- SPA: HR1000039 Pučinski otoci
- SAC HR2000941 Island of Svetac
  HR2000943 Island of Palagruža
  HR3000099 Islands of Brusnik and Svetac
  HR3000100 Island of Jabuka, offshore
  HR3000121 Island of Palagruža, offshore
  HR3000122 Islet of Galijula
  HR3000423 Jabuka Pit
  HR3000469 Vis water area
  HR4000008 Island of Jabuka
  HR4000009 Island of Brusnik

Based on the potential impacts of FPP the further analysis includes the areas of the ecological network with sea habitats as conservation objectives (Figure 6.1 and Figure 6.2). This includes sandbanks which are slightly covered by sea water all the time, reefs, submerged or partially submerged sea caves and posidonia beds (Posidonion oceanicae) (description of the habitats: table 6.4). Because of the geomorphology of the Adriatic Sea seabed, it is to expect that there are sandbanks which are slightly covered by sea water all the time, reefs, submerged sea caves along the entire project area covered by the plan and programme, but since there are almost no information about the seabed of the continental shelf of the Adriatic, it is not possible to assess the impact on those habitats outside the specified areas of the ecological network.

The potential impacts and their reach have been analysed in relation to the operations planned during the hydrocarbon exploration and production. The impacts of accidents are substantially different and they have been elaborated in chapter 6.2.6.

Table 6.2 Areas of the ecological network within the limits of the FPP project area

SAC/ SPA	Code	Name	Description
SPA	HR1000039	Pučinski otoci	The area of Pučinski otoci spreads from the island of Vis on the east, over Biševo and Brusinik up to the island of Jabuka on the west. The location of Pučinski otoci (Pelagic Islands) is the main breeding area of the Eleonora's falcon (Falco Eleonorae) and one of the two breeding areas of the Scopoli's shearwater (Calonectris diomedea) and the yelkouan shearwater (Puffinus yelkouan) in Croatia. It is also a significant area in the Adriatic migration corridor.
SAC	HR2000941	Island of Svetac	Svetac is an island with an area of 4.6 km^2 and the entire area of the island is a part of the ecological network. The island is covered with lush Mediterranean vegetation (*makija*), Aleppo pine (Pinus halepensis) and evergreen oak (Quercus ilex) forests. The conservation objectives of this area include Mediterranean continental plant communities, and especially Thero-Brachypodietea grasslands.
	HR2000943	Island of Palagruža	The Palagruža area of the ecological network is an archipelago made up of a group of islands and rocks, among which Velika and Mala Palagruža being the largest. The target species and habitats have been limited to the continental part of the archipelago. They primarily include the Mediterranean communities with the *Euphorbia dendroides* species, communities with species of the *Limonium* sort and Thero-Brachypodietea Mediterranean grasses.
	HR3000099	Islands of Brusnik and Svetac	This area of the ecological network covers the offshore area around the islands of Brusnik and Svetac and the cliff Kamnik within a 500 m radius. The sea depth of this location ranges from 0 to 110 m. Because of its habitat diversity, the entire area is exceptionally rich with fish.
	HR3000100	Island of Jabuka, offshore	The offshore of Jabuka is an area of the ecological network on the sea surface within a 500 m radius from the shoreline of the island. It is located 70 km north-west of the island of Vis and it is rather isolated. The seabed within the area is steep and rich with reefs. Despite its location in the Jabuka Pit the deepest point of the area is at 80 m.
	HR3000121	Palagruža, offshore	The Palagruža offshore is the area of the ecological network which encloses the Palagruža archipelago. It is characterised by sea cliffs, sandy seabeds, and especially beds of *Posidonia oceanica*.
	HR3000122	Islet of Galijula	Galijula is an islet located in the open sea about 3 miles south-east of Palagruža. The continental part of the island is located within the area of HR2000943 Island of Palagruža, whereas the marine part belongs to the area of the ecological network HR3000122 Islet of Galijula. The island is surrounded by Sandbanks which are slightly covered by sea water all the time and sea reefs which are the
	HR3000423	Jabuka Pit	Jabuka Pit is a depression in the Middle Adriatic. The area is located at a depth between 200 and 240 m. It is a familiar nursery area for many species of fish and cephalopods. Its seabed is sandy with reefs on steeper parts.
	HR3000469	Vis water area	This area includes a wider area around the islands of Vis and Biševo with a total area of 51,888.5 ha. The conservation objective of this area is the common bottlenose dolphin (*Tursiops truncatus*) which is here a permanent resident.
	HR4000008	Island of Jabuka	The island of Jabuka is located 70 km north-west of the island of Vis. It is a volcanic island, very steep, and in the shape of a pyramid. It is 97 m high. The conservation objective in this area includes chasmophytic communities, communities with species from the *Limonium* sort, and stenomediterranean
	HR4000009	Island of Brusnik	Brusnik is an uninhabited island located 23 km west of Vis with an area of 3 hectares, which is also the area of the ecological network. It is a volcanic island, which is 200 m long, 150 m wide and 23 m high. It is protected because of the Mediterranean steep coast overgrown with endemic species of the *Limonium* sort.

Figure 6.1 Map of the areas of the ecological network which can be affected by the implementation of the plan - part one

Figure 6.1

Key:
SPA
SAC
Blocks

(map, left-right)
SAC Jabuka Pit
SAC Island of Jabuka – offshore
SAC Brusnik and Svetac
SPA Pučinski otoci
SAC Vis Water Area

Figure 6.2 Map of the areas of the ecological network which can be affected by the implementation of the plan - part two

Figure 6.2

Key:
SPA
SAC
Blocks

(map, left-right)
SAC Palagruža – offshore
SPA Pučinski otoci
SAC Islet of Galijula

6.1.2 Description of the conservation objectives of the ecological network area

Several hundreds of bird species migrate over the Adriatic Sea each year, but even more species breeds, winters or resides there throughout the year. The plan and programme encompasses 27% of the Adriatic Sea area (36 822 km2) or 78% of its length (575 km) and negative impacts on the birds using it are possible Because of a large number of species listed in Annex I of the Birds Directive, the species have been classified into categories according to the intensity and duration of the potential impacts. In this way, 4 categories of birds have been formed:

- **Birds of marine habitats**: These are the species foraging in the sea (fish, cephalopods or shrimps). They breed on desert islands and cliffs and stay connected to the sea during their entire course of life. Their need for isolated and undisturbed breeding locations, their breeding sites are rare. The implementation of the FPP potentially has the highest negative effects to this category out of all bird species which are the conservation objective.
    - **The elaborated species**: Scopoli's shearwater (*Calonectris diomedea*), yelkouan shearwater (*Puffinus yelkouan*), European Shag (Mediterranean) (*Phalacrocorax aristotelis desmarestii*) and Audouin's gull (*Larus audouinii*).
- **Passage migrants**: The species that occur in the project area for a relatively short period. They use the Adriatic flyways and they use the islands as resting and gathering areas. The impact of the FPP implementation to passage migrants is possible during the migration periods.
    - **The elaborated species**: common crane (*Grus grus*)
- **Vultures which stay within the boundaries of the plan and programme project area**: As a rule, these are large birds that spend the majority of time flying. And when flying, they are gliding on the air-currents. They are flying high above the sea level and have a large radius of movement. Since they are top predators, the number of their species is small. This category also includes vultures that only winter or breed in the project area. In the area of Pučinski otoci the impact on this category is restricted and it can be minimised by use of the protection measures.
    - **The elaborated species**: Short-toed snake-eagle (*Circaetus gallicus*), hen harrier (*Circus cyaneus*), Eleonora's falcon (*Falco eleonorae*), peregrine falcon (*Falco peregrinus*).
- **Birds of terrestrial habitats**: These are the bird species residing in terrestrial habitats. They feed, breed and raise offspring never far from the coast. This category includes breeding birds, wintering birds and the species that are permanent residents of a specific area. Even if they do migrate, they undergo short-distance migrations. Therefore, the impacts on this category are small and negligible and the category will not be elaborated further within the Main Assessment.
    - **Species**: All bird species that do not fit in the previous three categories.

6.1.2.1 Bird species of marine habitats

Yelkouan shearwater (*Puffinus yelkouan*)

Yelkouan shearwater is a typical seabird that visits islands only for breeding. They nest in densely-populated colonies on coastal cliffs of islands and islets, rarely land, and in crevices, shelves and burrows in the ground if there are any (they use rabbit holes). The egg incubation period lasts from 48 to 52 days. The chick period lasts from 60 to 68 days. Both parents incubate the egg in turns and they share the feeding duties until the chick is ready to fledge. After the brood learns how to fly, the species spends some time on the Adriatic before migrating south to their wintering grounds. It is not known in which part of the Adriatic this species feeds, and its daily and seasonal migrations are also unknown. This species is the conservation objective for two localities within the ecological network of the Republic of Croatia: HR1000038 Lastovsko otočje HR1000039 Pučinski otoci (figure 6.3).

It is a breeding bird of pelagic islands of the Central Adriatic, Sveti Andrija, island of Svetac, islet of Kamnik and Lastovo archipelago, where several colonies have been registered in the past couple of years. The majority of the population nests in the Lastovo archipelago, 250'300 pairs, whereas the total population of the yelkouan shearwater in Croatia is estimated to 300-400 breeding pairs (Tutiš at all. 2013) (figure 6.4). During the breeding period, large flocks of up to 1,000 birds can be observed in the area adjacent to Lastovski otoci. The flocks of up to 1,000 birds were observed outside the breeding season in the North Adriatic (Stipičević i Lukač 2001). These flocks are probably made up of the Adriatic Sea breeding birds, but also of individuals from the remaining part of the Mediterranean Sean, e.g. the breeding birds of Malta. They come to their nests to feed their chicks only at night, especially moonlight nights, and the flocks are often gathering on the sea nearby. They fly low, rarely higher than 10 m above the sea surface, and they usually feed with small fish (mostly small oily fish) and squid, foraging them mainly by diving or on the very sea surface. Occasionally, they follow fishing boats.

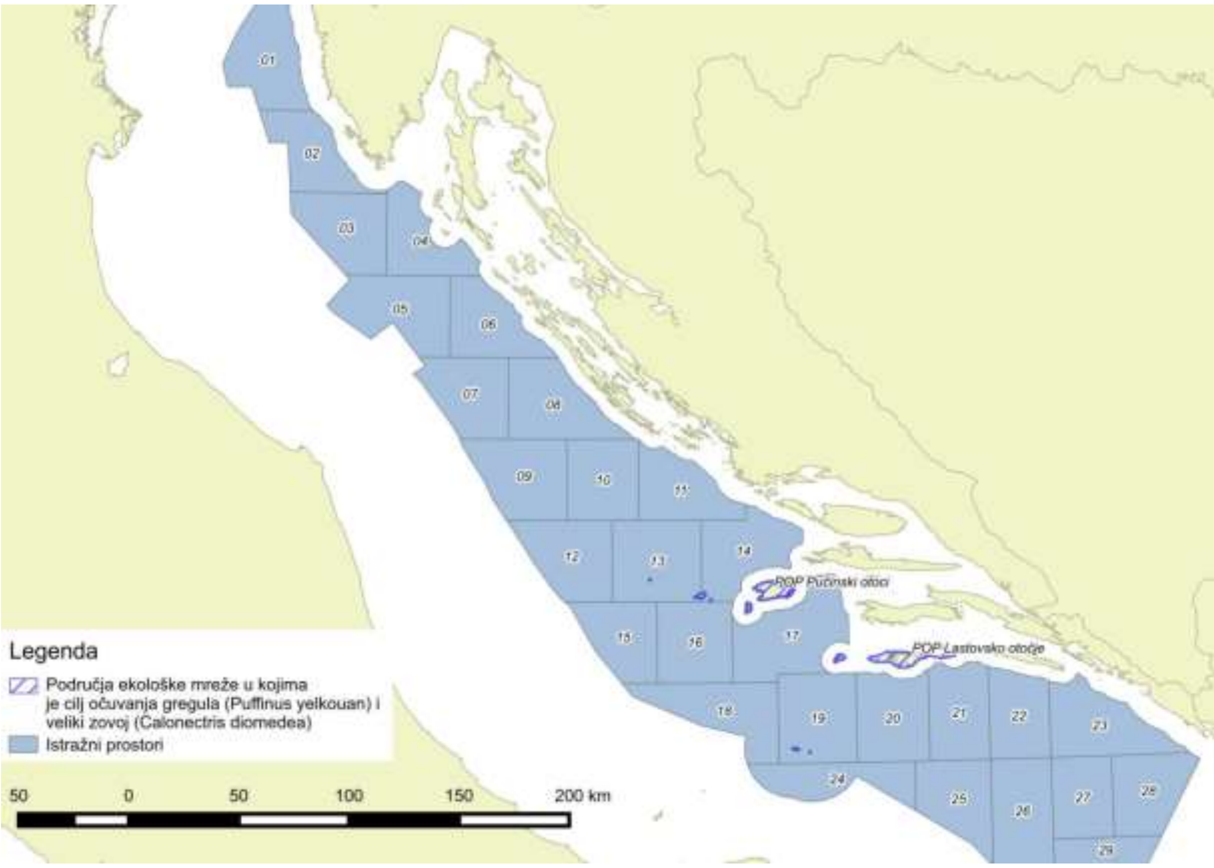


Figure 6.3 Areas of the ecological network with yelkouan shearwater and Scopoli's shearwater as the conservation objective

Figure 6.3

Key:
Ecological network areas with yelkouan shearwater (Puffinus yelkouan) and Scopoli's shearwater (Calonectris diomedea) as conservation objectives
Blocks

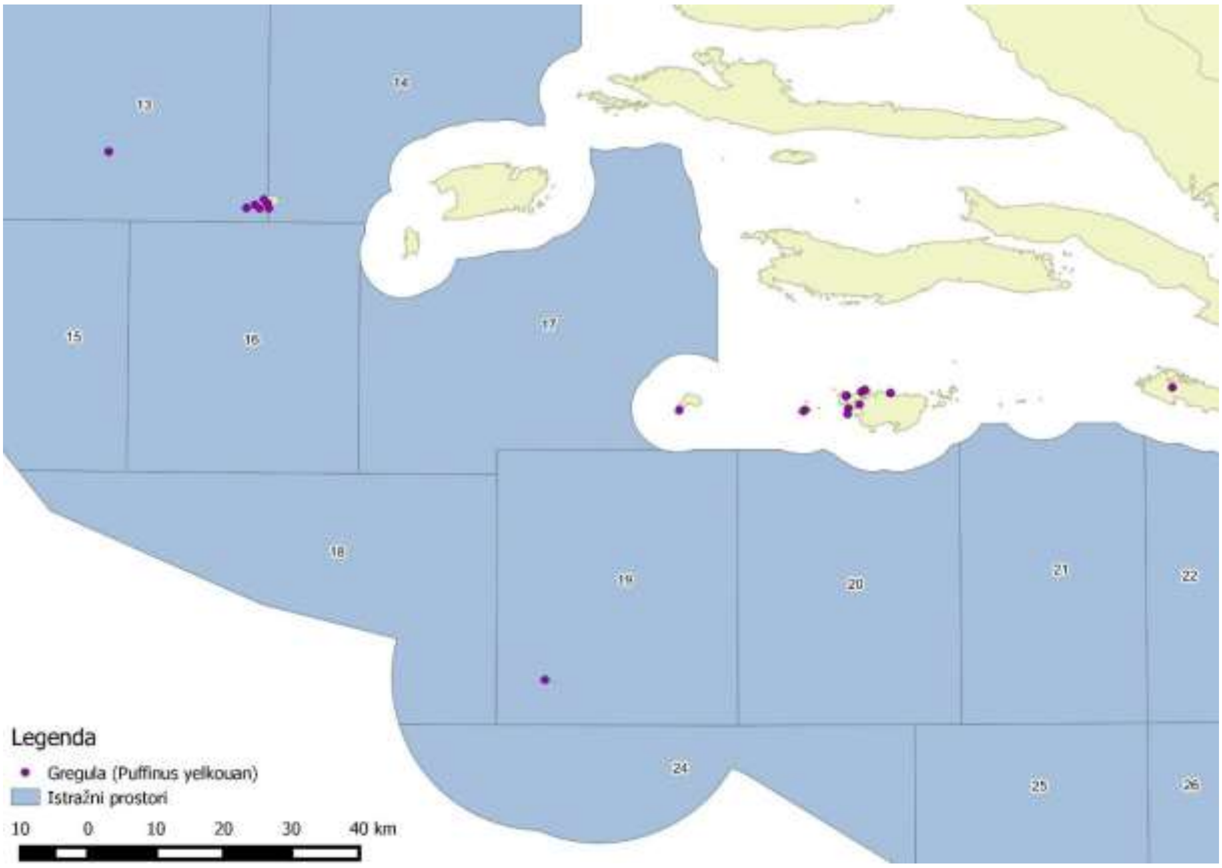


Figure 6.4 Yelkouan shearwater breeding area in Croatia (adjusted from The Red Book of Birds (*Crvena knjiga ptica*), Tutiš et al., 2013)

Figure 6.4
Key:
Yelkouan shearwater (Puffinus yelkouan)
blocks

Scopoli's shearwater (*Calonectris diomedea*)

The Scopoli's shearwater nests on outer South Adriatic islands: Sv. Andrija, Kamnik and Palagruža and several island of the Lastovo archipelago (Figure 6.5). The Croatian population of the Scopoli's shearwater ranges between 700 and 1250 breeding pairs (Tutiš at al., 2013). With respect to ecology, the Scopoli's shearwater is very similar to Yelkouan shearwater.
The species migrates into the Atlantic Ocean in autumn and returns to the Mediterranean in February. It is the biggest species of the order of petrel (*Procellariiformes*) in Croatia. During the day, the Scopoli's shearwater stays on the water surface in search for food. The Scopoli's shearwater feeds mostly on fish, which it forages by surface-seizing or by diving into the sea. In the evening or at dawn it gathers in flocks around the islands where it has its breeding colonies. Breeding starts in April. The Scopoli's shearwater visits colonies at night, and both parents feed the young. When foraging, it can fly over 20 km away from its breeding colony. The movement of the species in the Adriatic is unknown, which represents the main challenge in the assessment of FPP impact on this species. The Scopoli's shearwater is the conservation objective of two areas of the ecological network: HR1000038 Lastovsko otočje and HR1000039 Pučinski otoci (Figure 6.3).

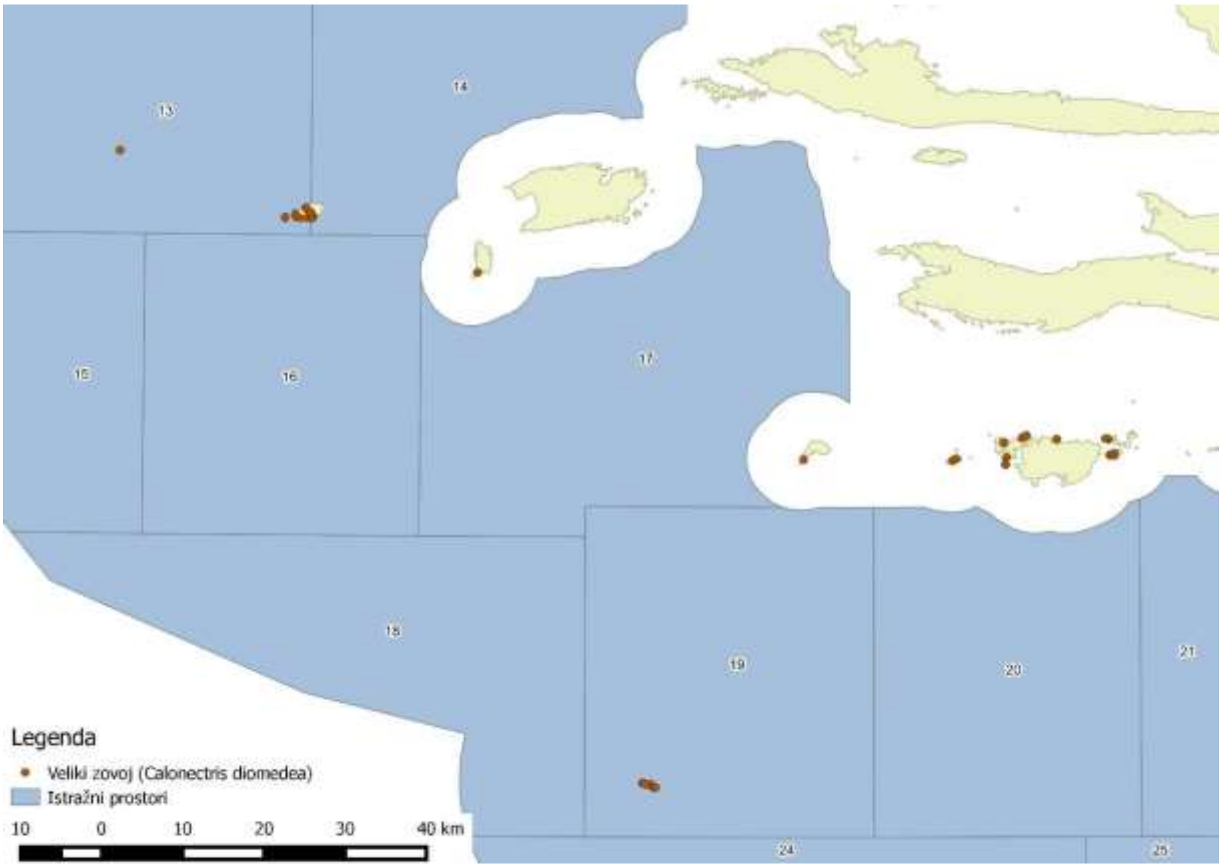


Figure 6.5 Scopoli's shearwater breeding area in Croatia (SINP)

Figure 6.5

Key:
Scopoli's shearwater (Calonectris diomedea)
Blocks

European shag (Mediterranean) (*Phalacrocorax aristotelis desmarestii*)

European shag (Mediterranean) has the largest population of all seabirds and the number ranges from 1600 and 2000 breeding pairs. It nests on small uninhabited islets along the Adriatic Sea. The largest population (more than 30% of the national population) nests in the Central Adriatic, within the area of the ecological network HR1000034 Northern part of Zadar archipelago. The remaining areas where the European shag (Mediterranean) is the subject of protection are presented in Figure 6.6. The pairs return to the same nest each year. European shag (Mediterranean) feeds only during the day, and during the incubation period one parent is always present in the nest. The species feeds on fish. When foraging it can fly up to 20 km away from its breeding colony outside the breeding season (Velando et al., 2005), whereas, during the breeding season, it usually forages within a radius of 4 km. Wanless and Harris, 1997, and Velando at al., 2005, pointed out that this species can be negatively affected by oil pollution, which may occur during the implementation of the FPP (see Chapter 6.2.1).

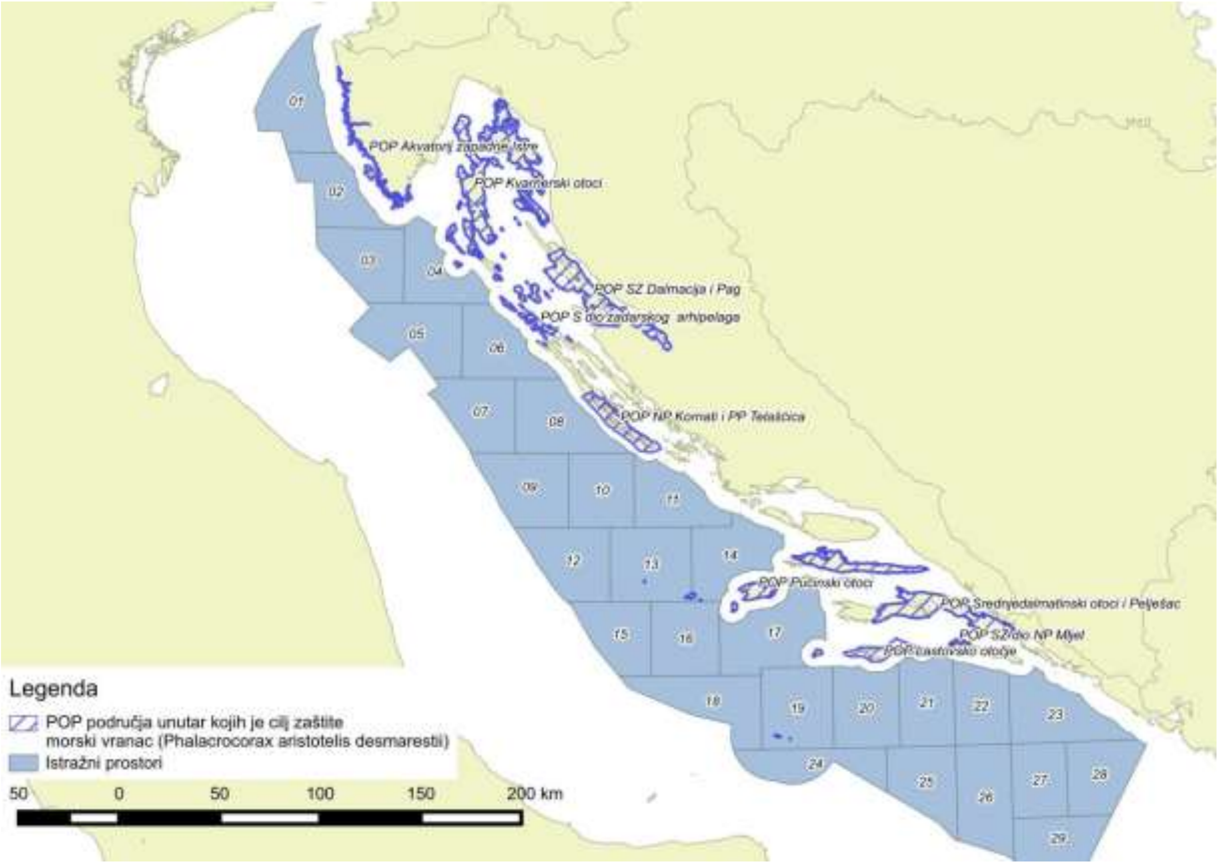


Figure 6.6 Areas of the ecological network with the European shag (Mediterranean) as the conservation objective

Figure 6.6

Key:
SPA areas with European shag (Mediterranean) (Phalacrocorax aristotelis desmarestii) as a conservation objective
Blocks

(map, left-right, up-down)
SPA Western Istria Water Area
SPA Kvarnerski otoci
SPA North-western Dalmatia and Pag
SPA Northern part of Zadar Archipelago
SPA Kornati National Park and Telaščica Nature Park
SPA Pučinski otoci
SPA Middle Dalmatia islands and Pelješac
SPA North-western part of Mljet National Park
SPA Lastovo islands

Audouin's gull (*Larus audouinii*)

The Audouin's gull is a medium sized gull residing in the Mediterranean area. The estimated population of the Audouin's gull in Croatia ranges between 60 and 70 breeding pairs. It breeds on several islands of the South Adriatic, on the island of Korčula, Mljet and Lastovo and on Pelješac peninsula (Figure 6.7, Tutiš at al., 2013). The eggs are laid in the second half of April, and they hatch at the end of May (del Hoyo at al.,) 1996). The young fledge the nest in the first half of July. After breeding the birds disperse widely around the Mediterranean coast (Sanpera et al., 2007; del Hoyo et al., 1996). Almost all juveniles and some adults migrate past Gibraltar during July-October (Olsen and Larsson, 2003), peaking in August (Guitiérrez and Guinart, 2008), to winter on the North African coast (del Hoyo et al., 1996). It returns to its breeding sites between late February and mid-April (del Hoyo et al., 1996). Breeding colonies are located on exposed rocky cliffs and on offshore islands or islets, normally not more than 50 m above sea level (Cramp and Simmons, 1983). The diet consists mostly of fish, especially Clupeiformes, for which it sometimes forages at night (Mañosa et al., 2004). During the non-breeding season, it migrates daily no further than 40 km (Hoogendoorn and Mackrill, 1987), while during the breeding season it stays much closer to the nest. The maximum recorded foraging range from a colony was 160 km (Mañosa et al., 2004). The areas of the ecological network where the Audouin's gull is the subject of protection are presented in Figure 6.8.

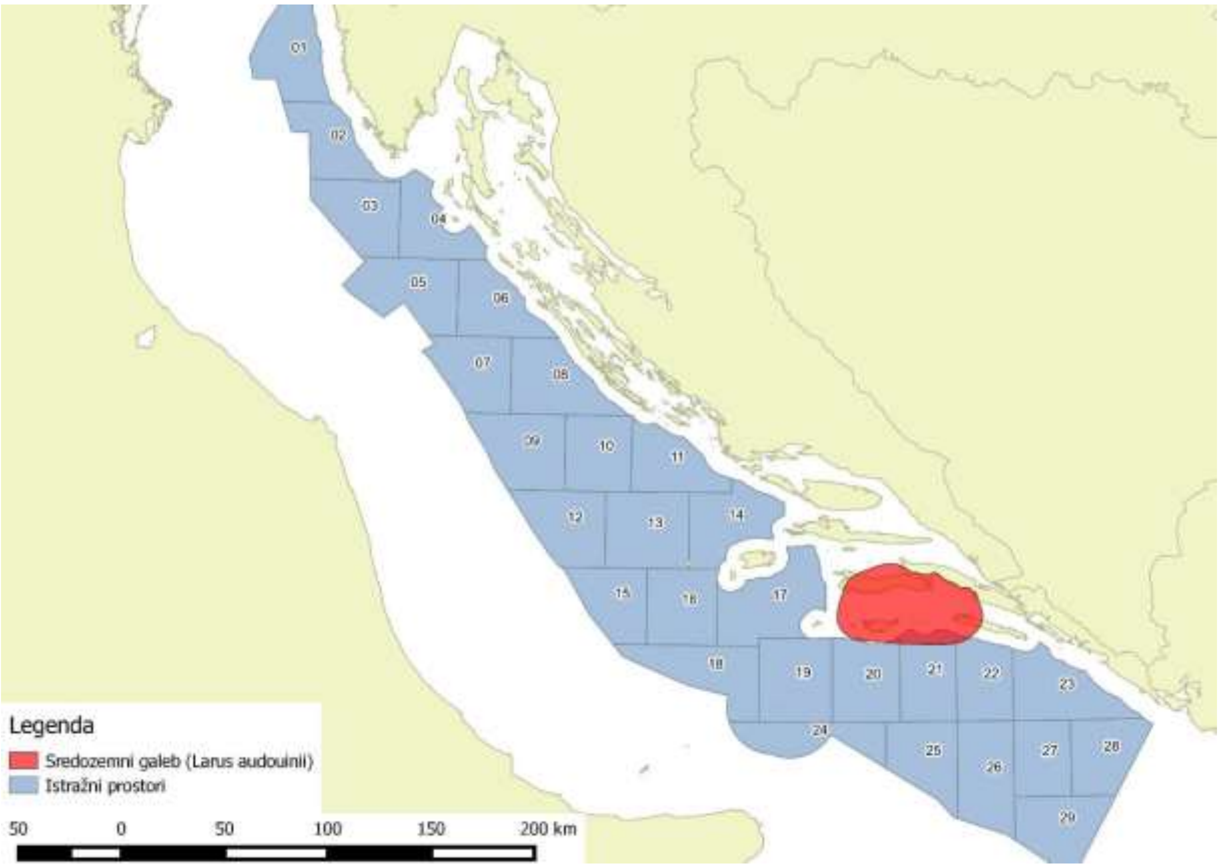


Figure 6.7 The Audouin's gull breeding area in Croatia (adjusted from The Red Book of Birds (*Crvena knjiga ptica*), Tutiš et al., 2013)

Figure 6.7 *Key:* *Audouin's gull (Larus audouinii)* *Blocks*

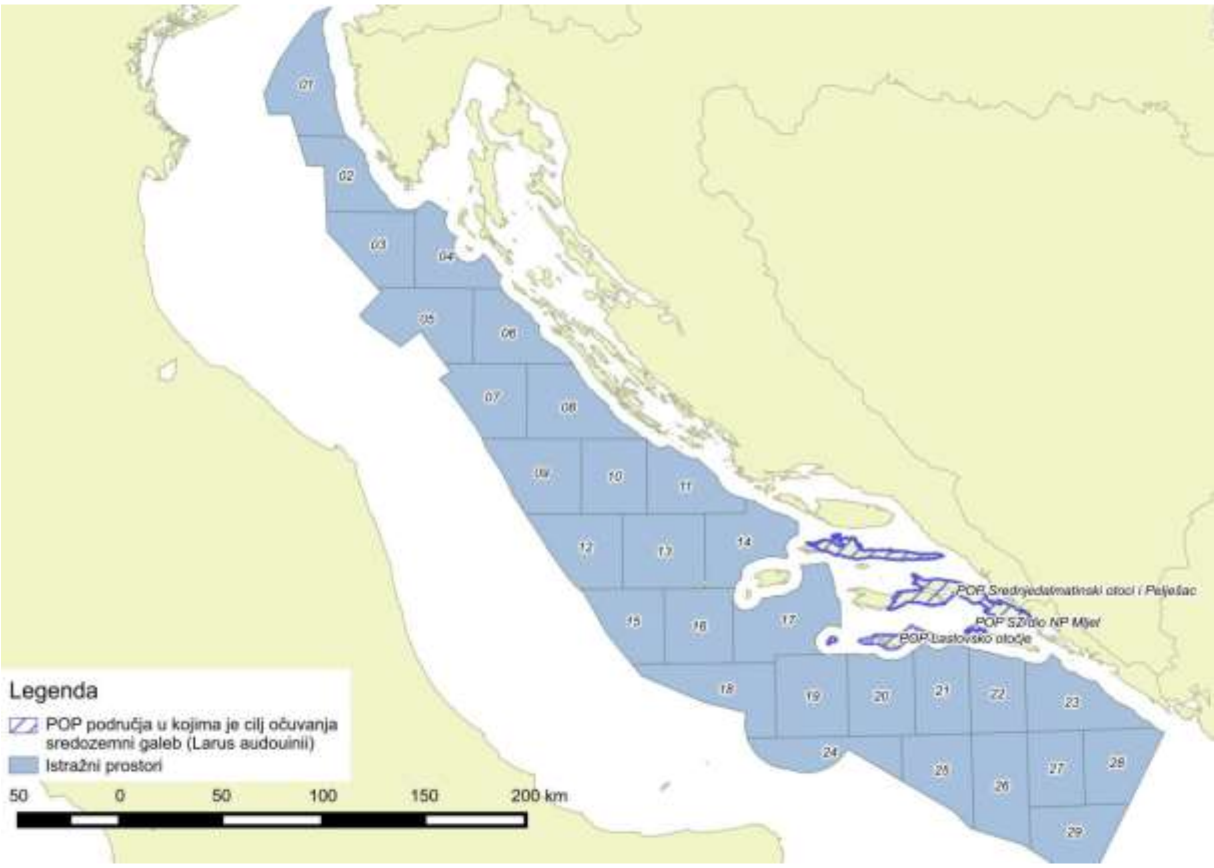


Figure 6.8 The areas of the ecological network with the Audouin's gull as the conservation objective

Figure 6.8

Key:
SPA areas with Audouin's gull (Larus audouinii) as a conservation objective
Blocks

6.1.2.2 Passage migrants

The effects of the hydrocarbon production on the passage migrants were studied by Russell (2005). The study showed that the highest impacts are possible in the production stage, when injuries can occur as a consequence of collision of the passage migrants with platforms. The night passage migrants are exposed to the highest risk of collision, they are followed by daily passage migrants, whereas the vultures are not affected by the risk because of their specific way of migration. On the other hand, the same author showed that there is a positive impact of platforms to passage migrants because they provide resting place during migrations.

Common crane (*Grus grus*)

The common crane (*Grus grus*) passes over the territory of the Republic of Croatia using two migration flyways: (1) over Slovenia, Istria into the river Po valley in autumn and (2) over Bosnia and Herzegovina across Dalmatian islands into the South Italy in autumn, while the spring migration routes may be moved further south and go across Monte Negro. During the autumn migration, the common crane rests in Hortobagy National Park in Hungary before its migration over the Adriatic. The migration starts in the morning, and it reaches the Adriatic coast in the evening. A smaller part of the population passes over Istria (one tenth of the entire population), and the larger part uses the flyway between the island of Susak and Vis. It passes over the South Italy up to the northern African coast where they winter. The Adriatic flyway is a part of the Baltic -Hungarian-Adriatic flyway (Figure 6.9), and it is considered that 80% of the species that winter in North Africa pass over Croatia. The biggest problem of passing over Croatia is the lack of resting locations in the western part of the Balkan Peninsula, in particular on the Adriatic coast and Croatian islands. On its flyway the common crane flies over several oilfields next to the coast of Italy, and a cumulative impact with the exploration blocks of the FPP (Stumberger, B & Schneider- Jacoby, M, 2010).

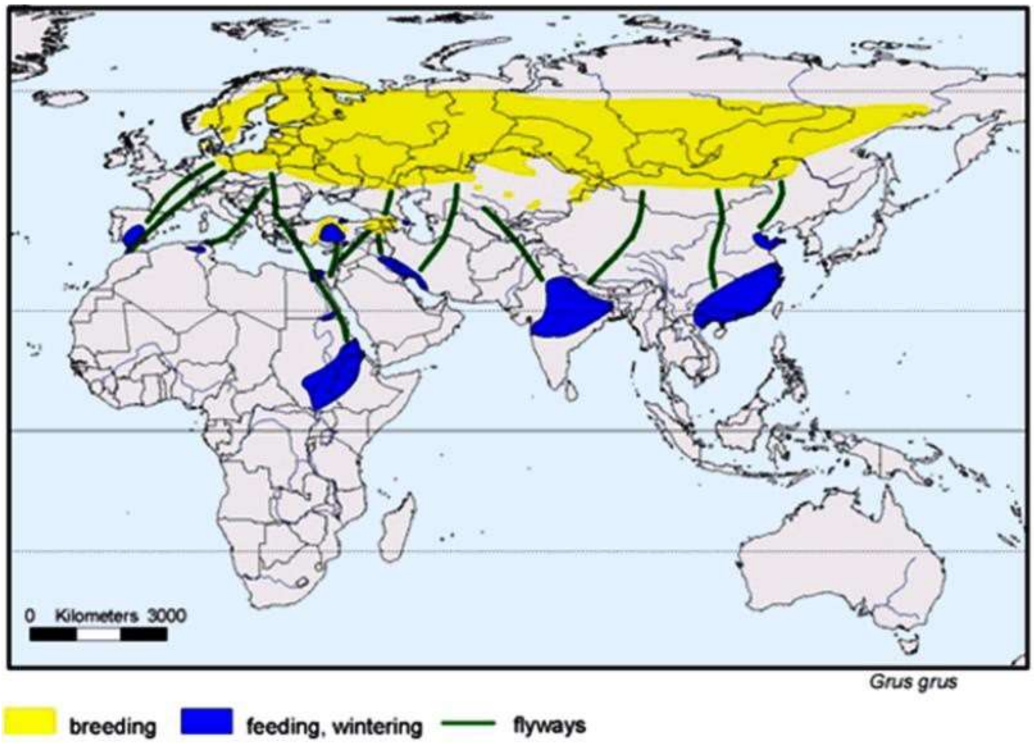


Figure 6.9 The framework flyways (green lines) and wintering (blue fields) and breeding (yellow fields) populations of the common crane (*Grus grus*)

6.1.2.3 Vultures

The Eleonora's falcon (*Falco eleonorae*) is the most important species of all vultures of this area, because here are its main breeding grounds. It nests colonially, and the entire Croatia population nests on unreachable cliffs of the island of Svetac, as well as on cliffs of some neighbouring islands (Figure 6.10). In mid-October, it migrates to Madagascar to return to its old nest at the beginning of April, where it will start to breed in late summer. The young hatch at the beginning of autumn, and the main part of its diet consists of migratory birds passing over the area. It is estimated that 65 to 100 pairs of birds breeds on territory of Pučinski island.

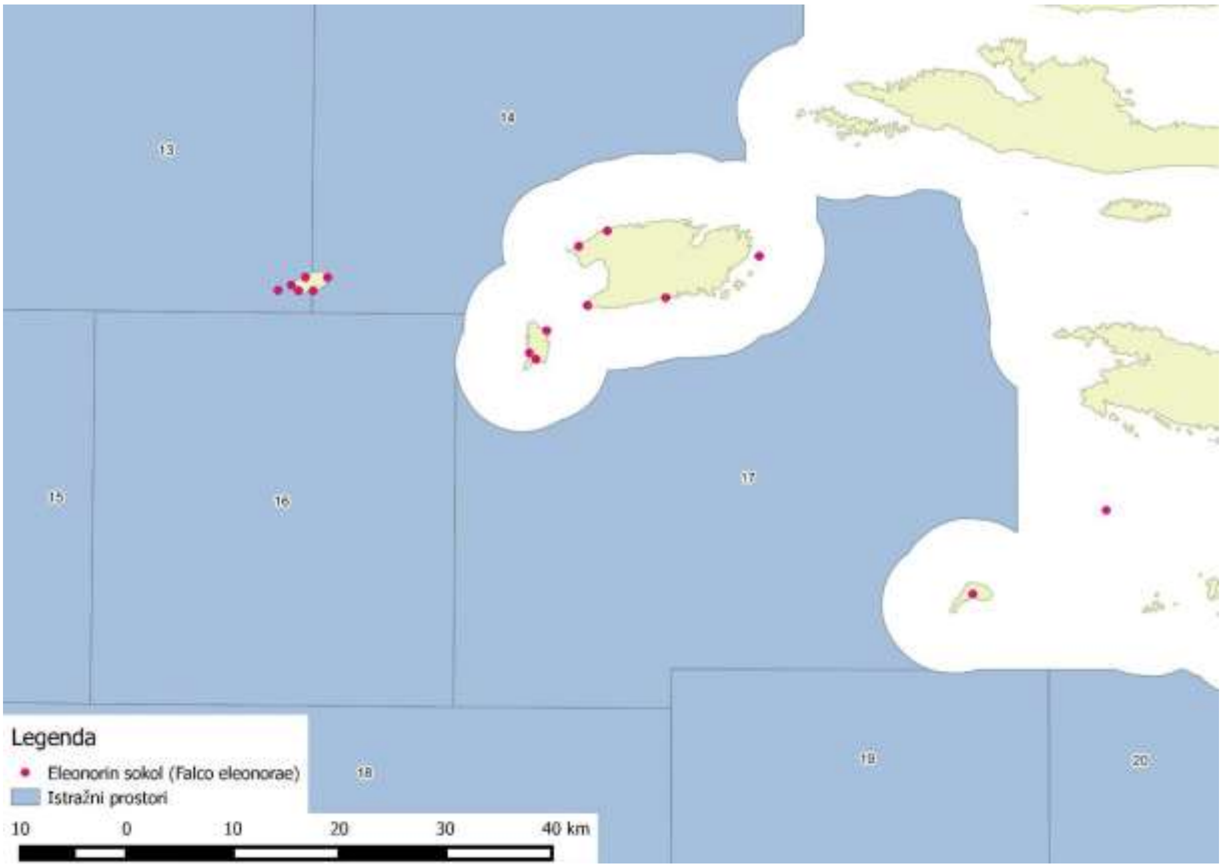


Figure 6.10 Eleonora's falcon breeding area in Croatia (SINP)

Figure 6.10

Key:
Eleonora's falcon (Falco eleonorae)
Blocks

The area of Pučinski otoci is breeding area for around 10 percent of the Croatian population of the peregrine falcon (*Falco peregrinus*). This species resides in the project area throughout the whole year and uses coastal habitats for foraging and breeding. Furthermore, Pučinski otoci are breeding grounds for the short-toed snake-eagle (*Circaetus gallicus*). Its population in this area is estimated to one pair. The species winters in Africa, south of Sahara, and starts the migration at the end of August and beginning of September. From March until May, the birds return for breeding. The female lays on egg which she incubates for a rather long period (45-47 days) and fledging takes place after next 60 to 80 days. The category of vultures in this ecological network area includes the hen harrier (*Circus cyaneus*), but unlike the previously mentioned species, this it does not breed in the area but winters here from October till March. Its population in the area of Pučinski otoci is estimated from 5 to 10 individuals, but the quality of information is poor.

HR1000039 Pučinski otoci

Within SPA HR1000039 Pučinski otoci there are 11 protected bird species, 3 of which belong to the bird category connected to marine habitats [Scopoli's shearwater (*Calonectris diomedea*), yelkouan shearwater (*Puffinus yelkouan*), European shag (Mediterranean) (*Phalacrocorax aristotelis desmarestii*)], 2 to the category of passage migrants [common crane (*Grus grus*), European honey-buzzard (*Pernis apivorus*)], 4 to the category of vultures [short-toed snake-eagle (*Circaetus gallicus*), hen harrier (*Circus cyaneus*), Eleonora's falcon (*Falco eleonorae*) and peregrin falcon (*Falco peregrinus*)] and 2 to the category of species connected to the terrestrial habitats [European nightjar(*Caprimulgus europaeus*), red-backed shrike (*Lanius collurio*)] (Table 6.3) It must be pointed out that the European honey-buzzard does not belong to the category of vultures in this area because it passes over Pučinski island.

Table 6.3 Conservation objectives of SPA HR1000039 Pučinski otoci

Code	Species	Group	Number in the habitat (pairs)		Quality of the information	Population size in relation to the presence in Croatia (%)	Protection	Global assessment of the habitat value
			MIN	MAX				
A010	*Calonectris diomedea*	marine	300	700	medium	>15%	excellen	excellent
A224	*Caprimulgus europaeus*	continental	50	100	poor	<2%	good	significant
A080	*Circaetus gallicus*	vulture	1	1	medium	<2%	excellen	significant
A082	*Circus cyaneus*	vulture	5*	10*	poor	<2%	good	good
A100	*Falco eleonorae*	vulture	65	100	good	>15%	excellen	excellent
A103	*Falco peregrinus*	vulture	8	10	good	2-15%	excellen	excellent
A127	*Grus grus*	passage	3000*	3000*	poor	2-15%	excellen	excellent
A338	*Lanius collurio*	continental	500	1000	poor	<2%	good	significant
A072	*Pernis apivorus*	passage	1000*	1000*	poor	2-15%	excellen	excellent
A392	*Phalacrocorax aristotelis desmarestii*	marine	5	10	poor	<2%	good	good
A464	*Puffinus yelkouan*	marine	50	100	medium	>15%	excellen	excellent

* number of individual birds

6.1.2.4 Common bottlenose dolphin (Tursiops truncatus)

Although aquatic environment obviously required adaptations, marine mammal hearing physiology is similar to those of terrestrial mammals. At the same time entire auditory system has been modified - pinnae and external auditory canals were lost, the middle and inner ear capsules fused, and the new ear complex migrated outward, dissociating from the skull (Ketten 1997).

Cetaceans have the broadest acoustic range of any known mammal group (Ketten 1997). Audiograms have been produced for 11 small cetacean species held in captivity (Au 1993), while for a number of other have been estimated based on their inner ear anatomy and sound they produce. Most toothed whales (Odontocetes) have functional hearing from 200 Hz to 100 kHz, while some species may hear frequencies as high as 200 kHz (Reynolds 2005).

Odontocete whistles have lower source levels than their clicks. Source levels for common bottlenose dolphins are 228 dB re 1 μPa at 1 m when echolocating in the presence of noise (Au 1993) and to 169 dB re 1 μPa at 1 m for whistles of bottlenose dolphins (Janik 2000). The strongest sound levels were found for sperm whale clicks, up to 236 dB re 1 μPa at 1 m (Mohl et al. 2003).

Active ensonified space for Odontocete sounds ranges from 1 km or less to several tens of km (Janik 2000; Barlow & Taylor 2005; Janik 2005; Miller 2006). Mysticetes mostly vocalize at frequencies below 1 kHz, with estimated source levels up to 180 dB re 1 μPa at 1 m (Richardson et al. 1995).

The common bottlenose dolphin (*Tursiops truncatus*) comprises the suborder of toothed whales and it is observed in the entire Adriatic Sea. The higher abundance and density have been registered in the area of the continental shelf up to the depth of 150-200 m and in the area of internal waters of the Republic of Croatia (Figure 6.12). The status of the species is not fully known. The abundance of the species in the Adriatic was estimated by an aerial survey to 5000 individuals (Holcer et al. 2010a; Fortuna et al. 2011b; Fortuna et al. 2014b; Holcer et al. 2014a) and this information may be considered a basis for further monitoring of the species on the subregional level. The Adriatic Sea population structure of common bottlenose dolphins comprises discrete entities in space ("local populations"). The areas of Kvarnerić, northern Dalmatia and Kornati islands, as well as Vis, Lastovo and Hvar water areas undergo a systematic long-term survey of the local populations. The results of the registered abundance and structure of the local population can be used as a basis for monitoring activities. Furthermore, the Republic of Croatia proposed a range of SACs for the ecological network with an aim of protection of the common bottlenose dolphin (Figure 6.11): HR3000161 Island of Cres – Lošinj, HR5000032 Western Istria water area, HR3000419 J. Molat-Dugi-Kornat-Murter-Pašman- Ugljan-Rivanj-Sestrunj-Molat, HR3000426 Lastovski and Mljetski kanal and HR4000001 Kornati National Park. The preliminary population abundance and structure estimates are required for these areas since the defragmentation of the species distribution due to the habitat degradation can cause isolation of specific parts of the population. Without these preliminary estimates in the ecological network areas, there is no meaning in processing the areas separately. The mitochondrial and nuclear DNA analyses reveal differentiation in the population structure the common bottlenose dolphin between different parts of the Adriatic Sea, but without the possibility of differentiation between individual ecological network areas.

During a biogeographic seminar held on 29 and 30 September 2014 in Zagreb, the EU Directorate-General for the Environment observed a lack of data referring to the pelagic population within which the FPP is implemented.

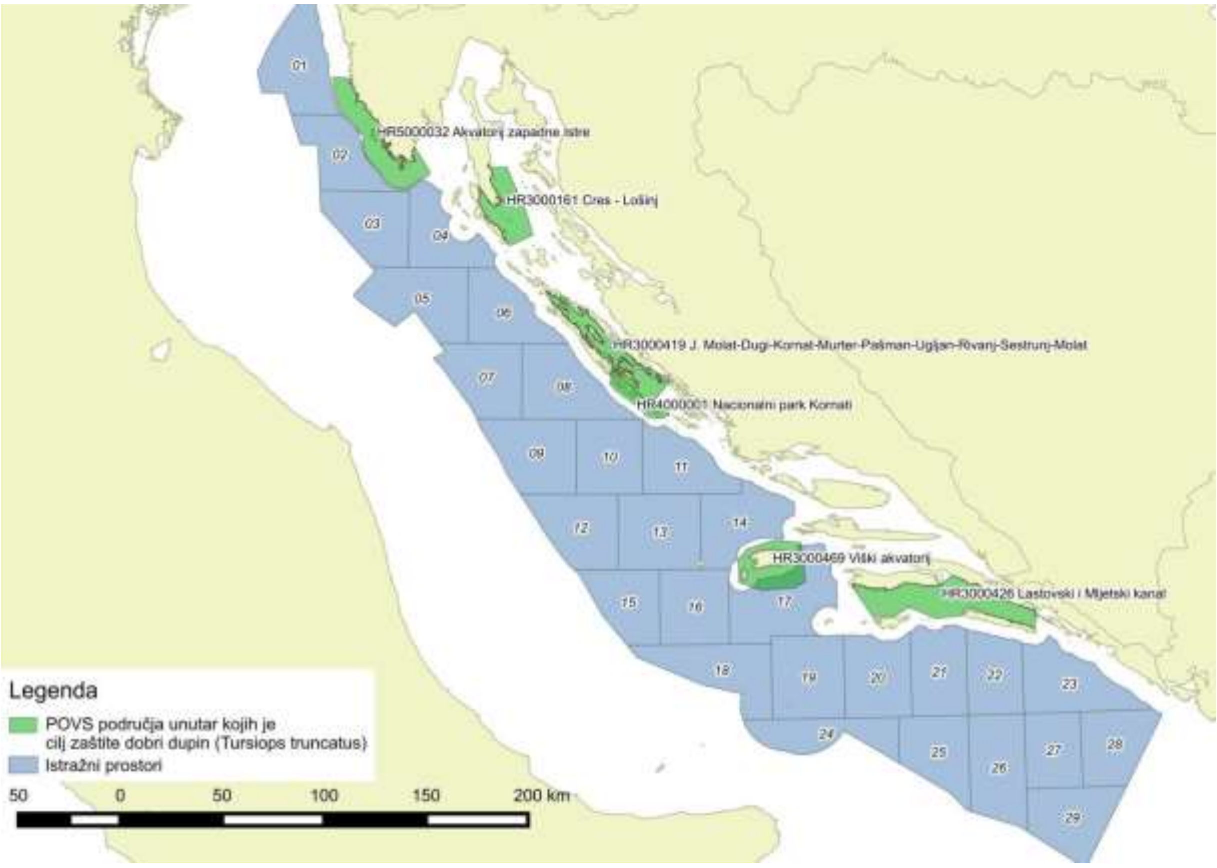


Figure 6.11 Areas of the ecological network with the common bottlenose dolphin as the conservation objective

Figure 6.11

Key:
SAC areas with common bottlenose dolphin (Tursiops truncatus) as a conservation objective
Blocks

(map, left-right, up-down)
Western Istria Water Area
Cres – Lošinj
Southern Molat-Dugi-Kornat-Murter-Pašman-Ugljan-Rivanj-Sestrunj-Molat
Kornati National Park
Vis Water Area
Lastovski kanal and Mljetski kanal

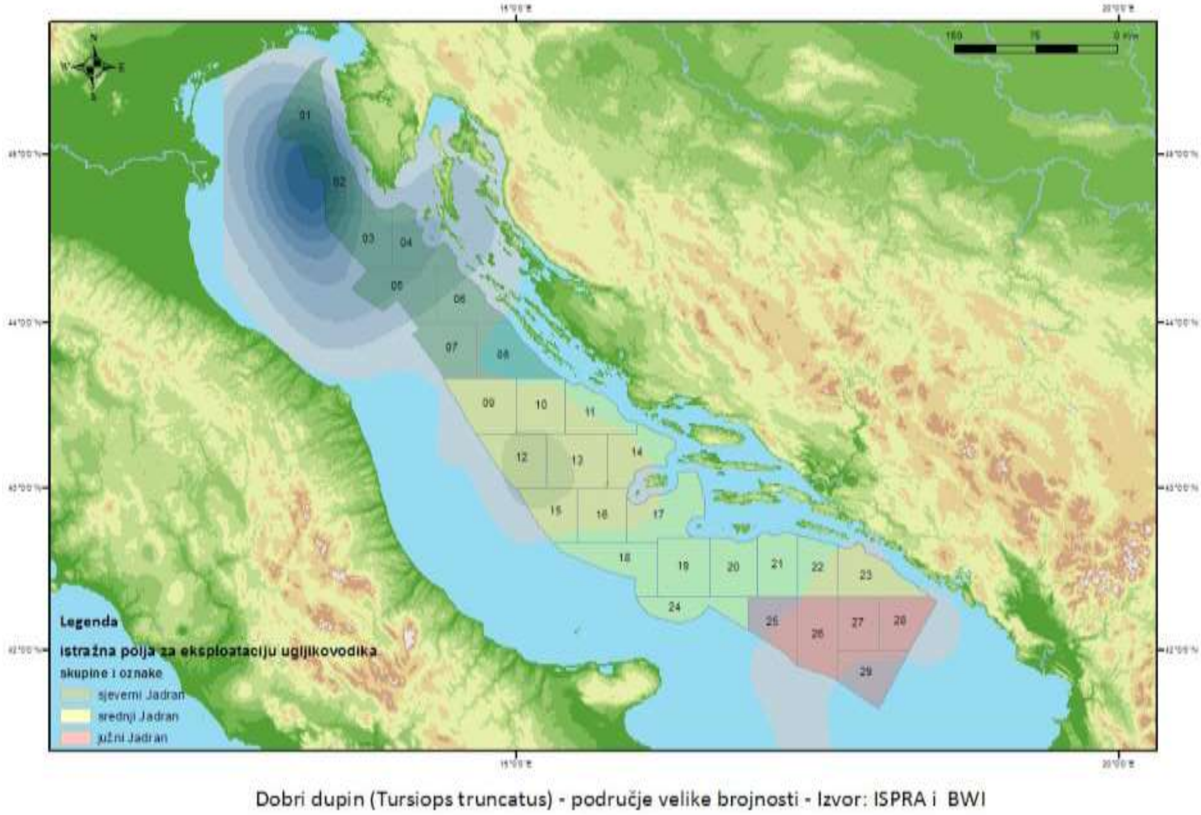


Figure 6.12 Distribution of the common bottlenose dolphin in the Adriatic

Figure 6.12

Key:
Hydrocarbon production blocks
(UNREADABLE) and designations
Northern Adriatic
Middle Adriatic
South Adriatic

Common bottlenose dolphin (Tursiops truncatus) – area of great abundance – Source ISPRA (Italian Institute for Environmental Protection and Research) and BWI (Blue World Institute)

6.1.2.5 Loggerhead sea turtle (*Caretta caretta*)

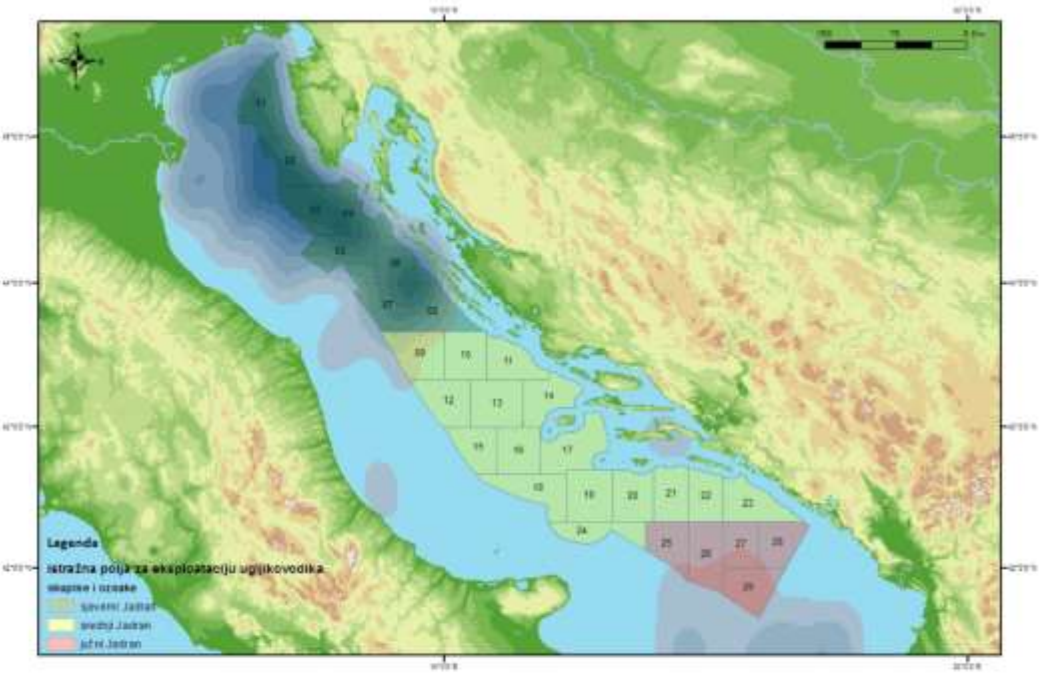
The loggerhead sea turtle is the most common sea turtle species in the Mediterranean basin. The ecology of this species is very complex. It exhibits complex life history characterised by switching between different habitats (Bolten 2003b; Casale et al. 2008) and shifts in trophic status and position within marine food webs (Bjorndal et al., 1997; Bjorndal, 2003).

Adult females lay eggs on sandy beaches. After hatching, juveniles enter the sea where their distribution in the Mediterranean is affected by sea currents. The first period of life they spend in the oceanic zone. After a few years, oceanic juveniles leave pelagic habitats and start to recruit neritic zones where they undergo through the ontogenetic habitat shift and start to feed predominantly on benthic prey (Bolten 2003a; Bolten 2003b). Once the loggerhead turtle settles to one neritic area, change to other neritic areas is highly unlikely (Casale et al., 2007).

The loggerhead turtle is the most abundant sea turtle species in the Adriatic Sea. The Adriatic is recognized as one of the most important foraging areas for the species in the Mediterranean basin (Casale & Margaritoulis 2010). Temporal analysis of records show that loggerheads are resident in the Adriatic throughout the year, but the spatial pattern of habitat use differs (Lazar 2009). A wide continental shelf of the northern and the central Adriatic Sea, with depths <200 m, rich with benthic communities and favourable temperature regimes during the summer makes this region one of the key neritic feeding habitats for loggerheads in the Mediterranean (Gamulin-Brida 1974; Supic & Orlic 1992; Kollmann & Stachowitsch 2001) Besides the importance of the Adriatic sea in the summer period, there are indications that the north-central Adriatic plays a role as an important wintering habitat (Lazar & Tvrtkovic 1995; Lazar & Tvrtkovic 2003; Casale et al., 2004) (Figure 6.13).
On the other hand, oceanic zone of the southern Adriatic seems to constitute pelagic developmental habitat for oceanic-stage juveniles, (Casale et al. 2005; Casale et al. 2007; Casale & Mariani 2014). However, data from that region are lacking.

Three types of the loggerhead turtle movement patterns have been observed in the Adriatic. The best documented are the migrations from foraging to breeding grounds (Zbinden et al. 2008; Schofield et al. 2009; Schofield et al. 2010; Zbinden et al. 2011; Schofield et al. 2013). Secondly, a less obvious pattern, is seasonal migration, and it refers to southward movements of both adults and juveniles from the northern Adriatic when temperatures fall in the cold season. A third type of movement pattern is the erratic pattern, with turtles wandering around areas of various size, even as large as part of the Adriatic (Casale et al. 2012). For both breeding and seasonal migrations, most of the observed routes were along the west and east Adriatic coasts (Hays et al. 2010a; Hays et al. 2010b; Casale et al. 2012).

Breeding of the loggerhead turtle that occurs in the Adriatic is very limited and sporadic (Mingozzi et al. 2008). The majority of the individuals in the Adriatic originate from Greece, and Turkey and Cyprus are the origin of a lower number of turtles (Lazar et al. 2004b; Lazar et al. 2007; Lazar 2009; Garofalo et al. 2013).
During the biogeographic seminar held on 29 and 30 September 2014 in Zagreb, the EU Directorate-General for the Environment recognized this species as a species subject to the "Scientific Reserve", which means that additional survey is required in order to establish the additional SACs.



Glavata želva (Caretta caretta) - područje velike brojnosti - Izvor: ISPRA i BWI

Figure 6.13 Distribution of the loggerhead turtle in the Adriatic

Figure 6.13

Key:
Hydrocarbon production blocks
(UNREADABLE) and designations
Northern Adriatic
Middle Adriatic
South Adriatic

Loggerhead sea turtle (Caretta caretta) – area of great abundance – Source ISPRA (Italian Institute for Environmental Protection and Research) and BWI (Blue World Institute)

6.1.2.6 Habitats

Within 5 SACs: HR3000099 Islands of Brusnik and Svetac, HR3000100 Island of Jabuka, offshore, HR3000121 Island of Palagruža, offshore, HR3000122 Islet of Galijula, HR3000423 Jabuka Pit, 4 habitat types have been put under protection:

- 1110 - Sandbanks which are slightly covered by sea water all the time,
- 1120 - Posidonia beds (Posidonion oceanicae),
- 1170 - Reefs,
- 8330 - Submerged or partially submerged sea caves.

The table below shows the distribution of habitat types according to ecological network areas with a brief description of the habitat:

Table 6.4 Description of the target habitats which may be affected by the implementation of the plan

Code	Habitat type	Ecological network area where the habitat type is under protection	Description of the habitat type

1110	Sandbanks which are slightly covered by sea water all the time	HR3000121 Island of Palagruža, offshore HR3000122 Islet of Galijula HR3000423 Jabuka Pit	The sandbanks consist mainly of mobile sandy sediments, but larger grain sizes, including boulders and cobbles, or smaller grain sizes including mud may also be present on a sandbank. Their water depth is seldom less than 20 m, and it can, however, extend to several hundred meters. Such sandbanks are characteristic by development of
1120	Posidonia beds (Posidonion oceanicae)	HR3000121 Palagruža offshore*	Posidonia (*Posidonia oceanica*) is a flowering plant that is endemic to the Mediterranean Sea. It forms dense beds which can be found at depths ranging almost from the sea surface to 40 m in the infralittoral zone, with abundant light on coarse sand, with more or less mud, and somewhere even on rocks.
1170	Reefs	HR3000099 Islands of Brusnik and Svetac HR3000100 Island Jabuka, offshore HR3000121 Island of Palagruža, offshore HR3000122 Islet of Galijula HR3000423 Jabuka Pit	Reefs are marine habitats rising from the seabed. As a rule, the reefs are located under the tidal zone, but in some cases they can even enter the wave-swash zone. In terms of their origin, the reefs are classified into two groups: hard substrata reefs which harbour flora and fauna on solid rocks and reefs created by the living creatures themselves (biogenic reefs). Due to the geomorphology of our coast, the solid rock reefs are relatively frequent in the Adriatic Sea. Unlike the solid rock reef, the biogenic reefs are a very rare and unexplored occurrence in the Adriatic, especially those of deep-sea coralligenous communities.
8330	Submerged or partially submerged sea caves	HR3000099 Islands of Brusnik and Svetac HR3000121 Island of Palagruža, offshore HR3000122 Islet of Galijula	The submerged or partially submerged sea caves are habitat closely connected with reefs. As it is the case with the reefs, the depth of the caves can vary. Biodiversity of these geological phenomena depends on their depth, orientation and indentation of the cave system.

* priority habitat in this area of the ecological network

6.2 Characteristics of impacts arising from implementation of the Framework Plan and Programme on the ecological network

Potential impacts arising from the implementation of the plan and programme to the ecological network species and habitats can be classified in accordance with the steps defined by the FPP into three categories:

- impacts during the exploration period;
- impacts during the production period;
- impacts during the removal of mining facilities and plants.

The impacts defined in this way tell us about the time interval when they can be expected. The impacts during the exploration period are expected in the first 2-7 years during the exploration works. Then, there are impacts of platforms and pipelines installation, hydrocarbon production and additional exploration. These impacts are expected during the next 25 years, at least, depending on the capacity of the discovered reservoirs. The last category of impacts is expected during the removal of mining facilities and plants. It is the shortest stage, which may and may not be implemented depending on the results of the relevant environmental studies, and it follows after the reservoirs have been exhausted.

Considering the nature of the impacts, they are estimated as being either positive or negative, direct or indirect, short-term, medium-term or long-term and cumulative or synergetic. Based on the ecological network biodiversity, the impacts are classified into three categories:

- impacts on the target bird species;
- impacts on the target species within SAC areas;
- impacts on the target habitats within SAC areas.

6.2.1 Impacts on the bird species which are the conservation objective of the ecological network area

The impacts on the bird species which are the conservation objective of the ecological network are possible in two FPP stages (exploration and production). The impacts have been differentiated according to the previously described categories, and umbrella species described in the previous chapter have been chosen for the assessment of impact intensity, and the assessed impact is also applied to other species. Since the umbrella species act as indicators for the assessment of status of the categories, the impacts are afterwards assessed in relation to the categories and not to indicators of species. Potentially significant negative impact of the FPP implementation is possible in case of disturbance of breeding colonies, which would negatively affect the number of breeding pairs. Table 6.5 describes potential impacts, whereas Table 6.6 classifies impacts into groups.

Table 6.5 Potential impacts of the FPP on the target bird species (+2 likely significant positive impact, +1 likely moderate positive impact, 0 likely no impact, -1 likely moderate negative impact, -2 likely significant negative impact (in accordance with the Guidelines for the Appropriate Assessment of the Project on the Ecological Network); D - direct impact, I - indirect impact; S - short-term impact, M - medium-term impact, L - lasting impact; E - exploration operations, P - production operations, ⦸ - the impact does not have that feature, ▯- the impact has that feature)

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Change of breeding colony conditions due to noise level increase during FPP operations	The noise impact can result in altered or unfavourable breeding conditions. During 2D and 3D surveys and in case of traffic increase, especially of increase of helicopter flights, a more significant negative impact is possible (Sultana, J i Borg, J. J. 2006).	-2	D	⦸	L	⦸	⦸	E,P
Reduction of the available food sources under the influence of the FPP operations	Reduced food quantity during the exploration operations due to seismic surveys and discharge of mud and technological water (Engas at al. 1998; McCualley et al. 2003).	-1	I	▯	S	▯	▯	E,P
Increase of the available food sources under the influence of the FPP operations	Increased food quantity during the production operation period since fishing is prohibited within 500 m zone from the platform (OG 52/10) (Russel, 2005).	+1	I	▯	M	▯	▯	P
Platform operation reduces the attractiveness of an area	When operating, platforms generate increased levels of noise, mud, technological, formation and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and technological water reduce the abundance of fish (Patun, 1999; Mario, 2002), and diversity of benthic communities which consequently affects quantities of prey and foraging success. Heavy metals contained in the mud tend to bioaccumulate through the food chain A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators. The noise from hydrocarbon extraction and drilling of wells can temporarily chase away the sea fauna, but it eventually	-1	I	⦸	S	⦸	▯	E,P
Concentration increase of floating hydrocarbons during the usual platform operation	Even small quantities of the floating hydrocarbons can adversely affect the watertight layer on birds' feathers, which reduces the efficiency of their thermal insulation. Such floating hydrocarbons occur during mud, formation and technological water spills and during well production capability testing (Ellis,	-1	I	⦸	M	⦸	⦸	P
Bird deaths resulting from collisions with helicopters	Bird deaths resulting from collisions with helicopters (Thorpe, J. 2003)	-1	D	⦸	S	⦸	⦸	E,P
Use of platforms as resting areas for migratory birds	Migratory birds can rest on platforms during their migrations (Russel, 2005)	+1	D	⦸	M	⦸	⦸	P
Disturbances to usual flyways	Due to reduced visibility, the birds become disoriented by platform lights, which increases the probability of collisions between the birds, and between the birds and platforms (Russel, 2005)	-1	D	⦸	M	⦸	⦸	P
Flaring of hydrocarbon during well production capability testing	During well production capability testing, hydrocarbons are flared on the platform and a flame is burning in the flare stack above the platform. The hydrocarbon combustion efficiency is never 100%. and unburned hydrocarbon components fall into the sea. Seabirds replace such amorphous material for food (Wanless and Harris, 1997;Velando et al. 2005).	-1	D	⦸	S	⦸	⦸	E
Swallowing of improperly disposed waste and getting tangled into such waste	During operations on exploration boats and platforms a certain quantity of solid waste is generated which ends up in the sea (Cadée, G. C. 2002).	-1	I	▯	M	⦸	⦸	E, P, R

Table 6.6 Potential impacts on the individual groups of birds

Use of habitats	Impact	Clarification
Birds in marine habitats	• Change of breeding colonies conditions due to noise level increase during the implementation of FPP operations • Reduction of the available food sources under the influence of the FPP operations • Increase of the available food sources under the influence of the FPP operations • Platform operation reduces the attractiveness of an area • Concentration increase of floating hydrocarbons during the usual platform operation • Collisions with helicopters • Swallowing of improperly disposed waste and getting tangled into such waste	Negative impacts on birds residing in marine habitats are possible during hydrocarbon exploration and production. Disturbances to breeding colonies are the most significant negative impact. The species of this category breed on desert islands and the increased noise level during exploration and production can chase those species away from the breeding sites. The cessation of the disturbance does not grant the return of the species to the breeding area, and therefore a relatively short-term adverse effect can cause a long-term damage to the breeding population. The indirect impacts on this category are possible if the FPP operations affect fish and cephalopods, i.e. the diet source of seabirds. In this context, seabirds could get scared of exploration boats or platforms, or they could accidentally eat the garbage generated on the exploration boats or platforms that ends up in the sea, which could have adverse effects on the abundance of species. On the other hand, safety zones are created around platforms in which fishing activities are prohibited, and the abundance of fish increases.
Passage migrants	• Bird deaths resulting from collisions with helicopters • Use of platforms as resting areas for migratory birds • Disturbances to usual flyways	Both positive and negative impact is possible on passage migrants. The positive impact is possible during the production of hydrocarbons, since passage migrants use platforms as resting areas. The negative impacts are possible during exploration and production periods due to collisions between passage migrants and helicopters, crashing of passage migrants into platforms and disturbances to birds passing over platforms during periods of reduced visibility. The negative impact of platforms reflects the most on the bird species that migrate at night, while the positive impact of platforms reflects equally on all passage migrants. During testing of hydrocarbon reservoir capability, it is possible that birds get killed by the flare.
Non-migrating vultures	• Bird deaths resulting from collisions with helicopters • Change of breeding colonies conditions due to noise level increase during the implementation of FPP operations (Eleonoras' falcon)	The passive flight (gliding) of vultures is a possible cause of bird death or injury in case of collisions with helicopters. Such accidents are expected to happen rarely, but since the vultures are mostly monogamous, death of a partner can disturb the stability of a population of particular area for a longer period of time. The increased noise level can influence the breeding success of the Eleonora's falcon (*Falco eleonorae*), which can eventually have a negative impact on the population of this species in
Birds in terrestrial habitats	• No negative impacts are expected for this bird category.	Since this category of birds resides only in terrestrial habitats, the FPP implementation will not have any negative impacts on the bird species comprising this category.

6.2.2 Impacts on marine mammals

The impact of noise pollution on cetaceans raises special concern, since the cetaceans largely depend on sound and since hearing is their main sense which plays an important role in their social interactions and biology of senses (Tyack and Miller, 2002).

ACCOBAMS (2013) defined groups for classification of negative impacts of noise to marine mammals. The first group includes physical traumas i.e. either temporary or permanent hearing impairment, non-lethal tissue damages and injuries which can become lethal in case of a direct exposure and result in death. Then, there is a group of impacts which cause behavioural changes. The behavioural changes can be either minor without changing the normal activity of individuals, or more pronounced so that the individuals cease with their usual activities. In the end, there is perturbation under ambient noise level which has no effect on organisms. The FPP implementation enables different types of noise which can have both physiological and behavioural effect on individuals. A potentially significant negative impact is enabled by utilisation of airguns, and negative impacts of lower intensity are possible due to the increased traffic of vessels, construction, utilisation and removal of platforms and intake of either accidentally or deliberately disposed solid waste (Table 6.7, Table 6.8). The impacts have been considered on the Adriatic Sea level, and not for each ecological network area where the common bottlenose dolphin is a target species (Figure 6.11). Such approach was applied primarily due to a lack of information on the populations of the common bottlenose dolphin within the ecological network areas, but also due to generality of the Plan and Programme.

Table 6.7 Potential impacts of the FPP on the marine mammals (+2 likely significant positive impact, +1 likely moderate positive impact, 0 likely no impact, -1 likely moderate negative impact, -2 likely significant negative impact (in accordance with the Guidelines for the Appropriate Assessment of the Project on the Ecological Network); D - direct impact, I - indirect impact; S - short-term impact, M - medium-term impact, L - lasting impact; E - exploration operations, P - production operations, R - removal of mining facilities)

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Increased level of airgun noise	2D and 3D surveys utilize airguns which produce short, but explosive impulses of sound. The affected individuals can suffer physiological and behavioural changes of higher or lower intensity with different negative consequences. A direct connection between individuals affected by the airgun noise and their mortality has not been established.	-1	D	🗐	S	🗐	⊘	E,P
Swallowing of improperly disposed waste and getting tangled into such waste	During operations on exploration boats and platforms a certain quantity of solid waste is generated which ends up in the sea. It may happen that this solid waste gets eaten by the marine mammals causing reduced functionality of their digestive system. (Tomas J. et al. 2002; Casale P. et al.	-1	I	🗐	M	🗐	⊘	E,P R
	2008 ; Simmonds, M. P. 2012).							
Platform operation reduces the attractiveness of an area	When operating, platforms generate increased levels of noise, mud, technological, formation and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and technological water reduce the abundance of fish (Patun, 1999; Mario, 2002), and diversity of benthic communities which consequently affects quantities of prey and foraging success. Heavy metals contained in the mud tend to bioaccumulate through the food chain A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators. The noise from hydrocarbon extraction and drilling of wells can temporarily chase away the sea fauna, but it eventually adapts to the new circumstances.	-1	D	⊘	M	⊘	⊘	E, P
Masking of sounds	Masking of sounds is the process which reduces the ability of marine mammals to recognize natural sounds in the environment, eventually causing their disorientation.	-1	D	🗐	M	🗐	⊘	E, P
Presence of production platforms	Since the Ordinance on the Main Technical Requirements on Safety and Security of Offshore Exploration and Production of Hydrocarbons in the Republic of Croatia (OG 52/10) prohibits any activity within a 500 m radius from any mining facility. Oil platforms installed in the sea become artificial reefs abundant with various species of vertebrates and invertebrates.	+1	D	⊘	M	⊘	⊘	P
Supporting operations which increase the traffic and noise in the sea	Collision with vessels and elevated sea ambient noise due to increased traffic negatively affects marine macrofauna (Nowacek, S M. et al. 2001)	-1	D	⊘	S	🗐	⊘	E, P, R
Disturbances to natural environment by the platform construction	The platform construction operations make specific levels of noise and introduces a new element into the area which can reduce the area attractiveness for a short period.	-1	D	⊘	S	⊘	⊘	E
Disturbances to natural environment by the platform removal	The platform removal operations can result in injury and death of organisms (Klima et al., 1988; Gitschalg et al., 2000).	-1	D	⊘	S	⊘	⊘	R

Table 6.8 Potential impacts on marine mammals

Group	Impact	Clarification
Marine mammals	• Increased airgun noise • Swallowing of improperly disposed waste and getting tangled into such waste • Platform operation reduces the attractiveness of an area • Masking of sounds • Presence of production platforms • Supporting operations which increase the traffic and noise in the sea • Disturbances to natural environment by the platform construction • Disturbances to natural environment by the platform removal	Potential impacts on the common bottlenose dolphin are mostly expected due to the elevated noise levels during the exploration period, construction of platforms and hydrocarbon production, where the utilization of airguns for 2D and 3D surveys is estimated as the most adverse source of noise. A minor negative effect of collisions with supply vessels is also possible. The impact of the increased noise made by ships is cumulative and adds to the noise levels already present in the Adriatic. The construction of production platforms can even have a minor positive impact due to the prohibition of fishing activities within a 500 m radius from the platform, which results in increased food sources in the vicinity of the platform. It must be emphasised that the real impact intensity will be able to be determined by producing a noise dispersion model.

6.2.3 Impact on sea turtles

Potentially significant negative impacts are possible on the species listed in Annex II and IV of the Habitats Directive which reside outside the Croatian ecological network. The species from that list, which this Strategic Study recognized as the most endangered are the loggerhead sea turtle (*Caretta caretta*), the green sea turtle (*Chelonia mydas*) and the leatherback sea turtle (*Dermochelys coriacea*). However, this document elaborates only the loggerhead sea turtle, due to its having the similar biology and ecology to other species and being the most abundant and the most researched sea turtle species in the Adriatic Sea. The recognized potential impacts can be also applied to the other two sea turtle species.

The implementation of the Plan and Programme can potentially have a significant impact on the sea turtle species during the utilization of airguns which can influence the behavioural changes and lead to injuries and death. Lower intensity impacts are possible due to the increased traffic of vessels, construction, utilisation and removal of platforms and intake of accidentally disposed solid waste by the sea turtle species. Table 6.9 explains potential impacts and Table 6.10 presents recognised impacts on the sea turtle species.

Table 6.9 Potential impacts of the FPP on the sea turtle species (+2 likely significant positive impact, +1 likely moderate positive impact, 0 likely no impact, -1 likely moderate negative impact, -2 likely significant negative impact (in accordance with the Guidelines for the Appropriate Assessment of the Project on the Ecological Network); D - direct impact, I - indirect impact; S - short-term impact, M - medium-term impact, L - lasting impact; E - exploration operations, P - production operations, R - removal of mining facilities)

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Increased level of airgun noise	2D and 3D surveys utilize airguns which produce short, but explosive impulses of sound. These sound impulses can cause the affected individuals to experience both physiological and behavioural changes of either higher or lower intensity with different negative consequences. A direct connection between the individuals affected by the airgun noise and their mortality was not established.	-1	D	[illegible]	S	[illegible]	⊘	E, P
Swallowing of improperly disposed waste and getting tangled into such waste	During operations on exploration boats and platforms a certain quantity of solid waste is generated which ends up in the sea. It may happen that this solid waste gets eaten by the sea turtles causing reduced functionality of their digestive system (Tomas J et al. 2002; Casale P. et al. 2008; Simmonds, M. P. 2012).	-1	I	[illegible]	M	[illegible]	⊘	E, P, R

Platform operation reduces the attractiveness of an area	When operating, platforms generate increased levels of noise, mud, technological, formation and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and technological water reduce the abundance of fish (Patun, 1999; Mario, 2002), and diversity of benthic communities which consequently affects quantities of prey and foraging success. Heavy metals contained in the mud tend to bioaccumulate through the food chain A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators. The noise from hydrocarbon extraction and drilling of wells can temporarily chase away the sea fauna, but it eventually adapts to the new circumstances.	-1	D	⦸	M	⦸	⦸	E, P
Presence of production platforms	Since the Ordinance (OG 52/10) prohibits any activity within a 500 m radius from any mining facility. Oil platforms installed in the sea become artificial reefs abundant with various species of vertebrates and invertebrates.	+1	D	⦸	M	⦸	⦸	P
Supporting operations which increase the traffic and noise in the sea	Collision with vessels and elevated sea ambient noise due to increased traffic negatively affects marine macrofauna (Nowacek, S M. et al. 2001)	-1	D	⦸	S	[illegible]	⦸	E, P, R
Disturbances to natural environment by the platform construction	The platform construction operations make specific levels of noise and introduces a new element into the area which can reduce the area attractiveness for a short period.	-1	D	⦸	S	⦸	⦸	E
Disturbances to natural environment by the platform removal	The platform removal operations can result in injury and death of organisms (Klima et al., 1988; Gitschalg et al., 2000).	-1	D	⦸	S	⦸	⦸	R

Table 6.10 Potential impacts to the sea turtle species

Group	Impact	Clarification
Sea turtle species	• Increased airgun noise • Swallowing of improperly disposed waste and getting tangled into such waste • Platform operation reduces the attractiveness of an area • Presence of production platforms	Potential impacts on the sea turtle species are mostly expected due to the elevated noise levels during the exploration period, construction of platforms and hydrocarbon production, where the utilization of airguns for 2D and 3D surveys is estimated as the most adverse source of noise. A minor negative effect of collisions with supply vessels is also possible. The impact of the increased noise made by ships is cumulative and adds to
	• Supporting operations which increase the traffic and noise in the sea • Disturbances to natural environment by the platform construction • Disturbances to natural environment by the platform removal	the noise levels already present in the Adriatic. The construction of production platforms can even have a minor positive impact due to the prohibition of fishing activities within a 500 m radius from the platform, which results in increased food sources in the vicinity of the platform. It must be emphasised that the real impact intensity will be difficult to estimate since little is known about the noise impact on this

6.2.4 Impact on habitats

The impact on the target habitats within SAC areas HR3000099 Brusnik and Svetac, HR3000100 Island of Jabuka off-shore, HR3000121 Palagruža off-shore, HR3000122 Islet of Galijula, HR3000423 Jabuka Pit, is expected primarily during the drilling of exploratory wells, installation, and, subsequently, removal, of platforms: In terms of the time and space, these operations are very limited, they are not conditioned by the marine habitat type, but the sea depth, and therefore, negative impacts are expected only if platforms were installed in exceptionally rare and, in terms of their surface area, small habitats (e.g. coral reefs): Since the seabed of the FPP area is almost unknown, a detailed impact assessment is expected on the lower planning levels. The following table provides an overview of the potential negative impacts of the FPP implementation-related impacts:

Table 6.11 Potential impacts of the FPP on the marine habitats (+2 likely significant positive impact, +1 likely moderate positive impact, 0 likely no impact, -1 likely moderate negative impact, -2 likely significant negative impact (in accordance with the Guidelines for the Appropriate Assessment of the Project on the Ecological Network); D - direct impact, I - indirect impact; S -

short-term impact, M - medium-term impact, L - lasting impact; E - exploration operations, P - production operations, R - removal of mining facilities)

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Anchoring of boats	The anchoring operations lead to seabed disturbance	-1	D	⦸	M	⦸	🗐	E, P,
Sedimentation of cuttings during well-drilling operations	Cuttings discharged during well drilling settle on the adjacent seabed contingent upon sea currents strength and grain size	-1	I	🗐	M	⦸	⦸	E, P
Well drilling	Mechanical destruction of habitats in the well area caused by drilling and laying of cement.	-1	D	⦸	M	⦸	🗐	E, P
Installation/construction of mining facilities and supporting infrastructure	Covering and shading of a part of the habitat affected by laying the foundation for the fixed or anchorage for the floating platforms as well as laying of pipelines and cables.	-1	D	🗐	M	⦸	🗐	P
Presence of production mining facilities and plants	Since the Ordinance (OG 52/10) prohibits any activity within a 500 m radius from any mining facility. Oil platforms installed in the sea become artificial reefs abundant with various species.	+1	I	⦸	M	⦸	⦸	P
Platform operation	During the platform operations, certain quantities of formation water, mud and technological water is discharged and they settle on the seabed carried by sea currents.	-1	I	🗐	M	⦸	⦸	E, P
Introduction of invasive organisms	Invasive foreign species can be imported to new locations by ships (tankers ballast water, anchors...)	-1	I	🗐	L	⦸	🗐	E, P
Removal of mining facilities and plants	The removal of mining facilities leads to seabed disturbance and destruction of the new habitat.	-1	D	⦸	S	⦸	🗐	R

The basic criterion used as a basis for the assessment of potential negative impacts was the presence of target habitats within the FPP area. It is considered that if there are no accidents, the impact on habitats will be limited to the small area in the vicinity of the location where wells and platforms are installed.
The recognized impacts from the previous table are distributed according to their expected effect on the target habitats of the ecological network areas (Table 6.12):

Table 6.12 Potential impacts on marine habitats

Code	Habitat	Impact	Clarification
1110	Sandbanks which are slightly covered by sea water all the time	• Anchoring of boats • Deposition of sediment during well drilling • Well drilling • Installation/construction of mining facilities and supporting infrastructure • Platform operation • Removal of mining facilities and plants • Introduction of invasive organisms	Negative impacts on the sandy seabed are possible during the exploration and production period and removal of mining facilities. The majority of impacts refers to the mechanical seabed disturbance, but since it is the case of mobile sediment, the balance will be re-established in a relatively short period. Therefore, from this perspective, the impacts on the sandy seabed are short-term and of low intensity. The potentially significant negative impact can be caused by the introduction of invasive organisms which can interfere with the structure of natural sandbank communities, but this impact depends on the environmental conditions and therefore, a more precise assessment will be possible after the locations and type of planned operations during the FPP implementation become known. There are potential negative impacts due to the water pollution by discharge of mud, formation and technological water, but the intensity of their effect depends on sea currents and quantity of pollutants, and its assessment is currently not possible.

1120	Posidonia beds (Posidonion oceanicae)	• Anchoring of boats • Deposition of sediment during well drilling • Well drilling • Installation/construction of mining facilities and supporting infrastructure • Platform operation • Removal of mining facilities and plants • Introduction of invasive organisms	Any mechanical disturbance has a potential significant impact on this habitat. Posidonia beds are very slowly recovered, and anchoring of ships, drilling of wells, installation and removal of mining facilities can have lasting consequences for this habitat. The mechanical disturbance works in synergy with the introduction of invasive species, which have more chances of survival in disturbed communities, thus additionally increasing negative impacts. Since *Posidonia oceanica* species is a sea-flowering plant, which is sensitive to sea water turbidity, which can have a potential negative impact. Furthermore, there are potential negative impacts due to the water pollution by discharge of mud, formation and technological water, but the intensity of their effects depends on sea currents and quantity of pollutants. On the present level of the FPP, when the locations of planned activities are not known, the assessment is not possible.
1170	Reefs	• Anchoring of boats • Deposition of sediment during well drilling • Well drilling • Installation/construction of mining facilities and supporting infrastructure • Platform operation • Removal of mining facilities and plants • Presence of production mining facilities and plants • Introduction of invasive organisms	As in the case of posidonia beds, the mechanical disturbances (anchoring of ships, drilling of wells, installation and removal of mining facilities) represents potential significant impacts on reefs. The mechanical disturbance works in synergy with the introduction of invasive species, which have more chances of survival in disturbed communities, thus additionally increasing negative impacts. There are potential negative impacts due to the water pollution by discharge of mud, formation and technological water, as well as turbidity of water by discharge of well cuttings. Their intensity depends on sea currents and quantity of pollutants. On the present level of the FPP, when the locations of planned activities are not known, the assessment is not possible. A potential positive impact of platform installation on reefs was additionally determined. The supporting platform piles, which act as artificial reefs, open a new space for settlement of immovable organisms which are typical for a reef community
8330	Submerged or partially submerged sea caves	• Well drilling • Installation/construction of mining facilities and supporting infrastructure • Removal of mining facilities and plants	Negative impact on sea caves is possible in case of their mechanical disturbance. The intensity of the impact caused by disturbance is hard to assess because it depends on the facility size. Since the connection between the sea caves and external environment is reduced and contingent upon the size, form and number of openings, no significant pollution impact is expected here during the normal platform operation (discharge of mud, formation and technological water and well cuttings).

6.2.5 Cumulative nature of the impact of the FPP implementation on the conservation objectives and integrity of the ecological network area

The current Adriatic noise levels have primarily been caused by maritime traffic. On the annual basis 22.000 ships pass through the Adriatic on its longitudinal traffic direction, and added to this must be tourist boat traffic, which is at its peak during summer months. The FPP foresees the additional sources of noise (seismic surveys, operations, installation and removal of platforms and increased boat traffic) with the potential cumulative impact on the Adriatic. Seismic surveys act as the biggest additional source of noise during the FPP implementation operations. The volume of sound waves during seismic surveys is seldom below 200 dB, which is, according to its intensity, the second strongest anthropogenic source of noise in the sea after explosions. Furthermore, the noise of lower intensity will be generated by well drilling, platform installation, hydrocarbon production and lastly, platform removal. Increase of the noise level is additionally expected during all stages of the FPP implementation, as well as from the supply activities carried out by boats and helicopters.

Platform operations i.e. hydrocarbon production operations will produce a constant low-frequency, low-intensity noise (up to 200 Hz), which will last as long as the production operations (20-30 years).
Since the course of the future activities is not known at this FPP stage, and since it depends on the survey results, it is necessary to estimate the natural capacity of the ecosystem for individual blocks on the level of the Appropriate Assessment of the Project on the Ecological Network, and assess if the work plan for the individual blocks exceeds the significance limits considering the conservation objectives and integrity of the ecological network area. On the strategic study level, it has been estimated that the implementation of activities in all blocks would cumulatively have a significant negative impact. This would especially come to the fore if the activities in block were implemented simultaneously. Based on the available data, the optimum number of blocks where the implementation of activities would not have a significant impact cannot be precisely determined. Considering the closed shape of the Adriatic, as well as potential impacts, a preliminary assessment is that the exploration (seismic surveys, exploratory wells) should not be implemented in more than three blocks at the same time. An EIA shall be conducted for the hydrocarbon production operation for each project, within which a Study of the Project Impact on the Environment will be developed, and an appropriate assessment of the project impact on the ecological network shall be conducted within the Study. The appropriate assessment shall estimate the cumulative impact on the conducted operations in the exploration stage as well as in relation to the potential number of production wells.
Ultimately, the FPP implementation will increase the noise levels in the sea, which can have a cumulative impact, with already existing sources of noise, on the target species of macrofauna (bottlenose dolphin and sea turtles).

6.2.6 Accidents

The Main Assessment recognizes a potential negative impact of accidents on the ecological network area. The accidents are possible during hydrocarbon exploration and production, but two accidents stand out in terms of the significance of negative impacts:

- oil and gas spills;
- discharge of hydrogen sulphide (H2S).

Oil spills and discharge of hydrogen sulphide have a negative impact on all organisms in the water column, seabed, seabirds and coastal habitats. The threatening accidents can have direct impacts on organisms, when an individual is affected (suffocation, poisoning), or these impacts can be on trophic networks (consumption and bioaccumulation of noxious substance through food). In case of birds, the contact of feather with oil results in a breakdown in the protective water-repellent layers, reduced thermal insulation provided by the feathers and reduced floating ability. Birds usually use their beaks and try to remove the oil from the feathers, they ingest oil in an effort to clean it off and expose themselves to a large risk of harming the digestive and nervous system, liver, lungs and other internal organs.
There are only few notes on the direct impact of oil spill on cetaceans, sea turtles or large fish. The impact is usually measured by monitoring the direct mortality, i.e. number of animals found dead. It is considered that cetaceans are able to avoid oil spills since their skin is less prone to contamination by oil i.e. they absorb less oil through skin because of the blubber, a thick layer of fat under the skin. However, the impact varies from species to species and it was determined that possibility of contact of common bottlenose dolphins with oils spills largely depends on the type of the spill and ability of the animals to observe the spill in a particular area.
Unlike direct mortality, in case of turtles and dolphins there is a long-term effect of pollution (“cryptic” mortality) i.e. mortality affecting population (Williams et al. 2011). For example, relatively well documented such impact is loss of 30-40% of two populations of killer whales in the area of Prince William Sound, Alaska after Exxon Valdez oil spill (Matkin et al. 2008). In case of accidental oil spill the most endangered habitats are those in the mediolitteral area (intertidal zone), because if the oil spill reaches the shore, they would be directly covered by oil. Habitats comprising photosynthetic organisms (sea flowering plants and algae are endangered as a result of habitat. A part of hydrocarbons is discharged in the water column, and in case of oil spill, the majority of habitats, i.e. organisms which live in these habitats are potentially at risk. It was observed that oil has the potential to persist in the environment long after a spill event and has been detected in sediment 30 years after a spill. (Effects of Oil on Wildlife and Habitat, 2010.).
The potential reasons for the above mentioned accidents, as well as code of practice and methods for reducing the accidents to minimum have been described in the introductory chapter (1.5.5 and 8.3.2.11) of this Strategic Study.
The intensity of impacts caused by oil spills and discharge of hydrogen sulphide is contingent upon the accident location, quantity of the spilt liquid and sea and atmosphere dynamics at the given moment. Since the Plan and Programme does not foresee detailed project locations, this chapter can define risk areas based on a general flow of the Adriatic Sea currents, which, due to complexity of processes that determine the sea current dynamics, does not represent the expected direction of currents around the future locations of wells. However, there is one rule that can be applied on this level of the strategic assessment: the closer areas of the ecological networks are at a higher risk from negative impacts that the remote areas (Figure 6.14). The map below shows the distance between the ecological network areas and blocks. The list of all presented areas is included in Annex 5.

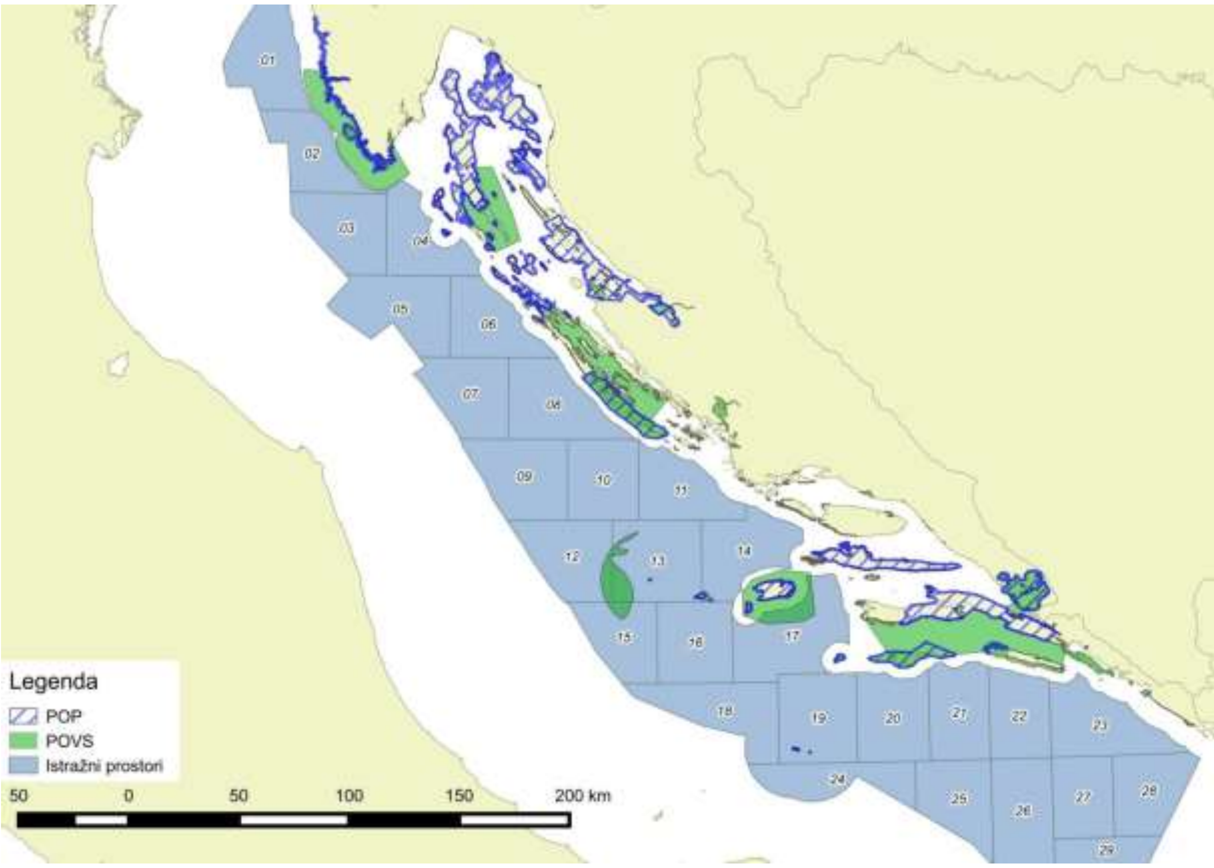


Figure 6.14 The ecological network areas at the highest risk of accidents

Figure 6.14

Key:
SPA
SAC
Blocks

6.3 Presentation of other suitable options (alternative solutions) and impacts of the alternative solutions on the conservation objectives and integrity of the ecological network area

The analysis of potential impact recognized a potentially significant negative impact on breeding populations of seabirds and Eleonora's falcon (-2). Pučinski Islands and islets (sv. Andrija, Svetac, Kamnik and Palagruža) are the breeding areas of the only population of *Puffinus yelkouan* (yelkouan shearwater) i *Calonectris diomedea* (Scopoli's shearwater) in Croatia and the main part of the Croatian population of *Falco eleonorae* (Eleonora's falcon), and the impacts caused by the FPP implementation can endanger them to the extent that they permanently leave the breeding sites. The alternative solution suggests movement of the project zone 1 km from the relevant part of the ecological network area Pučinski otoci within which the above mentioned species are the conservation objectives (Figure 6.15, Figure 6.16)

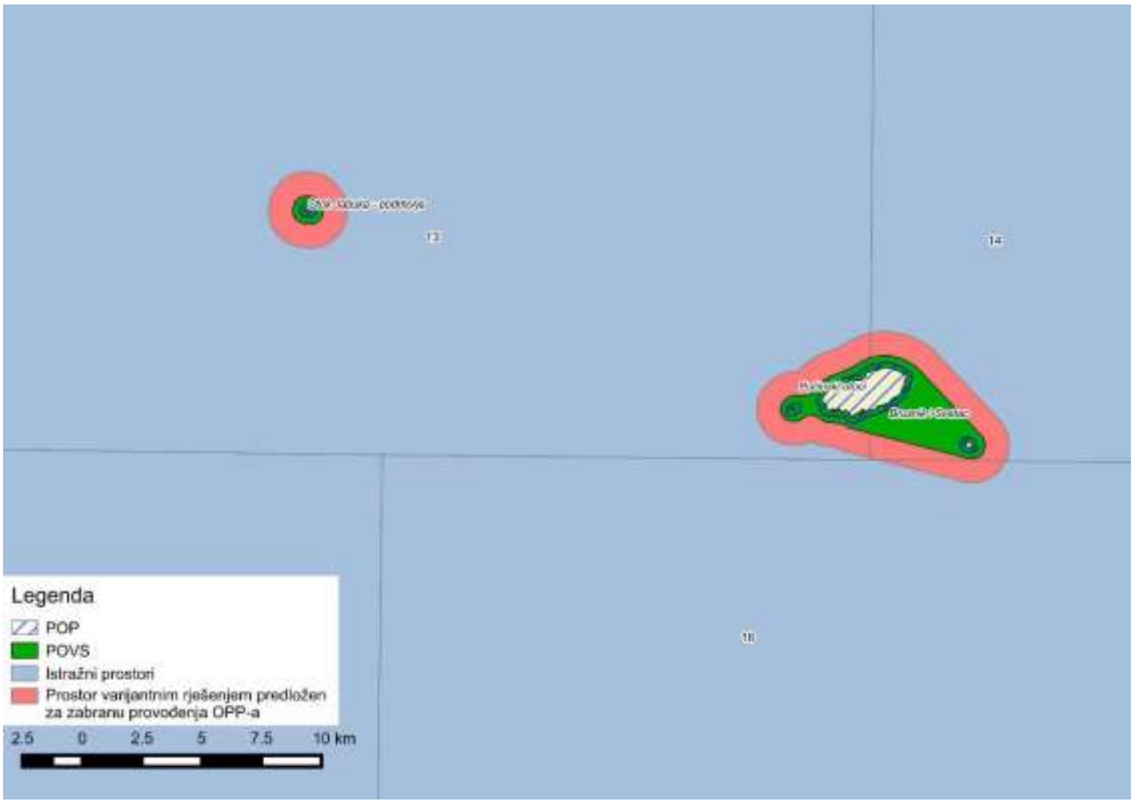


Figure 6.15 The map showing the Main Assessment alternative solution - part one

Figure 6.15

Key:
SPA
SAC
Blocks
Area proposed by the alternative solution for the introduction of the FPP implementation ban

Map (left-right)
Island of Jabuka – offshore
Pučinski otoci
Brusnik and Svetac

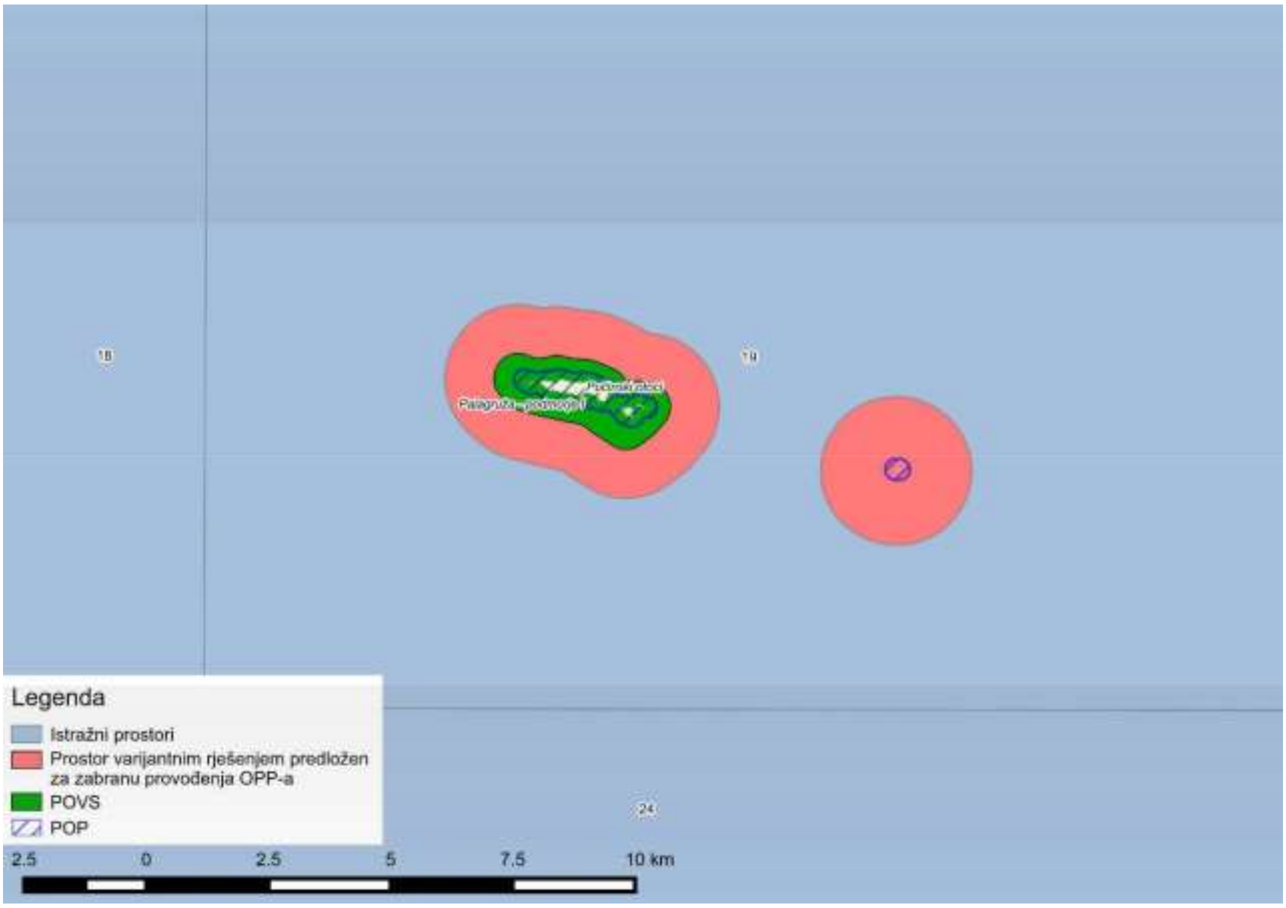


Figure 6.16 The map showing the Main Assessment alternative solution - part two

Figure 6.16

Key:
Blocks
Area proposed by the alternative solution for the introduction of the FPP implementation ban
SAC
SPA

Map (left-right)
Island of Palagruža – offshore
Pučinski otoci

6.4 Mitigation measures for adverse effects of the Framework Plan and Programme implementation on the conservation objectives and integrity of the ecological network area

<table>
<tr><th>Impact</th><th>FPP mitigation and improvement measures</th><th>Reasons for the measure</th></tr>
<tr><td>Noise impact on bird nesting</td><td>• The project zone should be moved 1 km from the relevant area of the ecological network Pučinski otoci (Pelagic Islands).</td><td></td></tr>
<tr><td>Reduction of the available food sources under the influence of the FPP operations</td><td rowspan="6">• Prescribe the appropriate protection measures by the procedure of the appropriate assessment of the project impact on the ecological network for the projects which will be defined during the FPP implementation taking into consideration both the impact assessed by the strategic study and the reasons for the measures.</td><td>Potential reduction of food sources for birds sources</td></tr>
<tr><td>Flaring of hydrocarbons during well production capability testing</td><td>Potential reduction of viability of seabirds due to insufficiently flared hydrocarbons.</td></tr>
<tr><td>Bird deaths resulting from collisions with helicopters</td><td>Potential deaths of passage migrants and vultures.</td></tr>
<tr><td>Disturbances to natural environment by the platform removal</td><td>Reduction of impact of platform removal on target species and habitats</td></tr>
<tr><td>Disturbances to usual flyways</td><td>Potential collision with platforms</td></tr>
<tr><td>Increased noise levels resulting from the FPP implementation</td><td>• Prior to implementing the FPP operations:
○ Make detailed noise dispersion models based on actual data about the environment in which the operations will be conducted
○ Determine the range, number and potential seasonality of presence of individual vulnerable species, and determine the acceptable variation in resulting values
○ Determine a detailed operating procedure for monitoring and protection of the listed species during performance of each particular operation representing a source of noise
○ Apply the Guidelines to address the impact of anthropogenic noise on cetaceans in the ACCOBAMS area</td><td>Reduction of the FPP noise impact on target species and habitats, especially marine mammals and turtles</td></tr>
</table>

6.5 Conclusion on the impact of the Framework Plan and Programme on the ecological network

Based on the available information, the Main Assessment recognized sea turtles, marine mammals (common bottlenose dolphin), seabirds, passage migrants and vultures as species on which the FPP implementation can potentially have a significant negative impact.

The information on impacts of hydrocarbon exploration and production on marine mammals, turtles and bird have not always been unambiguous. During a biogeographic seminar held on 29 and 30 September 2014 in Zagreb, the EU Directorate-General for the Environment observed a lack of data referring to the loggerhead sea turtle (*Caretta caretta*) and common bottlenose dolphin (*Tursiops truncatus*) as a problem that prevents definition of the appropriate management plan for that part of the ecological network of the Republic of Croatia.

Movement and feeding areas of species/colonies of seabirds are not familiar enough, and they can be more than 20 km distant from their breeding colonies. Therefore, in the current FPP stage, it is difficult to estimate the significance of the FPP impact for the previously mentioned target species.

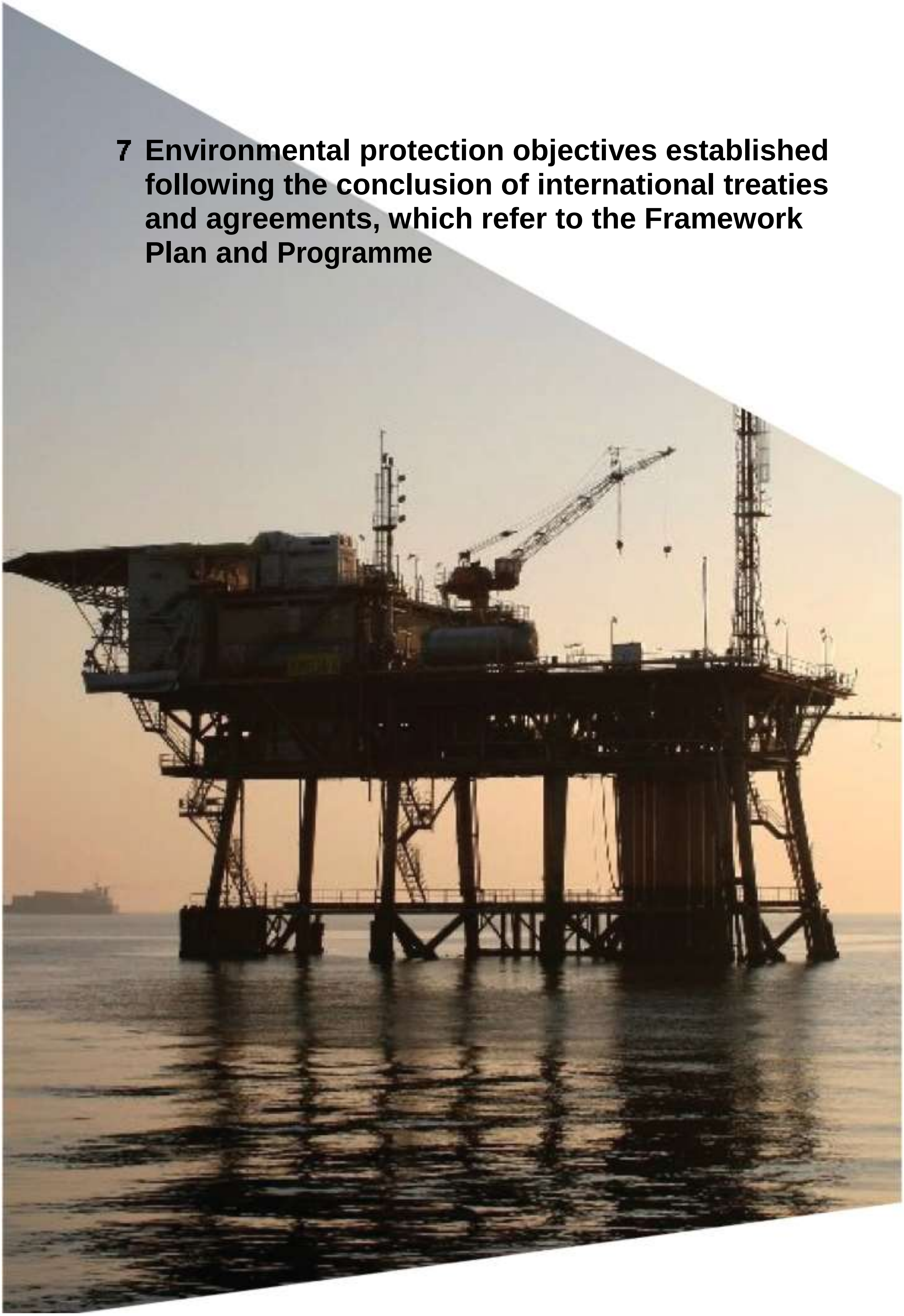
The proposed alternative solution moves the FPP operation area 1 km from the current limits of the ecological network, which should protect the breeding colonies from noise disturbances. Since the seabird feeding areas are not known, in order to provide adequate protection, these areas must be determined by the procedure of the appropriate assessment of the project impact on the ecological network for individual blocks and the appropriate protection measures must be prescribed.

Since no impact assessment on the ecological network has been conducted during the current hydrocarbon exploration and production operations, the planned FPP operations represent a new element in the sense of potential cumulative impact assessment. The mutual impact of the expected noise increase level during the implementation of FPP operations (seismic surveys, well drilling and development, helicopters, etc.) and current sources of noise in the Adriatic (22000 of vessels per year on the longitudinal traffic direction, fishing boats, nautical tourism, etc.) can be defined as the most pronounce cumulative impact. Therefore, on the level of this document, noise has been estimated as an important factor of potential impacts. After determining the type and intensity of planned activities for individual blocks, it will be possible to estimate this more precisely.

Despite the lack of information referring to the ecological network conservation objective, the conclusions of the Main Assessment are as follows:

1. During the FPP implementation operation, the highest impact of noise will be on the common bottlenose dolphin (*Tursiops truncatus*) and loggerhead sea turtle (*Caretta caretta*), then on seabirds (*C. diomedea, P. yelkouan, P. aristotelis desmarestii, L. audouinii*) and Eleonora's falcon (*F. eleonorae*) and passage migrants and lastly on the other vultures being the conservation objective of the ecological network area HR1000039 Pučinski otoci.
2. The most significant negative impact are possible during the utilization of airguns, then there are other noise sources and increased traffic as well as increased quantities of improperly disposed solid waste. The Main Assessment recognised potential positive impact as well, the most significant being the impact of the ban of unauthorized activities within a 500 m radius from the platform.
3. Cumulative impacts are possible in all stages of the FPP implementation and they are related to both hydrocarbon exploration and production stage. The implementation of operations in all blocks, can cumulatively have a significant negative impact. This would especially come to the fore if the activities in block were implemented simultaneously. Based on the available data, the optimum number of blocks where the implementation of activities would not have a significant impact cannot be precisely determined. Considering the closed shape of the Adriatic, as well as potential impacts, a preliminary assessment is that the exploration (seismic surveys, exploratory wells) should not be implemented in more than three blocks at the same time.
4. Negative impacts of accidents cannot be estimated in detail in the current stage of the Framework Plan and Programme. According to the available information, coastal and marine areas of the ecological network are exposed to the highest risk, and the risk level depends on the distance between the exploration and production facilities and ecological network areas. An important factor is also the type of the discovered and produced hydrocarbon. Impact of the oil-related accidents is proportionally bigger than the impact of the gas-related accidents.

7 Environmental protection objectives established following the conclusion of international treaties and agreements, which refer to the Framework Plan and Programme



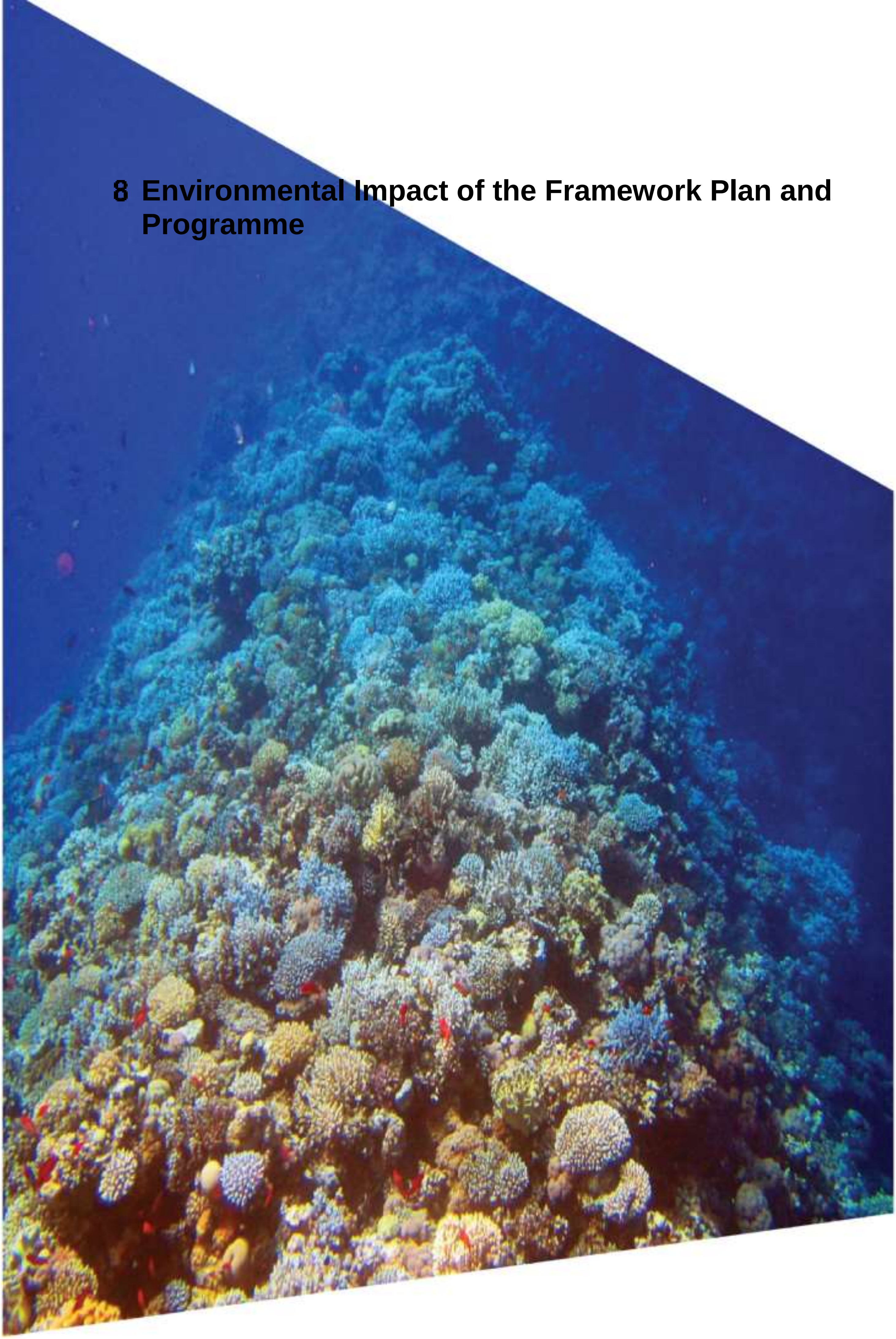
International convention	Convention objective	Correlation between the Study and the Convention objectives
International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	Prevention of marine pollution by oil. Prevention of marine pollution by chemicals in bulk. Prevention of marine pollution by harmful substances in packaged form, containers or portable tanks. Prevention of marine pollution by sewage from ships. Prevention of marine pollution by garbage and waste from ships.	Exploration and production of hydrocarbons in the Adriatic will be carried out in compliance with the international and national regulations regarding safe management of pollutants. Compliance with all the regulations relevant for the prevention of the pollution of the marine environment will result in the fulfilment of the Convention objectives.
Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) (1976)	Prevention and elimination of pollution in the Mediterranean Sea and protection and improvement of the marine environment in that area. Assessment and control of the pollution of the sea and coast. Ensuring sustainable management of natural marine and coastal resources. Integrating the environment into the social and economic development. Natural and cultural heritage protection. Strengthening solidarity among Mediterranean coastal states. Contributing to the improvement of the quality of life.	Exploration and production of hydrocarbons in the Adriatic will be carried out in compliance with the international and national regulations regarding safe management of pollutants. Compliance with all the regulations relevant for the prevention of the pollution of the marine environment will result in the fulfilment of the Convention objectives. The Strategic Study defines the way in which the activities/project, whose aim is to ensure the maintenance of a stable marine ecosystem, are to be carried out, i.e. it identifies activities which might deteriorate the quality of the Mediterranean Sea. The Study also prescribes the mitigation measures for adverse effects on people, environment and nature.
United Nations Convention on the Law of the Sea (UNCLOS) (1982)	Peaceful uses of the seas and oceans, the equitable and efficient utilization of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment. Conservation of marine mammals and, with the help of appropriate international organizations, conservation, management and study of cetaceans. Conservation of highly migratory species and promotion of their optimum utilization. Conservation of anadromous and catadromous fish, by establishing regulatory measures for fishing.	Strategic Study objectives refer to the protection of the sea and marine environment, especially to the protection of biodiversity, and therefore the mitigation measures for certain adverse effects refer to the conservation of biological diversity, with a special emphasis on migratory and vulnerable species.
United Nations Framework Convention on Climate Change (UNFCCC) (1992)	Achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.	The objective of the Strategic Study, among others, is to maintain the existing air quality and climatic conditions. In conformity with this objective, measures are defined for those impacts which might have a significant effect on the air quality and greenhouse gas emissions.
Convention on Biological Diversity (1992)	Conservation of the overall biological diversity. Sustainable use of the biological diversity components. Fair and equitable sharing of the benefits arising out of the utilization of genetic resources.	The Strategic Study aims at ensuring a good status of the species and habitats connected with the sea, providing guidelines for proper implementation of activities which might affect the biological diversity.
Stockholm Convention on Persistent Organic Pollutants (2001)	Reduction or elimination of the production, use, discharge, import and export of highly toxic substances for the purpose of protecting human health and the environment. Selecting alternatives regarding the persistent organic pollutants.	Projects which include the possibility of discharging highly toxic substances have been specifically identified and measures to avoid pollution have been presented. Those measures mostly imply compliance with the existing legislation regulating the discharge of highly toxic substances.

Vienna Convention for the Protection of the Ozone Layer (1985)	Protection of human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer.	Compliance with the provisions of this Convention will be achieved by implementing the following Strategic Study objective: Maintaining the existing quality of air and climatic conditions. Limitations have been defined with regard to those activities which might cause the modification of the ozone layer, whether in the form of legal regulations or Strategic Study measures.
Convention on the Conservation of Migratory Species of Wild Animals (CMS) (1979)	Protection and conservation of migratory species and their habitats on a global level. Promoting national policies for the conservation of wild animals and plants and their natural habitats. Ensuring wild animals and plants protection in planning and development policies and measures against pollution. Promoting education and exchange of information on the need to conserve wild animals and plants and their natural habitats.	Conservation of biological diversity, with an emphasis on the conservation of migratory species and their habitats, is one the more important Strategic Study principles. Mitigation measures have been defined for those activities that might have an adverse effect on migratory species and their habitats.
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) 1975	The Convention objective is to ensure controlled international trade and prevent commercial exploitation of endangered species, maintain an ecological balance within the populations of species which are a subject of international trade, and provide support to Convention Parties with the aim of achieving sustainable trade in endangered species of wild fauna and flora.	Since the main objective of this Convention refers to the conservation of endangered species in nature, by implementing Strategy measures, the Convention objectives will also be fulfilled. The Strategy prescribes measures whose main purpose is the conservation of endangered species and habitats as well as the conservation of the overall biological diversity of the marine ecosystem.
Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention)	Conservation of European wild flora and fauna and their natural habitats as well as endangered migratory species. Conservation measures require prohibition of all forms of deliberate capture and keeping and deliberate killing, the deliberate damage to or destruction of breeding or resting sites, as well as any form of disturbance or trade in these species.	The Strategic Study provides guidelines for the conservation of endangered habitats and species affected by the FPP and the Bern Convention objectives will, therefore, be supported by the measures defined within this Study.
Other important documents	**Document objective**	**Correlation between the Study and the Convention objectives**
Agenda 21 of the United Nations Conference on Environment and Development (1992)	Agenda 21, also known as the Rio Declaration, is a comprehensive programme of action which should be implemented on all levels (globally, nationally, locally) with the aim of reducing the human beings' impact on the environment. Chapter 17 of the Agenda 21 refers to the protection of the oceans and one part of the chapter refers to the States' requirements to take additional measures regarding the control of the marine environment from potentially adverse offshore activities, including adverse impacts of the oil and gas platforms.	The implementation of the Strategic Study objectives (which refer to the protection of the marine environment, conservation of biological diversity, prevention of environmental pollution) will also ensure the compliance with the principles of Agenda 21. The Strategic Study defines the measures mitigating and minimising the potential adverse impacts of the oil and gas platforms as well as the activities taking place.
Kyoto Protocol 1997	Parties of the Kyoto Protocol are require to individually prescribed under law the reduction or limitation of the greenhouse gas emissions they are causing.	Compliance with the provisions of this Protocol will be achieved by implementing the following Strategic Study objective: Maintaining the existing quality of air and climatic conditions.

The Montreal Protocol on Substances that Deplete the Ozone Layer (1987)	The Protocol is an addition to the Vienna Convention and it was designed to regulate the production and consumption of ozone depleting substances. A schedule has been set regarding the phasing-out of certain substances which were proven to have a negative impact on the ozone layer and which can be replaced.	Compliance with the provisions of this Protocol will be achieved by implementing the following Strategic Study objective: Maintaining the existing quality of air and climatic conditions.
European Union Directives	**Directive objective**	**Correlation between the Study and the Convention objectives**
Directive 2013/30/EC on safety of offshore oil and gas operations	Reduce as far as possible the occurrence of major accidents relating to offshore oil and gas operations and to limit their consequences,thus increasing the protection of the marine environment and coastal economies against pollution. The Directive contributes to the protection of the marine environment with its objective of achieving a good ecological status by 2020.	Compliance with the measures defined in the Strategic Study, whose aim is to reduce the negative impact on the marine environment, and implementing the relevant legal regulations during the performance of certain activities will ensure compliance with the afore mentioned Directive.
Directive 2014/89/EU establishing a framework for maritime spatial planning	Achieve the sustainable coexistence of different uses and, where applicable, the suitable apportionment of maritime space to appropriate uses. The main purpose of maritime spatial planning is to promote sustainable development and to identify the utilisation of maritime space for different sea uses as well as to manage spatial uses and conflicts in marine areas. Maritime spatial planning also aims at identifying and encouraging multi-purpose uses, in accordance with the relevant national policies and legislation.	This Strategy analyses the compliance of the FPP and national policies on the sea use and, therefore, the objective of the Directive referring to the promotion of the sustainable use of maritime space will be fulfilled. The Study also analyses the impacts on tourism (landscape aspect) and prescribes the appropriate mitigation measures for adverse impacts on these two components of the environment.
Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment	Provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment.	The Strategic Study provides an overview of the activities planned within the Plan and Programme with regard to certain components of the environment, it defines the potential impacts on the environment and offers impact mitigation/elimination measures.
EU Water Framework Directive (2000/60/EC)	Aims at enhanced protection and improvement of the aquatic environment, *inter alia*, through specific measures for the progressive reduction of discharges, emissions and losses of priority hazardous substances and the cessation or phasing-out of discharges, emissions and losses of priority hazardous substances.	Activities which can change the quality of sea water, i.e. cause pollution or change of the chemical parameters of the sea, have been identified, their impact on the components of the environment has been analysed and measures reducing the impact of the potential marine pollution have been prescribed.

Habitats Directive (92/43/EEC) and Birds Directive (2009/147/EC) (Natura 2000)	The general objective of the Birds Directive is the long-term protection and management of natural resources, i.e. conservation of all bird species in wild habitats of the territory covered by the Directive, including protection, management and control of those species. The man objective of the Habitats Directive is to promote the conservation of biological diversity, taking into consideration the economic, social, cultural and regional requirements. The objective of the Natura 2000 network, which refers to the Habitats Directive and the Birds Directive, is to assure the long-term survival of Europe's most valuable and threatened species and habitats.	The Strategic Study provides guidelines for the conservation of vulnerable habitats and species living by or in the sea, i.e. it defines measure which will minimise or eliminate the impacts of the activities on the species and habitats covered by these two directives.
Marine Strategy Framework Directive (2008/56/EC)	Protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected. Prevent and reduce pollution in the marine environment so as to ensure that there are no risks to marine biodiversity, marine ecosystems or legitimate uses of the sea. Other objectives: Promotion of the sustainable use of the sea and conservation of the marine ecosystems. Establishment of marine protected areas. Development of marine strategies by Member States.	The Strategic Study provides measures for the conservation of marine protected areas and conservation of vulnerable species and habitats with the aim of ensuring the conservation of the biological diversity of the sea. Activities which can change the quality of sea water, i.e. cause pollution or change of the chemical parameters of the sea, have been identified, their impact on the components of the environment has been analysed and measures reducing the impact of the potential marine pollution have been prescribed.

8 Environmental Impact of the Framework Plan and Programme



8.1 Overview of Hydrocarbon Exploration and Production Operations with Regard to Their Potential Environmental Impacts

8.1.1 Hydrocarbon Exploration Phase

In the exploration phase, at least one exploration well will be built in each block for the purpose of establishing the presence of commercially recoverable quantities of hydrocarbons. The concessionaire may conduct additional seismic surveys and/or other reservoir explorations which will be helpful in selecting the well location more accurately and in identifying geological risks. Depending on the final well depth and potential problems during drilling, the execution of a well may take from 40 to 120 days (Regg *et al*. 2000). In the exploration phase, at least one exploration well will be built in each block for the purpose of establishing the presence of commercially recoverable quantities of hydrocarbons.

The water depth in the area of blocks 1 to 8, which are in the Northern Adriatic, is up to 100 m (shallow water), while the water depth in blocks 1 to 4 is below 50 m, either wholly or partly. The water depth in the area of blocks 9 to 24, which are in the central Adriatic, is from 100 to 200 m (medium water), while the water depth in certain blocks reaches up to 500 m (blocks 20 to 24). The water depth in the area of blocks 25 to 29, which are in the southern Adriatic, ranges from 500 to over 1000 m (deep water). The water depth in the area of blocks 27 and 29 exceeds 1000 m, while in the remaining areas it exceeds the given value only in certain parts.

Depending on the water depth in the observed area (below 50 m and up to above 100 m), jackups (Northern Adriatic) (water depth up to 110 – 120 m), semisubmersibles, or drillships may be used. Contractors select the type of the drilling platform depending on the characteristics of the physical environment (including water depth), expected drilling depth, and the required mobility based on expected weather and sea conditions. Regardless of their type, all drilling platforms have a drilling tower, drilling equipment, storage, working, and housing area, firefighting equipment, and life-saving equipment, as well as a possibility of crew transfer and of supply (e.g. berths/dock space to support work boats, heliport for helicopter landings and take-offs).

Each exploration well will be drilled down to a pre-determined depth and suspended or abandoned in compliance with the standards applicable in the oil industry. During drilling, the water-base drilling mud and well cuttings, as well as other wastewaters will be discharged from the drilling platform, in compliance with the valid limitations on wastewater discharge.

In case that during the execution of an exploration well a hydrocarbon reservoir is discovered, the well will be tested for the purpose of determining its productivity, reservoir pressure, reservoir rock permeability, and/or hydrocarbon reservoir size. During well testing, the inflow of smaller quantities of reservoir fluids (oil and gas) to the surface and their flaring are to be expected. If the testing results are positive, the well will be appropriately secured by setting up cement or mechanical plugs and a well suspension cap and suspended until a decision on its completion and production start has been adopted.
If during the execution of an exploration well no commercial hydrocarbon reservoirs are discovered, the exploration well will be appropriately sealed by cement or mechanical plugs and abandoned, while the seabed around the exploration well will be rehabilitated and decommissioned.

8.1.1.1 Offshore Sound and Human Activities

Acoustic energy propagates efficiently and travels fast over great distances. Water enables sound to travel five times faster than in the air. At the same time, sound attenuates less over same distance in the water than in the air, and low frequencies can travel hundreds of kilometres with little loss in energy (Sorensen *et al*. 1984). The fact that sound travels faster and further in the water makes anthropogenic noise in the water more important. Sound propagation in the water is mostly affected by frequency of the sound, depth, and density differences along the water column, which varies primarily with temperature and pressure (Sorensen *et al*. 1984). Due to differences in physics of the sound, sound levels in the air and water are referenced differently making them less comparable and therefore more complex to evaluate the impact.
As light gets absorbed in the water, vision becomes of little use in deeper water. Therefore, sound is the only way animals can find prey, orientate, and communicate (on short or long distances) while under water.
Many human activities on the sea generate noise that is sometimes of very high intensity. Offshore activities such as shipping, dredging (deepening and maintenance of navigation waterways and entries to ports), construction, seismic surveying, military activities, etc. increased immensely in recent history, producing sound that adds to the sea ambient noise already present in the marine environment. With increase in human activities, it has been estimated that the amount of man-made noise rose 10 to 100 times (depending on the frequencies), causing concerns over the effects of long term exposure of marine mammals to such noise (Tyack 2008).
For comparison of the total human-made underwater noise sources energy output per year (in joules) (Hildebrand 2005) lists the highest amount of 2.1 x 1015 J, representing the contribution from nuclear explosions and ship-shock trials. Following is

the total noise generated by seismic airgun surveys (3.9 x 1013 J), military sonars (2.6 x 1013 J), super tankers, merchant vessels, and fishing vessels (3.8 x 1012 J). It is obvious that apart from explosions, seismic airgun surveys are the most intense man-made noise in the marine environment.

Distances where impact of such activities can be identified could be huge. Analysing 10 years of noise recordings from the Mid-Atlantic Ridge, Nieukirk *et al*. (2012) found that the sound generated by seismic airguns could be heard at distances of 4000 km from survey vessels. They also found that noise was present during 80-95% of the time for more than 12 months in some locations. When several surveys were recorded simultaneously, whale sounds were masked (drowned out), and the airgun noise became the dominant part of background noise levels.
The importance of noise and its adverse impact on marine fauna has been recognised by a number of international agreements. At the last conference of the signatory states of the Convention on Biological Diversity (CBD) in 2014, a Resolution on underwater noise was adopted, inviting CMS, IWC, and IMO to assist countries in minimising and mitigating the potential significant adverse impacts of anthropogenic underwater noise on marine and coastal biodiversity.

8.1.1.2 Noise Sources

In the case of hydrocarbon exploration and extraction, depending on the operational phase, different sources of noise are present. Noise sources include seismic surveying, sonar use, drilling, noise from transport vessels, construction of platforms for the extraction of oil and natural gas, laying of pipelines, and active extraction, but also decommissioning of the structures constructed in the sea, either by mechanical or explosive removal.

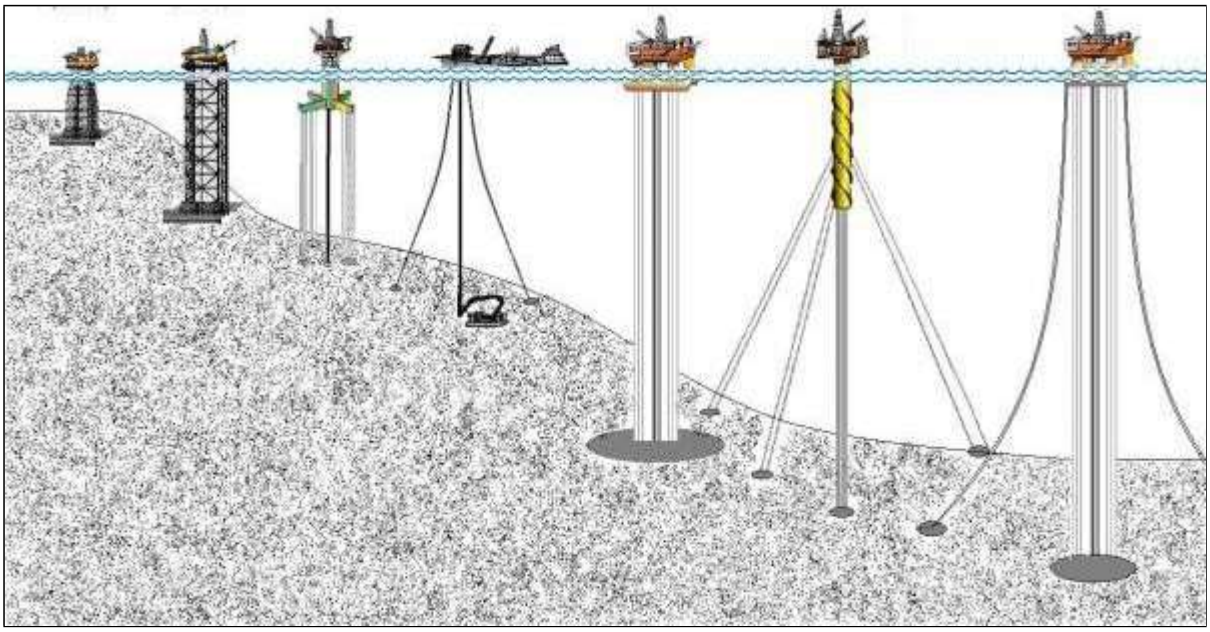
8.1.1.2.1 Seismic Surveys

Arrays of airguns produce sound pressure wave for seismic reflection profiling (Dragoset 2000). They contain a specified volume of air under high pressure, which after sudden release creates a sound pressure wave from the released air bubble. Array is suspended 1-10 m under the surface. They fire approximately every 10 s, while ship travels 4-5 knots. Airguns are designed to maximise downward transmission of energy. Multiple airguns are fired with synchronous timing to produce a coherent pulse of sound (NRC 2005). Seismic survey airgun arrays consist of up to 48 airguns and up to ten seismic receiving streamers (hydrophone arrays), which record seismic activity while being towed some 200 m behind a vessel (Hildebrand 2005). Source levels of airgun arrays are back-calculated to an equivalent source concentrated into a 1-m-radius volume, yielding source levels as high as 259 dB peak re 1 µPa at 1 m output pressure (Greene & Moore 1995). The far-field pressure from an airgun array is focused vertically, being about 6 dB stronger in the vertical direction than in the horizontal direction for typical arrays (Hildebrand 2005). Still, significant amounts of acoustic energy is transmitted horizontally (Richardson *et al*. 1995). The peak pressure levels for seismic survey airgun arrays are in the 5 to 300 Hz frequency range. Recently, repeated seismic "3D" surveys for temporal monitoring of producing oil fields, called "4-D" surveys, have been used in practice (Woma & Fagbenro 2013).

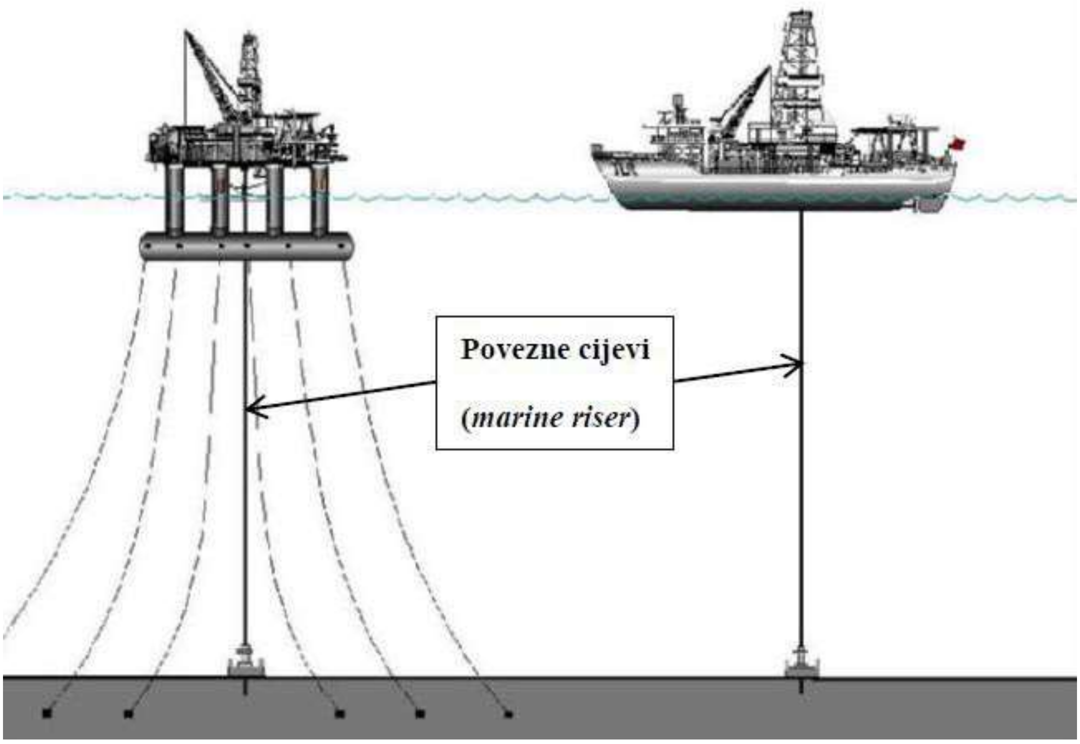
8.1.1.3 Installation and Removal of a Drilling Platform

Depending on the type of the drilling platform used, seabed sediments can be disturbed in a certain area during the installation and removal of a drilling platform (Picture 8.1).

Jackups are used in waters less than 100 m deep. They can be moved, i.e. towed to the location; upon arrival to the location, their legs are hydraulically lowered and they penetrate the seabed. In doing so, a jackup occupies a seabed area of approximately 10 m2. Classically moored semisubmersibles are kept in their position by radially distributed anchors, where their installation and pulling of anchors and chains impacts the seabed. Normally moored semisubmersibles are kept in their position by 6 to 12 anchors, which are placed radially around the platform, extending up to 3 km or more (Picture 8.2). The length of each mooring anchor can be five to seven times larger than the water depth. According to MMS (2007b), seabed area required for classically moored semisubmersibles varies depending on the mooring configuration, but generally it is 2 do 3 ha. Since the area of an individual block in the Adriatic Sea ranges from 1 000 to 1 600 km2, the area of the affected seabed would amount from 0.00125% to 0.0003% of the area of an individual block. After the drilling platform has been removed from the location, traces of rig legs or anchor scars will probably remain in the seabed for months and years; eventually, they will disappear, because seabed sediments will redistribute under the influence of sea currents and benthic organisms. In the study conducted by Continental Shelf Associates, Inc. (2006), at well locations in the Gulf of Mexico, at a depth of nearly 1000 m, anchor scars were discovered even 14 years after the drilling was completed. Some anchor scars ranged from less than 100 m to over 3 km in length.



Picture 8.1 Comparative presentation of the way in which platforms are supported on or anchored in the seabed



Picture 8.2 Installation of a conventionally moored semisubmersible (left) and a dynamically positioned drillship (right) (source: Regg *et al*. 2000).

Dynamically positioned semisubmersibles use a computer-managed system, which enables that the semisubmersible position is maintained by means of thrusters and propellers, thus avoiding the need for anchoring. Drillships are self-propelling, they can operate in the deep and very deep waters, their load-bearing capacity is usually larger than the load-bearing capacity of semisubmersibles, and they are dynamically positioned at the location (they do no use guylines). The ship's middle holds a moon pool through which a connection can be established between the drilling tower and the seabed (Picture 8.2).

8.1.1.3.1 Pile Driving in Relation to Sound

The construction of a new platform could include pile driving. During hammering, loud impulsive sound, of similar frequency components to those generated by airguns, is released (Richardson *et al*. 1995). The highest sound pressures are reached at low frequencies between 100 and 300 Hz (Ainslie *et al*. 2009). Source levels can be high, levels of 131-135 dB re 1 µPa at 1 km from a construction site can be reached (Richardson *et al.* 1995).

Pile driving produces noise when an impact hammer hits a pile, causing disturbance of water, which generates sound (Saleem 2011). Also, some of the sound generated in the air enters the water and contributes to the overall noise level. Finally, force of impact is also transmitted to the seabed causing vibrations.

Pile driving produces an impulsive sound, characterised by short sound waves of high intensity which are comparable to seismic airgun sound (Richardson *et al.* 1995). Peak noise intensity levels and noise exposure levels arising from pile driving are high. Peak levels of 208 dB re 1 μPa have been measured at 57 m distance with sound exposure level (SEL) of 178 dB re 1 μPa2-s (Ainslie *et al.* 2009). During hammering, the sound is repeated approximately every 0.8-1.5 s intervals, where a full hammering cycle takes about 2 hours to complete. It is also repeated every 24 hours (Kats 2009).
The noise generated during pile driving depends mostly on sediment type and power of the hammer used, but of importance are also salinity, sea state, diameter of the pile, etc.

8.1.1.4 Presence of Drilling Platform

Drilling platforms are usually present at the location where a well is being executed in a period of about 70 to 90 days. Drilling platforms can be seen from the shore, at a distance from 5 to 16 km, while small structures (such as a single drilling rig) are barely visible at a distance of 5 km. On clear nights, lights on the top of the drilling tower can be visible at a distance of approximately 32 km (MMS 2007b). The eastern border of the exploration area observed is determined by the line 10 km away from the shore and 6 km away from the external island line. These are also the minimum distances of individual blocks from the shore.

8.1.1.4.1 Drilling and Platform Operations

Activities that generate noise include drilling, extraction structure installation and removal, and related vessel traffic. The most significant are sound pressure levels associated with drilling, with maximum broadband (10 Hz–10 kHz) energy of 190 dB re 1 μPa at 1 m (Reynolds 2005). The noise generated during drilling is associated with drilling equipment installed on the drillship, as well as the main propellers and thrusters of the boat. Additional noise is generated through movements of ships and helicopters. Noise is also generated during the installation of long-term or temporary fixed structures. Moreover, vessels that transport different equipment (such as parts of the platforms) to the location generate short-term noise.

8.1.1.5 Discharge of Drilling Mud and Well Cuttings

During the initial drilling of a wellbore, well cuttings, sea water, and excess cement slurry are discharged on the seabed (at the end of cementing of a string of casings – drive pipes). Cement slurries consist of water, cement mixture, and additives, some of which are used also in water-base drilling muds. Most of this material deposits within an area of a diameter ranging from several meters to several tens of meters around the well, where deposits of not more than several centimetres to several tens of centimetres are created (Neff 2005).

After marine risers have been installed, it is possible to return the drilling mud with well cuttings from the well to the drilling platform, where it is processed by means of surface equipment for the extraction of solid particles (vibrators with shale shakers, drilling mud cleaners, centrifuges). Well cuttings are discharged into the sea, while the drilling mud is re-injected into the well by means of a set of drilling tools (drilling mud circulation), and this procedure is repeated until all characteristics of the drilling mud have worsened to such an extent that it is also discharged into the sea. During drilling, well cuttings are almost continuously being discharged into the sea. The cuttings are of irregular shape, while their size ranges from the size of clay particles (< 2 μm) to the size of coarse gravel (> 30 mm). Discharged well cuttings have a tendency to quickly sink to the bottom within a radius of several hundred meters, while the discharged drilling mud can disperse several kilometres, thus creating a thin layer or even a layer of immeasurable thickness (Neff 2005). Depending on the intensity of sea currents in the observed area, the drilling mud is likely to be dispersed over a wider area, with only larger well cuttings depositing in the vicinity of the well location.

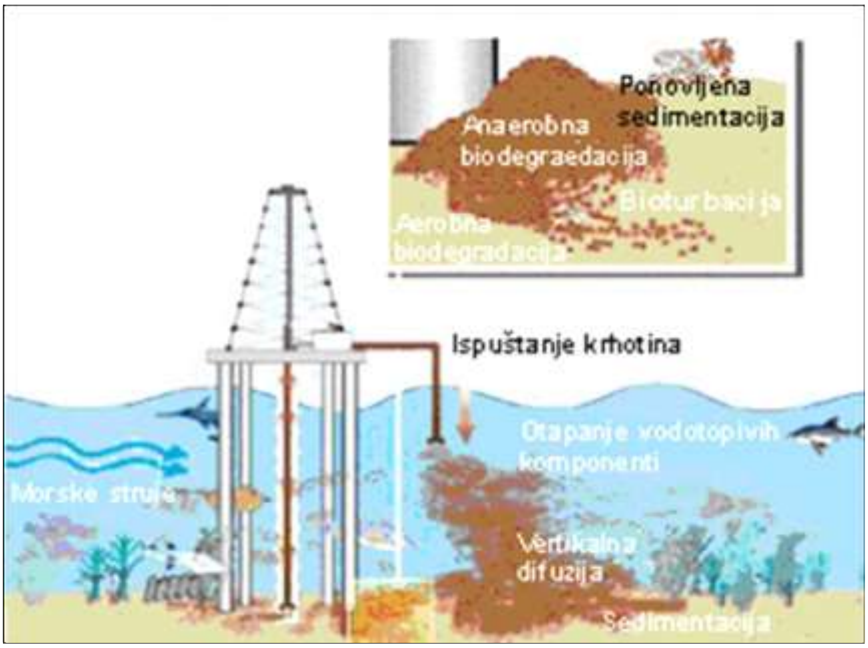
In the deposits on the seabed around the well, there may be an increase in the concentration of barium (barium sulphate), which is added to the drilling mud for a specified purpose of increasing its density, being at the same time also the main insoluble component of the discharged drilling mud. The concentrations of most metals in the drilling mud are similar to those present in sea sediments, but the concentrations of some metals (e.g. cadmium, copper, lead, mercury, and zinc) can be higher within several hundreds of meters from the well location (Boothe & Presley 1989).

Water-base drilling muds are usually of low toxicity. Drilling muds used during offshore operations must have lethal concentration (LC50) below 30 000 pm before they are discharged. For example, KCl/polymer drilling mud has a LC50 of 58 000 to 66 000 ppm, lignosulfonate drilling mud of 283 500 to 880 000 ppm, and bentonite suspension of over 1 000 000 ppm (Gaurina-Međimurec 2009). However, the bioaccumulation of heavy metals has been recognised as a major problem recently (Gbadebo
A.M. *et al.* 2000; Neff 2002).

Discharged well cuttings are most visible in the radius of 500 m of the platform, while in certain cases they have been observed at distances from 2 to 3 km (Survey conducted in the Gulf of Mexico at depths of 1000 m, Continental Shelf Associates, Inc. 2006).

When oil-base drilling muds are used, well cuttings separated from the oil-base drilling mud on the platform (together with small quantities of the oil-base drilling mud which remains on them) may not be discharged into the sea due to their toxicity, while the oil-base drilling mud itself is recycled and reused during the execution of a new well. Accumulations of well cuttings from an oil-base drilling mud can have a three-way impact on the local ecosystem:

suffocation of organisms, direct toxic impact, and anoxic conditions caused by microbiological degradation of organic components (Davis *et al*. 1984; Melton *et al*. 2004; Neff 2005). Picture 8.3 shows the impact of the discharge of well cuttings from oil-base drilling muds into the sea. During the execution of exploration and development wells in the Adriatic Sea, no oil-base drilling muds are expected to be used, for which Chapter 10 of this Strategic Study provides an appropriate measure.



Picture 8.3 Impact of the discharge of well cuttings from oil-base and synthetic-base drilling muds into the sea (Melton *et al*. 2004)

If during drilling a synthetic-base drilling mud is used for the flushing of a wellbore, only well cuttings and a small percentage of the synthetic-base drilling mud which has remained on them will be discharged into the sea. The synthetic-base drilling mud itself is not discharged into the sea, but recycled and reused during the execution of a new well. Well cuttings separated from a synthetic-base drilling mud are prone to accumulate, and they quickly sink in the vicinity of the well, usually within a radius of several hundred metres (Neff *et al*. 2000; Melton *et al.* 2004) (Picture 8.3). The behaviour of well cuttings from a synthetic-base drilling mud differs somewhat from the behaviour of well cuttings from a water-base drilling mud (Neff *et al*. 2000). Cleaned well cuttings from a synthetic-base drilling mud usually contain around 10% of synthetic compounds (Neff *et al*. 2000).

By developing the technology to clean well cuttings, the concentration of synthetic compounds on cuttings can be reduced to below 5%, so that such cuttings disperse and sediment in a larger area, thus preventing the creation of cutting accumulations and speeding up biodegradation (Getliff *et al*. 1997). Surveys conducted by Continental Shelf Associates, Inc., (2006) show that in the area the disposal of well cuttings from a synthetic-base drilling mud is related with an increased concentration of organic carbon in aerobic conditions. Changes arise mostly in the area of approximately 500 m around each drilling platform and can last several years.

In general, for the disposal of the drilling mud and well cuttings, different methods can be used, namely: discharge into the sea, transport to the mainland and onshore disposal, and injection into wells (Gaurina-Međimurec 2014). The selection of the method depends on technological, economical, and ecological parameters. Although each method has its advantages and disadvantages, the discharge of waste into the sea or ocean represents the easiest and cheapest way to dispose of the drilling mud and well cuttings, and therefore efforts are being made for all components of the drilling mud to be ecologically acceptable (Gaurina-Međimurec & Krištafor 2005). On the occasion of discharging the drilling mud and well cuttings into the sea, it is necessary to determine their potential environmental impact in order to establish whether the discharge is a suitable method to dispose of the drilling mud and well cuttings on a certain location. The data which need to be known prior to waste discharge are: water depth, distance from the shore, sea conditions (wind, waves, sea currents), chemical and physical properties of the drilling mud and well cuttings, and the presence and sensitivity of biological communities in the area where the drilling mud and well cuttings are planned to be discharged.

8.1.1.6 Discharge of Other Wastewaters

Other routine discharges during exploration drilling usually include treated wastewaters and municipal waste. The MARPOL Regulations apply to the such discharges. Sewage and sanitary waste comprises toilet waste. Sanitary waste is treated by means of a sanitary appliance which produces effluent with a minimum remaining chlorine concentration of 1.0 mg/L and without visible floating solid particles or oil and fat. The sludge resulting from wastewater treatment is transported to the shore to be disposed of in an approved facility. Municipal wastewaters, which include water from showers, wash-basins, laundry-room and ship kitchen, safety showers, etc., do not have to be treated before discharge. Work boats are equipped with an approved offshore sanitary appliance. Waste foods are ground down before being discharged, in compliance with the MARPOL requirements. Sanitary and municipal wastewaters from the drilling platform and work boats can have impact on the concentration of suspended solids, nutrients and chlorine, as well as on the biological oxygen demand (BOD).

Drainage from the deck covers all wastewaters resulting from precipitation, plant washing, deck washing, tank cleaning, and drainage of pavements and gutters, including capping and working space. Platforms are designed in such a way as to prevent the run-off and discharge of oily drainage. The flow is redirected towards separation systems, depending on the area where has been collected There is no discharge into the drainage from the deck of free oils which could cause a film, glow, or change in the colour of the water surface, or deposition of emulsions or sludge below the water surface. Only non-oily water (<15 ppm oil in the water) is discharged into the sea. If the deck is contaminated, the oily drainage from the deck is retained by means of absorbents or collected in a pollution pan, which is located below the rig floor, for the purpose of recycling and/or disposal. Since the water from the oily areas is separated and treated before being discharged, the drainage from the deck is not expected to produce a visible glow or any other noticeable impact on the water quality. The volume of deck drainage varies depending on the quantity of precipitation. Under the assumption that a typical area of a drillship is 10 000 m2 and that the maximum monthly precipitation is around 100 mm, the monthly average deck drainage would be 1000 m3. The volume of water used for deck washing can amount approximately to additional 200 l a month.

Different additional discharges usually occur from a number sources on drilling platforms. Some of the examples are unpolluted freshwater and saltwater used for water cooling and ballast, desalination unit discharges, BOP fluid discharges, and boiler blowdown discharges (USEPA 1993). Drilling platforms and work boats must meet the MARPOL requirements, including the provisions related to wastewaters, waste from the food, oily waste, and garbage. Discharged wastewaters are expected to quickly dilute in the open sea. The impact will probably be immeasurable after about ten metres from the discharge point. Accordingly, it can be concluded that the wastewaters will be similar to those from other vessels in the observed area.

8.1.1.7 Waste Materials

Petroleum operations generate waste, including paper, plastic, wood, glass, and metal waste, i.e. marine debris. The majority of marine debris is related to ship kitchen and food serving, as well as to operational appliances, such as loading platforms, containers used for drilling muds and chemical additives (sacks, drums, and canisters), and protective coverings used on sacks with drilling-mud additives and on drillpipes (MMS 2007b). Some personal items, such as safety helmets and life-belts, get occasionally lost on the sea by accident. In general, garbage from the ship kitchen, operational garbage, and household garbage are collected and stored on the lower deck, in the vicinity of the loading dock, in large vessels covered by net. Drilling operations require consumables, equipment, and personnel, thus generating more solid waste than production operations. All solid waste generated during exploration drilling in the observed blocks is expected to be transported to the shore by work boats for the purpose of its disposal in approved disposal facilities. On the basis of historical data for a typical drillship, it is expected that around 40 000 kg of solid waste will be generated a month. MARPOL prohibits disposal of waste into the sea; the drilling platforms operate in compliance with the Garbage Management Plan in order to ensure compliance with MARPOL. Moreover, most oil companies has waste management programmes, which apply the principles of waste generation decrease and waste reuse and recycling in order to reduce the quantity of generated waste.

8.1.1.8 WellTesting

If during drilling a hydrocarbon reservoir is discovered, well testing can be carried out. Well testing is a procedure used to determine the formation fluid flow, pressure, permeability, and/or volume of the hydrocarbon reservoir. Usually, a drill stem test (DST) is carried out with tester tools that enable opening and closing of the well at the bottomhole with valves activated on the surface.

The set of tester tools contains one or more manometers measuring and recording pressure changes over time. Pressure recordings are interpreted after the testing and extraction of tester tools from the well. The measurement consists of a flow over a short period of time (5 to 10 min), followed by a period of increased pressure for about an hour, which is used to determine the initial reservoir pressure (static period). The flowing pressure is measured again during the flow period (the second flowing period) in a duration from 4 to 24 hours in order to establish a stable flow towards the surface, if possible, followed by the measurement of pressure increase (the second static period), which is used to determine the permeability and potential flow (Schlumberger 2008a).

If during well testing hydrocarbons are recovered to the surface, they are flared. Hydrocarbon flaring releases emissions into the atmosphere. Gas resulting from testing is either flared or discharged directly into the atmosphere. The table below shows examples of potential pollutant emissions into the air as a result of flaring of 795 m3 of oil and 707 921 m^3 of gas (MMS 2008).

Table 8.1 Estimated pollutant emissions into the air during well testing

Source	Emissions (tonnes)				
	CO	NOx	Suspended particles	SOx	Volatile organic compounds
Oil 795 m^3	0.48	4.53	0.95	15.49	0.03
Gas 707 921 m^3	4.41	0.81	---	0.01	0.68
Total	4.89	5.34	0.95	15.50	0.71

Apart from the atmospheric emissions as shown in the table, crude oil flaring may result in incomplete combustion and falling of non-combusted oil drops onto the sea surface. Creation of a visible glow on the sea surface would represent a violation of the water quality standards, and should therefore be avoided.

8.1.1.9 Accompanying Activities

During exploratory drilling, work (service) boats and helicopters provide support from an onshore base. Croatian ports have a potential to organise a logistics centre for hydrocarbon exploration, which will cover all the services necessary for operators dealing with oil and gas exploration in the Adriatic. They will streamline the supply process cost of hydrocarbon exploration in the Adriatic and at the same time provide for the application of the highest environment and nature protection standards. Typical functions/requirements of an onshore base are: docks used for the loading/unloading of the equipment and machinery necessary for offshore operations; dispatching of the personnel and equipment; temporary storage facilities for the material and equipment; and a 24-hour dispatcher. A typical project includes two work boats making at least one return trip a day between the onshore base and the drilling platform. The most frequent types of service boats for exploratory drilling are crew boats (about 34 m long and used to transport personnel to and from the drilling platform) and supply boats (about 55 m long and used to transport equipment and supplies for the platform). Other vessels that may be used include tugs, which provide support with the distribution of anchors for conventionally moored semisubmersibles. Helicopters provide additional support to offshore oil and gas exploration. Typically, a helicopter will be used for personnel transport, security, emergencies, etc. It is assumed that a helicopter would make two circular trips a day. At the moment, it is not know from which aerodrome the helicopters will take off. Work boats and helicopters normally take the shortest route between the platform location and the onshore base, as permitted by time and traffic.

8.1.2 Hydrocarbon Production Phase

In the observed blocks, different drilling and production platforms may be used; their selection depends on a range of parameters, such as water depth, reservoir type, vicinity of an existing oil and gas infrastructure, etc. The following platforms may be used: jacket platforms fixed to the seabed, tower platforms fixed to the seabed, dynamically positioned hydrocarbon production, storage and offloading units, or subsea systems remotely controlled from platforms located in the shallow waters or onshore. Operations necessary to start the production of discovered hydrocarbons usually require more than seven years (Regg *et al*. 2000). The production phase includes also the drilling of development wells. Development wells can be executed, depending on the water depth, from fixed platforms or mobile units, such as semisubmersibles or drillships (either anchored or dynamically positioned). The number of wells that may be drilled from one platform depends on the type of the production structure used, on the reservoir size, and on the drilling/production strategy. The execution of exploration wells has already been described. The execution of development (production) wells is a similar process, except that it usually takes less time. The execution of a development well usually takes 40 to 60 days in relation to the execution of an exploration well, which usually takes 70 to 90 days (Regg *et al*. 2000), including its completion. On a production platform, oil and gas are processed and prepared for transport, which includes: fluid/gas separation, dehydration, acid gas removal, and gas compression. The offloading (transport) of gaseous and liquid hydrocarbons, as well as of the produced water (to the platform where it is treated before being discharged into the sea) is conducted by subsea pipelines, which can be buried or laid on the seabed. Depending on their intended use, subsea pipelines can be: (1) flowlines/local pipelines (from the production well to the subsea well manifolds and to the production and/or compression platform, as well as between the production platforms), and (2) offloading pipelines/trunk lines (from the production and/or compression platform to the mainland or to the seagoing vessel, etc.). After offloading oil or gas to the shore, these components can require further processing in facilities such as petroleum refineries, gas processing plants, or petrochemical plants. The need for such onshore processing plants, if any, is not established in this phase.

8.1.2.1 Installation of a Production Platform and Pipelines

During the installation of production facilities, the seabed area may be occupied, a negative impact on benthic (demersal) organisms may occur, and the saltwater may become turbid. The total occupied seabed area during the installation of a typical platform is estimated to 2 ha (MMS 2007b). Spars and subsea facilities usually impact smaller seabed areas. The actual impact of the installation of production facilities will depend on the type of the facility selected for an individual project. The following activities can have an impact on the environment during the installation of a platform which is fixed to the seabed:

- Towing of components to the location;
- Installation of structures on the seabed, including foundation templates, platform jackets, manifolds, wellheads, flowline sleds, umbilical termination units, and other equipment;
- Driving of pilots or anchor pilots into the seabed (e.g. by means of a hydraulic hammer);
- Anchoring of barges during the installation of the facility;

- Discharging of wastewaters, pollutant emissions into the air, and noise from barges and tugs used during the installation of the facility.

The installation of pipelines for each individual project takes from several weeks to several months. It is assumed that the pipe laying barges will install pipeline(s), with the assistance of supply vessels and the crew boat/work boat, along the pre-determined corridors (routes). Parts of pipelines are welded together and laid on the seabed as the barge is moving along the pipeline route. Pipe laying barges can be anchored (using anchors to keep their position) or dynamically positioned. As to pipelines leading from wells to production platforms which are located in the deep waters, pipe laying by means of a conventionally anchored barge is limited to those parts of the pipeline route which are in the waters up to 300 m
deep. If a dynamically positioned barge is used to lay parts of the pipeline, the impact of the anchoring along those corridors is to be avoided.

8.1.2.2 Presence of a Production Platform and Subsea Pipelines

Unlike drilling platforms, production platforms usually remain at the same location 20 to 30 years, i.e. until a decision on the discontinuation of production has been adopted.

8.1.2.2.1 Drilling and Platform Operations

Operations include borehole casing, cementing, perforating, pumping, pipe laying, pile driving, and ship and helicopter support. The noise generated during production is less than the noise during drilling. Hydrocarbon production can generate received levels as high as 135 dB re 1 μPa at 1 km from the source (Greene & Moore 1995), which suggests source levels as high as 195 dB re 1 μPa at 1 m, with peak frequencies at 40–100 Hz (Reynolds 2005). The noise generated by vessel engines and propellers is similar to the noise generated by the regional maritime transport.

8.1.2.3 Discharge of Drilling Mud and Well Cuttings

Potential impacts of the discharge of the drilling mud are, in terms of quality, similar to the ones described in Chapter 8.1.1.5. It is to be expected that in the production period, several wells will be drilled in each block, so that the quantities of the drilling mud and well cuttings which will be discharged into the sea will be larger. Consequently, the seabed area where the drilling mud and well cuttings will deposit will be many times larger than in the exploration period. This will result in changes of seabed outlines and of the concentration of barium and other metals. These changes arise mostly in the area of approximately 500 m around each drilling platform.

8.1.2.4 Discharge of Produced Water and Other Wastewaters

The discharge of wastewaters during hydrocarbon production, with the exception of the waste generated during the execution of a development well (drilling mud and well cuttings), encompasses other types of waste, as well. These are: produced water, formation treatment fluids (stimulation fluids), and fluids used during the completion and workover of production wells (workover fluids). Sanitary, municipal, and drainage waters are addressed in Chapter 8.1.1.6.
Produced water is water obtained on the surface during hydrocarbon production which frequently makes the largest volume of the wastewater discharged into the sea. The quantity of the discharged produced water can vary significantly from field to field, but also during hydrocarbon production in a single field. In general, in the initial production period, the share of produced water in the recovered liquid is small; during production, it increases up to the maximum quantity in the last production phase, when even 95% of water can be produced in relation to only 5% of oil. During the production life-cycle of the field, even 10 times as much produced water can be produced as oil. Accordingly, the quantities of produced water discharged into the sea may vary, depending on the reservoir age, type of the recovered hydrocarbon, quantity of the water needed for injection, and capacity of the produced water treater on the production platform. After passing through treaters, the produced water from the production platform is discharged into the sea through submerged caissons. The discharge rate is usually between 0.3 and 23 835 m3/d (2007b).
For example, the present quantity of the recovered produced water on Ivana A production platform amounts to around 250 m^3/d, on Ika A production platform to around 200 m^3/d, and on Marica and Katarina production platforms to around 30 m^3/d (Ecoina 2013). The concentration of total oils in untreated produced water from the recovered natural gas from reservoirs in "Northern Adriatic" and "Marica" production fields
is 2 to 9 mg/L (one-time measurement) and meets the requirements of the Protocol for the Protection of the Mediterranean Sea against pollution resulting from exploration and exploitation of the continental shelf and the seabed and its subsoil, which provides limit values of up to 100 mg/L (one-time measurement) and 40 mg/L (monthly average). Measurements have also shown that the recovered untreated produced water, pursuant to HRN EN ISO 11348-2:2000 method (Determination of the inhibitory effect of water samples on the light emission of *Vibrio fischeri*) is not toxic (Ecoina 2013). Chemical properties of the produced water discharged into the sea from eight production platforms in the Gulf of Mexico, in the period from April 2003 to May 2005, are shown in Table 8.2 (Veil *et al*. 2005). Recovered produced water contains different chemicals (inorganic salts, metals, organic compounds, and radionuclides) which are dissolved from reservoir rocks where it was for millions of years. The salinity (concentration of total dissolved solids – TDS) of the produced water from subsurface reservoirs is mostly higher than the salinity of the saltwater. Special chemicals can be added to the produced water during its treatment.

Table 8.2 Chemical properties of the produced water (Veil *et al*. 2005)

Parameter (unit of measurement)	Concentration			
	Low	**Medium**	**Maximum**	**Minimum**
Biochemical oxygen demand (BOD) (mg/L)	957	583	11 108	80
Dissolved BOD (mg/L)	498	432	1128	132
Suspended BOD (mg/L)	76	57	146	16
Total organic carbon (TOC) (mg/L)	564	261	4880	26
Dissolved TOC (mg/L)	216	147	620	67
Suspended TOC (mg/L)	32	13	127	5
Nitrates (mg/L)	2.15	1.15	15.8	0.60
Nitrites (mg/L)	0.05	0.05	0.06	0.05
Ammonium (mg/L)	74	74	246	14
Total nitrogen (mg/L)	83	81	216	17
Orthophosphates (mg/L)	0.43	0.14	6.6	0.10
Total phosphorus (mg/L)	0.71	0.28	7.9	0.10
Conductivity (IS/cm)	87 452	86 480	165 000	360
Salinity (g/L)	100	84	251	0
Temperature (°C)	38	32	80	20
pH	6.29	6.50	7.25	1.77

After being discharged, the produced water is quickly diluted, usually 30 to 100 times in several ten meters (OGP 2005). At a distance of 500 to 1000 m from the discharge point, the dilution factor is 1000 to 100 000 or more.

Completion and workover fluids are used in production wells during mining operations which are executed for the purpose of maintaining or improving the baseline and well capacity. For completion, aqueous salt solutions (e.g. $CaCl_2$ aqueous solution) are used as fluids to flush the drilling mud from the wellbore and thus prevent damages to reservoirs. Excess fluids related to well completion and workover can be discharged into the sea. Potential major pollutants are: oils and fats, metals, and different organic compounds (USEPA 1993). Before they are discharged into the sea, fluids circulating through the well are centrifuged in order to remove all remaining hydrocarbons. Smaller additional quantities of wastewater can come from different sources, such as: desalinisation unit wastewater, BOP fluid, boiler cleaning wastewater, excess cement slurry, and unpolluted freshwater and saltwater.

Formation treatment fluids (stimulation fluids) are injected into a reservoir in order to remove damages to reservoir rocks and increase well capacity; they consist of inhibited acids and oil-base solvents (USEPA 1993) and may not be discharged into the sea.

During production, produced sand will also occur as waste. The term produced sand refers to suspended solid particles, which are brought to the surface after hydraulic fracturing, accumulated formation sand, and other particles, including scale generated during production (MMS 2007b). This waste includes also sediments created in the formation water treatment system, such as solid particles removed from the liquid during filtration. Formation sand is transported to the shore and disposed of as non-hazardous waste. Estimated, totally generated quantities of the formation sand on a production platform can range from 0 to 5.56 m^3/d (USEPA 1993).

8.1.2.5 Waste Materials

All solid waste generated during hydrocarbon production is transported to the shore and handed over to a legal person authorised for its disposal. In general, in the course of production, less solid waste is generated than during drilling. On the basis of historical data for a typical drillship, it is expected that around 40 000 kg of solid waste will be generated a month (including household waste, waste oils, oil/petrol filters, absorbents, oily water, paperboard, plastic, paper, batteries, wood, etc.). MARPOL prohibits disposal of garbage and waste into the sea; the drilling platforms operate in compliance with the Garbage Management Plan in order to ensure compliance with MARPOL. Moreover, most oil companies has waste management programmes, which apply the principles of waste generation decrease and waste reuse and recycling in order to reduce the quantity of generated waste.

8.1.2.6 Pollutant Emissions into the Air

Plants on the platform are usually propelled by diesel engines or gas engines emitting air pollutants: CO, NO_X, SO_X, suspended particles, volatile organic compounds (VOC), and greenhouse gases, such as CO2 and CH4. Work boats and helicopters will also emit pollutants into the air resulting from the combustion of diesel oil (boats) and aircraft fuel (helicopters). Table 8.3 indicates estimated pollutant emissions into the air during the execution of a typical development well and the operation of a production platform (MMS 2007b).

Table 8.3 Estimated pollutant emissions into the air during the execution of a typical development well and the operationof a production platform (MMS 2007b).

Source	Emissions (tonnes/year)				
	CO	NOx	Suspended particles	SOx	Volatile organic compounds
Execution of a development	5.2	19.5	0.54	2.3	1.9
Operation of a production platform	47.3	40.0	0.41	1.8	18.8

8.1.2.7 Accompanying Activities

During exploratory drilling, work (service) boats and helicopters will provide support from an onshore base. Croatian ports have a potential to organise a logistics centre for hydrocarbon exploration, which will cover all the services necessary for operators dealing with oil and gas exploration in the Adriatic. They will streamline the supply process cost of hydrocarbon exploration in the Adriatic and at the same time provide for the application of the highest environment and nature protection standards. A typical project includes two work boars making at least one return trip a day between the onshore base and the platform. Moreover, a helicopter will be used to transport personnel and, where necessary, equipment urgently required for the plant. It is assumed that a helicopter would make two circular trips a day. At the moment, it is not know from which aerodrome the helicopters will take off. Work boats and helicopters normally take the shortest route between the platform location and the onshore base, as permitted by time and traffic.

8.1.3 Mining Plant and Facility Removal Phase

Decommissioning is a process of dismantling production and offloading facilities and of restoring the area where production took place in compliance with the requirements of the concession and/or regulations. In compliance with the Mining Act (OG 56/13 and 14/14) (Title IV: LAND REHABILITATION), each mining economic entity shall execute rehabilitation of the land where mining activities were carried out. If the concessionaire does not execute rehabilitation or the successive rehabilitation of the land where the mining activities were carried out, pursuant to the verified mining project on the basis of which the concession has been granted, the body competent for mining affairs which granted the concession shall order the implementation of the rehabilitation activities within appropriate time. If the concessionaire does not execute the rehabilitation, this will be done by a third party, and costs will be borne by the concessionaire. Land rehabilitation is carried out by taking all necessary measures to prevent any threat to people, property, and environment.

For the removal of production wells, different methods can be used (MMS 2005a) and they can be generally divided into explosive and non-explosive ones. At this moment, it is not known which method will be used for the removal of production platforms in the Adriatic. The application of the selected method can be managed by divers, remotely operated vehicles, or from the surface.

When selecting the method in which operations will be executed, due account should be taken of the size and type of the facility, water depth, efficiency, potential environmental impact, and weather conditions. For subsea pipelines, the most common international practice is to abandon them and leave them on the seabed (Scandpower Risk Management Inc. 2004). Before they are abandoned, pipelines are completely cleaned up to an immeasurable level of hydrocarbons. In certain cases, after pipelines have been completely cleaned, pipes can be used as scrap iron.

Before removing the platform, containers, process equipment, and pipelines have to be flushed and cleaned from any remaining hydrocarbons. The removal of platform equipment includes cutting of pipes and cables between deck modules, module separation, installation of padeyes (on the deck) to fasten loads during the lifting of modules, and fixing of the structure. Deck elements are removed in the reverse order to the one applied during their installation (http://www.rigzone.com/).

8.2 Environmental goals and indicators for the impact assessment

Table 8.4 Select environmental goals of the FPP and source programme documents from which they originate

Environmental goals	Programme document on the EU, international or national level from which the goal originates*
Good environmental status of the sea and seabed	• International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) • Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention), 1976 • United Nations Convention on the Law of the Sea (UNCLOS) 1982 • Directive 2013/30/EU on safety of offshore oil and gas operations • Water Framework Directive (2000/60/EC) • Marine Strategy Framework Directive (2008/56/EC) • Water Management Strategy (OG 91/08) • Contingency Plan for Accidental Marine Pollution (OG 92/08)
Good environmental status of marine species and habitats, with special emphasis on cetaceans, turtles, fish, invertebrates and birds	• Convention on Biological Diversity, 1992 • Convention on the Conservation of Migratory Species of Wild Animals (CMS) 1979 • The Habitats Directive (92/43/EEC) and the Birds Directive (2009/147/EC) (Natura 2000) • Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention), 1976 • Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1975 • Convention on the conservation of European wildlife and natural habitats (Bern Convention)
Protected subsea cultural heritage and natural landscape	• Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention), 1976 • Spatial Development Strategy of the Republic of Croatia (OG 76/13) • Maritime Development and Integrated Maritime Policy Strategy of the Republic of Croatia for the period from 2014 to 2020 (OG 93/14)
Programme implementation in alignment with other economic activities	• Spatial Development Strategy of the Republic of Croatia (OG 76/13) • Maritime Development and Integrated Maritime Policy Strategy of the Republic of Croatia for the period from 2014 to 2020 (OG 93/14) • Strategy for the Development of Tourism in the Republic of Croatia by 2020 (OG 55/13) • National Strategic Plan for Development of Fisheries, 2013 • Directive 2014/89/EU establishing a framework for maritime spatial planning
Maintaining current air quality and climate conditions	• Stockholm Convention on Persistent Organic Pollutants, 2001 • Vienna Convention for the Protection of the Ozone Layer, 1985 • United Nations Framework Convention on Climate Change (UNFCCC), 1992
Maintaining human health and quality of life	• Convention for the Protection of the Mediterranean Sea Against Pollution (Barcelona Convention), 1976 • United Nations Convention on the Law of the Sea (UNCLOS) 1982 • United Nations Framework Convention on Climate Change (UNFCCC), 1992 • Stockholm Convention on Persistent Organic Pollutants, 2001 • Vienna Convention for the Protection of the Ozone Layer, 1985 • Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991) • Convention on the Transboundary Effects of Industrial Accidents (Helsinki, 1992) • Directive 2013/30/EU on safety of offshore oil and gas operations • Water Framework Directive (2000/60/EC) • Maritime Development and Integrated Maritime Policy Strategy of the Republic of Croatia for the period from 2014 to 2020 (OG 93/14) • Water Management Strategy (OG 91/08) • Contingency Plan for Accidental Marine Pollution (OG 92/08)
Reduced risk of accidents	• Directive 2013/30/EU on safety of offshore oil and gas operations • Contingency Plan for Accidental Marine Pollution (OG 92/08) • Convention on Environmental Impact Assessment in a Transboundary Context (Espoo, 1991) • Convention on the Transboundary Effects of Industrial Accidents (Helsinki, 1992) • Maritime Development and Integrated Maritime Policy Strategy of the Republic of Croatia for the period from 2014 to 2020 (OG 93/14) • Water Framework Directive (2000/60/EC)

Goals are most commonly defined at the level of the EU or the national level, therefore this table lists only those programme documents that define the goals at the highest possible level, assuming that lower level programme documents, as well as legislation, are aligned with the goals of the programme documents concerned.

8.3 FPP implementation impact assessment

8.3.1 Impact assessment methodology

On the basis of data on current status and projected status of individual indicators after FPP implementation, the following subchapters give the expected status and indicator trends which form the basis for assessment of potential improvement/deterioration of status, as well as the extent of impact. These data are used to determine the FPP's contribution to environmental goals.

Table 8.5 Methodology table for the assessment of impact on respective environment components

Affected component	Criteria for definition of impact levels
Chemical properties	**Negligible negative impact** The impact of FPP implementation is negligible if: - the FPP will not be implemented, or no impact on chemical properties of the marine environment has been established in the impact assessment **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - all stages of the FPP are implemented with the attached Licensee's planned Activity and Exploration Programme, in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network were previously carried out in accordance with applicable regulations. The assessment defines the acceptable limits of alterations in the marine environment's chemical properties. **Unacceptable negative impact** The impact of FPP implementation is significant if: - all stages of the FPP are implemented without a Licensee's Activity and Exploration Programme, in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network were carried out in accordance with applicable regulations, and operations are carried out without supervision, or the chemical properties of the marine environment are altered beyond the defined acceptable limits as a result of FPP implementation. No actual and feasible mitigation measures exist for the impacts above which could reduce the impacts to a negligible level.

Climate characteristics – air	**Negligible negative impact** The impact of FPP implementation is negligible if: - the design of technological processes and accompanying activities prevents emissions of pollutants (CO, NO_x,SO_x, airborne particles, greenhouse gases - CO_2 and CH_4) into the air. --- **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - the design of technological processes and accompanying activities results in emissions of pollutants into the air within acceptable limits. Actual and feasible mitigation measures exist for the impacts above and are able to reduce the impacts to a negligible level. --- **Unacceptable negative impact** The impact of FPP implementation is significant if: as a result of technological processes and accompanying activities, no protection measures can be prescribed to reduce the emissions of pollutants to acceptable limit values. No actual and feasible mitigation measures exist for the impacts above which could reduce the impacts to a negligible level.
Noise	**Negligible negative impact** The impact of FPP implementation is negligible if: - the FPP is implemented with an established noise dispersion model which defines the upper tolerance limits of noise levels --- **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - the level of noise established in the noise dispersion model exceeds the upper tolerance limit. Actual and feasible mitigation measures exist for the impacts above and

	are able to reduce the impacts to a negligible level. **Unacceptable negative impact** The impact of FPP implementation is significant if: - the noise produced exceeds the tolerance limit defined in the noise dispersion
Biodiversity	**Positive impact** The impact of FPP implementation is positive if: - implementation of one of the stages of FPP results in development of rare habitat
	Negligible negative impact The impact of FPP implementation is negligible if: - the FPP will not be implemented, or no impact on species and habitats has been established in the Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network carried out in the early stage of project planning in line with the precautionary principle. **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - all stages of the FPP are implemented with the attached Licensee's planned Activity and Exploration Programme, in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network were previously carried out in accordance with applicable regulations. Actual and feasible mitigation measures exist for the impacts above and are able to reduce the impacts to a negligible level, or sufficient data for the impact assessment is not available and needs to be collected through further environmental impact assessment procedures. **Unacceptable negative impact** The impact of FPP implementation is significant if: - all stages of the FPP are implemented without a Licensee's Activity and Exploration Programme evaluated by the bodies competent for environment and nature

Cetaceans and sea turtles	**Significant negative impact** The FPP has significant negative impact if: - fatal injuries occur - permanent hearing damage occurs - the population of a larger area is affected (size, fitness, higher mortality, etc.) - permanent abandoning of locations and changes in use of locations occur - permanent changes in behaviour occur **Negative impact** The FPP has significant negative impact if its implementation causes: - temporary hearing damage (changes in hearing thresholds) - temporarily disabled communication - temporary abandoning of locations - temporary changes in behaviour **Negligible impact** The impact of FPP implementation is negligible if: - there are no changes in population size, behaviour or physical characteristics of cetaceans and sea turtles **Positive impact**

Ecological network	**Positive impact** The impact of FPP implementation is positive if:
	Negligible negative impact The impact of FPP implementation is negligible if: - the FPP will not be implemented, or no impact on the goals of protection of the ecological network has been established in the impact assessment **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - all stages of the FPP are implemented with the attached Licensee's planned Activity and Exploration Programme, in respect of which an Appropriate Assessment of the project impact on the ecological network were previously carried out in accordance with applicable regulations. Actual and feasible mitigation measures exist for the impacts above and are able to reduce the impacts to a negligible level, or sufficient data for the impact assessment is not available and needs to be collected through further appropriate assessment procedures. **Unacceptable negative impact** The impact of FPP implementation is significant if:
Marine and seabed pollution	**Negligible negative impact** The impact of FPP implementation is negligible if: - during and after the exploration or production drilling, levels of pollutants remained within acceptable limits as defined in the legislative regulations. **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - as a result of the exploration or production drilling, levels of pollutants exceeded the acceptable limits as defined in the regulations. Actual and feasible mitigation measures exist for the impacts above and are able to reduce the impacts to a negligible level. **Unacceptable negative impact** The impact of FPP implementation is significant if:
Fisheries	**Positive impact** - implementation of the FPP will increase the share of fisheries in the gross domestic product of the Republic of Croatia **Negligible negative impact** The impact of FPP implementation is negligible if: - implementation of the FPP will not reduce the share of fisheries in the gross domestic product of the Republic of Croatia **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - implementation of the FPP accompanied by the mitigation measures will reduce the share of fisheries in the gross domestic product of the Republic of Croatia

	- implementation of the FPP will reduce the share of fisheries in the gross domestic product of the Republic of Croatia No actual and feasible mitigation measures exist for the impacts above which could reduce the impacts to a negligible level.
Tourism	**Negligible negative impact** The impact of FPP implementation is negligible if: the FPP will not be implemented or the Licensee's Activity and Exploration Programme impact assessment has found that platforms are located so that they do not disturb the scenic view-points or reduce an area's attractiveness for tourism, as they are not visible from land and/or the sea **Negligible negative impact due to impact mitigation measures** - all stages of the FPP are implemented with the attached Licensee's Activity and Exploration Programme, in respect of which procedures of Environmental Impact Assessment was previously carried out in accordance with applicable regulations.
Maritime shipping, maritime transport and waterways	**Negligible negative impact** The impact of FPP implementation is negligible if: - there are no changes in the shipping routes established in the Adriatic and no new routes are introduced. **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - changes are requested to shipping routes established in the Adriatic and the competent bodies in charge of their approval find the requests acceptable Actual and feasible mitigation measures exist for the impacts above and are able to reduce the impacts to a negligible level.
Waste management	**Negligible negative impact** The impact of FPP implementation is negligible if: - waste material generated by the implementation of the FPP does not affect marine pollution, that is, sea water quality and sediment indicators do not exceed the limits set in legislative regulations. **Negligible negative impact due to impact mitigation measures** The impact of FPP implementation is negligible due to impact mitigation measures if: - the quantities of waste material generated by the implementation of the FPP contribute to marine pollution, that is, sea water quality and sediment indicators are outside the limits set in legislative regulations. Actual and feasible mitigation measures exist for the impacts above and are able to reduce the impacts to a negligible level. **Unacceptable negative impact** The impact of FPP implementation is significant if:
Socioeconomic characteristics	**Positive impact** The impact of FPP implementation is positive if it will: create direct financial benefit for the Republic of Croatia through fees for exploration

8.3.2 FPP implementation impact assessment

As the FPP deals with planning on a strategic level, technical solutions and locations of the wells inside the blocks are not yet known. In accordance with the legislation in force, the planning system and practice, more detailed planning/design of final solutions, selection of the best technologies and spatial arrangement of projects is foreseen in the subsequent stages of implementation of the FPP, at which point they will also be subjected to the Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network, which will examine the impacts and prescribe the required impact mitigation measures. This document therefore only indicates the mitigation measures and/or recommendations identifiable at the strategic level.

8.3.2.1 Chemical properties

8.3.2.1.1 Impact of exploratory and production wells on pH value, dissolved oxygen, nutrients and organic matter in the Adriatic

Quantities of formation water discharged into the sea vary depending on the age of the reservoir, the type of extracted hydrocarbons, the quantity of water required for injection and the capacity of the formation water treatment device on the production platform. After treatment, formation water is discharged into the sea through submerged caissons. The rate of discharge is normally between 0.3 and 28,835 m3/d (MMS, 2007b). Produced formation water contains various chemicals (inorganic salts, metals, organic compounds and radionuclides) dissolved from reservoir rocks in which the water has been accumulating for millions of years. The salinity (concentrations of total dissolved solids – TDS) of formation water from subsoil reservoirs is usually higher than in sea water. During treatment of formation water special chemicals may be added to it.

After it is discharged, formation water is diluted very rapidly, typically by 30 to 100 times at a distance of several dozen meters. At a distance of 500 to 1,000 m from the discharge site the dilution factor is 1,000 to 100,000 or higher.

In addition to formation water, well maintenance fluids, sanitary and domestic waste and deck drainage is also discharged into the sea from exploratory and production wells.

One person is considered to produce 100 L/d of sanitary water and 220 L/d of domestic waste water. Sanitary water is estimated to generate 240 mg/L of BOD. Assuming a typical crew on a drilling rig of 130 persons, a drilling rig is roughly expected to produce 13,000 litres of sanitary water per day, resulting in 3.1 kg of BOD, as well as 28,600 litres of domestic waste water per day. The discharged waste water is expected to dissolve rapidly in the open sea (MMS, 2007b).

As it may be concluded from previous monitoring results, the largest fluctuations of sea water dissolved oxygen and nutrient salt concentrations and pH were observed at stations with direct anthropogenic effects; in the immediate vicinity of exploration and production platforms, it may be expected that the values of these parameters will change.

Impact ranking:

Negligible negative impact due to impact mitigation measures as the acceptable limits of alterations in the chemical properties of the marine environment will be defined during the assessment of impact on the environment and the ecological network for precisely delineated types of operations, at which point the exact locations of platforms, the operations performed and their schedule, as well as the technological processes and the quantities of substances discharged into the environment will be defined.

									Synergistic
Impact of exploratory and production wells on pH value, dissolved oxygen, nutrients and organic matter in the Adriatic	-	✓	⊘	✓	⊘	✓	⊘	✓	⊘

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.2 Climate characteristics

8.3.2.2.1 Impact of pollutant emissions into the air

If hydrocarbons are released on the surface during well testing, they are burned off using flares. Hydrocarbon flaring results in atmospheric emissions. Gas extracted during exploration is flared or vented directly into the atmosphere. Table 8.6 gives examples of potential emissions of pollutants into the air from the combustion of 795 m3 of oil and 707,921 m3 of gas (MMS, 2008).

Table 8.6 Estimated emissions of pollutants into the air during well testing

Source	Emissions (tonnes)				
	CO	NOx	Airborne particles	SOx	Volatile organic compounds
Oil 795 m^3	0.48	4.53	0.95	15.49	0.03
Gas 707 921 m^3	4.41	0.81	---	0.01	0.68
Total	4.89	5.34	0.95	15.50	0.71

Pollutant emissions into the air from well testing operations are estimated to have a localized impact on air quality in the vicinity of the well during the testing period (1 to 2 days).

Rigs are usually powered by diesel or gas engines which emit the following air pollutants: CO, NOx, SOx, airborne particles, volatile organic compounds – VOC and greenhouse gases, such as CO_2 i CH_4. Supply vessels and helicopters will also emit pollutants into the air by burning diesel fuel (vessels) or jet fuel (helicopters). Table 8.7 indicates estimated pollutant emissions into the air during the drilling of a typical development well and during the operation of a production platform (MMS, 2007b).

Table 8.7 Estimated pollutant emissions into the air during the drilling of a typical development well and during the operation of a production platform (MMS, 2007b)

Source	Emissions (tonnes/year)				
	CO	NOx	Airborne particles	SOx	Volatile organic compounds
Development well drilling	5.2	19.5	0.54	2.3	1.9
Production platform operation	47.3	40.0	0.41	1.8	18.8

Some of these gases produce various compounds through degradation, and the degradation and transformation products affect global warming. In addition, CO_2 i CH_4 are greenhouse gases and contribute to global warming. Emissions of pollutants into the air from platforms are expected to disperse rapidly into the marine atmosphere.

Air quality may deteriorate within several hundred meters from the drilling rig. However, no noticeable impact on the quality of air along the coast or on land is expected, as the quantities of pollutants are relatively small and are discharged far from the coast. Platforms and supply vessels must comply with MARPOL Annex VI, which sets limits to emissions of sulphur dioxide and nitrogen oxides from vessel exhausts and prohibits intentional venting of substances depleting the ozone layer, including halons and chlorofluorocarbons. MARPOL also sets the limits for nitrogen oxide emissions from diesel engines and prohibits the combustion of certain products, such as contaminated packaging materials and polychlorinated biphenyls. In addition, in accordance with the Regulation on the essential technical requirements, safety and security standards in the exploration and exploitation of hydrocarbons from the Croatian underwater (OG 52/10), licensees and operators are required to ensure that all machinery, equipment and fittings in use comply with the generally accepted standards of the international oil and gas industry, and that they are suitably designed and well maintained.

Due to all of the above, the impact of pollutants on the air during planned FPP operations is estimated as

negligible negative impact.

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term	Medium-term	Long-	Cumulative	Synergistic
Impact of pollutant emissions into the air	-	✓	⊘	⊘	⊘	⊘	✓	✓	⊘

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.3 Noise

8.3.2.3.1 Impact of increased noise

Increased noise occurs during exploratory operations as a result of airgun use, which created high intensity noise that disturbs subsea "peace" and interferes with the normal functioning of animals. The noise produced during drilling of exploratory wells, as well as noises coming from machines which form part of the drilling rig, cause increased noise levels, and the highest levels of noise are generated during well drilling.

During hydrocarbon exploration and production the number of vessels at sea is also higher, which results in increased noise from vessel propulsion systems, as well as cavitation noise. A larger number of vessels implies more sonars that also produce noise. The cumulative impact of all noises created in a certain area during hydrocarbon exploration and production results in increased levels of noise.

Impact ranking:

Negligible negative impact due to impact mitigation measures as the operations planned in the FPP (2D and 3D seismic surveying, drilling of exploratory and production wells, increase in marine traffic and accompanying activities (helicopter traffic) will increase the level of noise from anthropogenic sources. Noise levels will have to remain below the upper tolerance limit defined in the noise dispersion model.

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term	Medium-term	Long-	Cumulative	Synergistic
Noise level	-	✓	⊘	⊘	⊘	✓	⊘	✓	⊘

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.4 Biodiversity

8.3.2.4.1 Marine mammals, sea turtles and cartilaginous fish

8.3.2.4.1.1 Marine mammals and sound

Although they adapted to life in water, marine mammal hearing physiology is similar to the one in terrestrial mammals. At the same time, the anatomy of the hearing apparatus was modified - the pinnae and external auditory canals were lost, the middle and inner ear cavities merged, and the new auditory complex migrated outward, dissociating from the skull (Ketten 1997).

Cetaceans have the broadest range of acoustic sensitivity of any known mammal group (Ketten, 1997). Audiograms were produced for 11 small cetacean species through research on animals in captivity (Au, 1993), and were estimated for several other species on the basis of inner ear anatomy and sounds produced by the animals. The majority of toothed whales (Odontoceti) have functional hearing from 200 Hz to 100 kHz, while some species are able to hear frequencies as high as 200 kHz (Reynolds, 2005). The advantage of using high frequency sounds is the reduced influence of ambient noise which decreases with higher frequencies, and the animals can therefore hear the sounds they produce more easily and more clearly. Baleen whales (Mysticeti) are presumed to hear frequencies between 10 Hz and 20 – 30 kHz (NRC, 2005).

Depending on their size and ecology, cetaceans produce different types of sounds and use different frequencies - broadband and burst clicks, frequency modulated whistles and tonal calls. In general, baleen whales (Mysticeti) produce and use low frequency sounds in the range of 10 Hz to 1 kHz. Smaller toothed whales (Odontoceti) use medium to high frequency sounds ranging from 1 kHz to 200 kHz (Richardson et al., 1995). All species of toothed whales are presumed to use echolocation, although it has been demonstrated only in 11 small species (Au, 1993). Depending on the environment they inhabit, species can be grouped into two types: type 1, inhabiting shallow sea waters and complex environments, such as river estuaries and coastal areas, and using sounds with peak frequencies above 100 kHz, and type 2, using sounds with peak frequencies below 80 kHz and inhabiting open environments (Wartzok and Ketten, 1999). The most common Cetaceans in the Adriatic, *T. truncatus* and *S. coeruleoalba* , are typical representatives of type 2 echolocators.

Toothed whale whistles have lower source levels than their clicks. Source levels for bottlenose dolphins are 228 dB re 1 μPa at 1 m when echolocating in the presence of noise (Au, 1993) and up to 169 dB re 1 μPa at 1 m for whistles (Janik, 2000). The highest sound levels have been measured for sperm whale clicks, which can reach 236 dB re 1 μPa at a distance of 1 m (Mohl et al., 2003).

The space in which sounds produced by toothed whales actively propagate can be in the range of 1 km or less to several dozen kilometres (Janik, 2000; Barlow and Taylor, 2005; Janik, 2005; Miller, 2006). Baleen whales most commonly vocalise at frequencies below 1 kHz, and the estimated sound intensity is 180 dB re 1 μPa at 1 m (Richardson et al., 1995).

8.3.2.4.1.1.1 Impact of anthropogenic noise

Acoustic pollution is of special concern for cetaceans as they are highly dependent on sound not only as their main sense, but also in their social interactions and sensory biology (Tyack and Miller, 2002). Effects of anthropogenic noise can range from simple difficulties in detection of sound to disturbance, changes in behaviour, hearing damage, injuries and death. The effect will largely depend on the exposure time, sound pressure and total sound wave energy, as well as their frequency. The development of criteria to assess the impact of noise on cetaceans has been proposed by various researchers. Different criteria are used to establish impact zones and enable the assessment of risks and adoption of impact mitigation measures. At the same time, virtually no measures have been actually tested in the natural environment, which means their efficiency is questionable.

Gordon et al., 2003) group the primary concerns of the effects into five main categories: physical effects (including tissue damage, damage to ears, permanent or temporary threshold shift), perceptual effects (masking of sounds produced or that should be heard by the animal), behavioural effects (disruption of normal behaviour – avoidance of some areas, altered dive patterns, etc.), chronic effects (stress leading to reduced viability and disease) and indirect effects (such as reduced availability of prey).

8.3.2.4.1.1.1.1 Physical damage

In theory, physical injuries can occur when animals are exposed to very high amplitude sounds. Such injuries are similar to blast injuries.

At present there is no evidence that the noise generated by airguns caused acute tissue damage in marine mammals. The rise time of the pressure wave generated by airguns is lower than in the case of explosions, therefore the ability to cause damage to tissues is lower. Nevertheless, due to a number of reasons it is difficult to estimate the mortality related to the transmission and the magnitude of sound pressure waves caused by seismic surveying. Many stranded animals go unnoticed, a large number of carcases are never recovered, and many animals that die at sea never reach the coast. Furthermore, the animals that are found are usually in advanced stages of decomposition, which makes it impossible to identify the subtle lesions caused by noise and barotrauma (Weilgart, 2007; Peltier et al., 2012).

Rapid changes in pressure may cause separation of gases from the blood and formation of bubbles. In cases of mass stranding of animals belonging to species *Z. cavirostris*, low frequency active sonar (LFAS) was identified as the probable cause of lesions which occurred due to gas bubble growth in the tissues of diving animals. The sonar's impact was likely exacerbated by the abrupt ascent of the frightened animals from a great depth, causing embolism to occur (Fernández et al, 2005). It has been estimated that exposure to 500 Hz sounds of 210 dB re 1 µPa could cause bubble growth and decompression sickness in marine mammals, but such effects are unlikely below 190 dB re 1 µPa (Crum and Mao, 1996).

Strandings of Cuvier's beaked whales are the most prominent example, but similar strandings of other species have been documented as well. Sonar-related embolism has been found in tissues of Risso's dolphins, short-beaked common dolphins and harbour porpoises (*Phocoena phocoena*) (Jepson at al, 2005), which indicates that not only deep divers are affected by noise. Noise could therefore have a more widespread impact than previously considered.

High-intensity, impulsive blasts can damage cetacean ears (Ketten et al., 1993). Exposure to high intensity noise causes a shift in the threshold of hearing sensitivity. Depending on the sound power spectrum, the animal's sensitivity and the duration of exposure, this shift can be permanent (PTS) or temporary (TTS). The threshold shift is a result of temporary or permanent damage to sensory hair cells in the inner ear or auditory nerves. In case of temporary shift, normal hearing sensitivity returns after some time. In case of permanent shift, the death of sensory hair cells or damage to nerves is permanent. Hearing damage, TTS and PTS should be considered as serious impact for Cetaceans as they are fully dependant on their acoustic sense. In case of such permanent or temporary injury, their communication with other individuals is impaired and echolocation can be disabled, resulting in poor nutrition, disorientation and stranding, vulnerability to predators, etc.

The construction of new platforms may include pile driving into the seabed. Possible changes in behaviour and vocalisation related to this activity were discussed by (David, 2006). The assessment of potential impact of pile driving on the protected population of common bottlenose dolphins in the Moray Firth Special Area of Conservation indicated that hearing damage occurs at a distance of 100 m (Bailey et al, 2010). The same authors demonstrated that disturbance and other forms of impact on behaviour can occur at a distance of 50 km from the source. A number of other studies showed that pile driving causes behavioural changes in different species of cetaceans (Carstensen et al., 2006.; Thompson et al., 2010.; Dähne et al., 2013.; Pirotta et al., 2014.)

Results of experiments carried out on common bottlenose dolphins in captivity indicate that changes in the behaviour can occur at 178 dB r re 1 µPa (for exposure to 1-second tones at 3, 20 and 75 kHz), while temporary threshold shift was observed at levels of 193 to 196 dB re 1 µPa (for exposure to 1-second tones at 20 kHz) (Ridgway at al., 1997). According to results of several studies, a wide range of exposure durations and sound levels was found to cause temporary hearing threshold shifts in toothed whales (Nachtigall et al., 2003.; Nachtigall et al., 2004.; Mooney et al., 2009). Sound pressure levels of 155 – 160 dB re 1 µPa caused TTS after only 30 minutes of exposure to broadband noise centred around 6 – 7 kHz (Nachtigall et al., 2004.; Mooney et al., 2009.).

Since it is difficult to estimate the impact of short, impulse sound waves, such as airgun blasts, the sound exposure level (SEL) has been developed as a unit of measurement similar to the unit for measurement of energy, and is expressed in decibels, referenced to 1 µPa2-s in water. As threshold shifts depend on both the sound pressure level and duration of exposure, SEL can characterize noise exposure and can be used to assess criteria for acoustic damage in marine mammals (Mooney et al., 2009; Finneran et al., 2010). The lowest sound exposure level required for the onset of TTS in common bottlenose dolphins exposed to short duration tones at 3-kHz is about 195 dB re 1 µPa2-s (Finneran et al., 2005).

Finneran et al. (2011) found no measurable hearing sensitivity threshold shift in three bottlenose dolphins after exposure to 10 sound impulses, produced from a seismic air gun at an interval of 10 s/impulse with a total cumulative sound exposure level of approximately 176 dB e 1 µPa2-s. and one at 195 dB e 1 µPa2-s. The author indicated that lack of TTS could be related to frequency content of the related seismic airgun impulse. An onset of TTS has been found in a harbour porpoise at a sound exposure level of 164 dB re 1 µPa2-s from seismic airgun impulse (Lucke et al. 2009) and in a beluga at a sound exposure level of 186 dB re 1 µPa2-s from a seismic watergun (Finneran et al., 2002).

Although such measurements were mostly obtained from research on captive animals, they are frequently used to estimate safe distances and duration of exposure of cetaceans to noise. Weilgart (2007) pointed out that taking such a small number of research results and extrapolating it to entire populations worldwide is potentially wrong. Cook (2006) found that variations in individual hearing sensitivity can lead to differences of up to 80 dB in the minimum values at which threshold shifts occur, based on hearing tests in 62 common bottlenose dolphins from Sarasota Bay, Florida. In addition, data obtained from captive animals should not be taken as representative of the acoustic properties of the species, since closed environments present completely different physical conditions which influence hearing and vocalisation (Au, 1993). Cook (2006) also found that, in general, captive animals show higher level of hearing impairment than similar-aged wild animals. Finally, food used as reward for captive animals could motivate them to tolerate higher noise levels (Weilgart, 2007).

When considering the impact of noise, it should be noted that theoretical modelling of threshold shifts is unlikely to be able to provide a full view of the impact levels, since the hearing apparatus is just one of several sensitive systems in an animal's body. Frequencies outside the animal's normal range of hearing could have an impact on air-filled cavities due to resonance, and could also cause embolism (Hildebrand, 2005; Weilgart, 2007) An example is the mass stranding of beaked whales in the Bahamas, where animals became disoriented and died although they were not exposed to levels of noise that could cause even temporary threshold shifts. It was found that the sound caused decompression sickness due to a change in behaviour (Jepson et al., 2003). There are indications that seismic surveying along the Galapagos islands also caused mass stranding of beaked whales (Gentry, 2002).

8.3.2.4.1.1.1.2 Masking of sounds

Masking is considered to be the impairment of the ability to detect sounds. As relatively high sound pressure levels are required to generate acute hearing damage in cetaceans, the area around the source where such levels could be reached is relatively small. On the other hand, masking, which occurs at much lower sound pressure levels and over a much larger area, could have a more significant impact on a large part of the population. The ratio of sound level and background noise level at which masking occurs is called the critical ratio (CR). Richardson et al. (1995) summarised the knowledge on critical ratios and showed that mammals can barely detect a sound if the sound level equals the level of background noise in a one-third octave band.

Hearing, that is, the ability to detect sound, is crucial for marine mammals. A very short period of masking, such as a single pulse of sound, or several separated pulses, may not affect populations or individual fitness. However, if impulse sounds are produced repeatedly from many sources over a wide area, they may merge and increase the level of overall background noise (Nieukirk et al., 2004). As a consequence of masking, the animal's ability to communicate and use sound is reduced (Clark et al., 2009). This is particularly important for toothed whales, which rely on low frequency sounds that travel far. For toothed whales, masking is mostly related to high frequency noise sources, such as vessel engines, seismic surveying, construction, etc. (Richardson et al., 1995). To compensate for the impact of sound masking, animals attempt to modify their own signals by changing the frequency or increasing the repetition rate. Such changes could affect the biological and social functions of sound in individual species (Parks et al., 2011). A particular instance where masking could have serious consequence is the impact of masking on the frequency modulated calls and whistles that are crucial for social cohesion and information exchange. The precision of target detection in space also decreases uniformly in the presence of masking noise. A 15–20 dB increase in noise levels caused a drop in accurate target detection from 100% to just 50%, and the animals stopped emitting clicks and started to guess whether the target was in the area not (Au, 1993).

8.3.2.4.1.1.1.3 Behavioural effects

Marine mammals respond to noise in complex and poorly understood way (Richardson et al., 1995). Significant effects of noise may extend to entire populations as a result of widespread exposure. Behavioural responses may range from subtle changes in surfacing and breathing patterns, cessation of vocalization or increased vocalisation, to active avoidance or escape from the region of highest sound levels (Hildebrand, 2005; Weilgart, 2007; Tyack, 2008). Examples of behavioural effects include the abandonment of an important activity (e.g. feeding, nursing) or important habitats. Repeated abandonment of such vital activities can lead to detrimental consequences for the animals affected. As groups of animals have limited and defined home-ranges, moving and displacement can force animals to enter habitats that are not suitable or habitats already occupied by other animals (Nowacek et al., 2007; Weilgart, 2007). Few studies document long-term responses to anthropogenic noise by marine mammals in the Adriatic. Research carried out in Kvarnerić (northern Adriatic) show clear correlation between areas of high anthropogenic pressure and bottlenose dolphin avoidance (Rako et al., 2007). Elevated sea ambient noise and increased number of fast moving recreational vessels resulted in low encounter rates indicating avoidance of noisy areas or change in behaviour (Rako et al., 2012; Rako et al., 2013).

Activities that interfere with normal behaviour of animals or the ability to survive and reproduce may effect the viability of the population. Noise from vessels and seismic surveying could be the cause of low reproductive success of fin whales in the Mediterranean (Castellote et al., 2010). The significance of such activities is often difficult to identify over a short period of time, particularly for animals that have long lifespans and inhabit large areas (Wilson, 1995; Pleslić et al., 2014).

Over time, animals can habituate to noise. Habituation or "non-responsiveness" to noise can be caused by the animals becoming accustomed to noise, or may indicate that the noisy area is important enough for the animal to decide to tolerate the noise. Habituation can lead to hearing loss and increased mortality of animals with impaired hearing (Todd et al., 1996).

Due to the current lack of data on behavioural changes caused by anthropogenic sound, understanding the impact of noise on marine mammals is one of the key research priorities set by the American National Research Council (NRC, 2003).

8.3.2.4.1.1.1.4 Chronic effects

Noise is a known stressor. Long term impact of man-made sounds on populations and ecosystems, either alone or in combination with other stresses, can have impact on rest and sleep or the immune system. The extent of impact of acoustically induced strandings on population mortality is unclear.

Widespread impaired hearing or non-fatal injuries may result in significant impact on populations. Humpback whales exposed to explosions showed little reaction to the noise, yet subsequently an unusual increase in fatal entanglement in fishing gear occurred, possibly because of impaired hearing (Todd et al., 1996). Long term consequences of noise impact are very difficult or nearly impossible to predict. Due to a number of constraints, only short term studies are usually carried out. Such studies may indicate serious impact on populations in some cases, but most of the time subtle changes lead to serious consequences over longer periods of time. For example, Bejder et al. (2006) showed that although the short term response of a local bottlenose dolphin population to dolphin-watching tourism was moderate, the long-term impact was much more evident, clearly relating the disturbance to the noted decline in numbers.

In order to be able to evaluate the potential effects of noise, it is crucial to characterize and monitor marine mammal populations in areas of high-intensity anthropogenic sound, such as oil exploration regions and high intensity development areas (Hildebrand, 2005). Additionally, it is important to identify what is considered a “biologically significant” impact prior to the start of research and monitoring (Weilgart, 2007). Monitoring activities should include the assessment of medium and long-term effects on populations, monitoring of exposure to noise and development of suitable mitigation measures.

8.3.2.4.1.1.1.5 Cumulative and indirect impact

Cetaceans are facing a large number of threats. In the Adriatic they range from habitat degradation, lack of prey, bycatch, direct catch and pollution to global warming. Anthropogenic noise could additionally exacerbate the negative impact of bycatch as sound masking and hearing impairment or damage could prevent the animals from avoiding the fishing gear.

Prey distribution also affects the distribution of Cetaceans (Lusseau et al., 2004). Noise can cause a range of negative responses in fish and cephalopods, which can in turn reflect on Cetaceans. Changes in fish behaviour, changes in schooling patterns and distribution, changes in migration patterns, etc. with longer or shorter spatial and temporal impact have been identified in a number of locations (Popper et al., 2003; Popper et al., 2004; Slabbekoorn et al., 2010; Fewtrell and McCauley, 2012; Løkkeborg et al., 2012; Mooney et al., 2012).

The synergistic impact of different sources of noise should also be considered. Marine traffic, multiple seismic surveys at the same time, military operations, etc. could additionally increase noise levels to critical levels that can cause permanent damage.

8.3.2.4.1.1.2 Zones of impact, mitigation and impact monitoring

In the attempt to describe different types of noise impact, Richardson et al. (1995) considered four zones of impact:

1. the zone of audibility (the area within which the sound is both above the animal’s hearing threshold and detectable above background noise)
2. the zone of responsiveness (the region within which behavioural reactions in response to the sound occur)
3. the zone of masking (the zone within which the sound may mask other biologically significant sounds)
4. the zone of hearing loss, discomfort or injury (the area within which the sound level is sufficient to cause threshold shifts or hearing damage).

Although this approach somewhat simplifies the impact of different levels of noise, zones of influence were previously often used as a framework for assessment. Based on this approach various impact mitigation measures have been developed. When using this approach to regulate anticipated sound levels, it should be taken into consideration that it does not fully describe the known behavioural changes caused by noise (Nowacek et al., 2007; Ellison et al., 2012).

Standard guidelines for minimisation of the risk of injury and disturbance have been developed by the Joint Nature Conservation Committee (JNCC 2010) and have been used in the development and application of a number of other similar guidelines (Weir and Dolman, 2007; Compton et al., 2008). The current version was updated in 2010, but the guidelines have been a subject of significant criticism (Gordon et al. 2003; Parsons et al. 2009) for their "common sense" approach to mitigation as opposed to the use of scientific evidence of proven efficacy. Parsons et al. (2009) listed a number of shortcomings of these guidelines. In particular, they objected the allowed number of airguns, inappropriate consideration of environmental factors and oceanographic features, impact on other species (prey) and finally the lack of institutional, independent monitoring and verification of compliance with the guidelines.

Southall et al. (2007) set additional standards for the development of criteria to describe conditions under which animals are at risk. Thirteen experts in the field of acoustics proposed criteria for the onset of two categories of impact: (1) injury and

(2) behavioural disturbance, along with a set of measurements taking into consideration single pulses, multiple pulses and continuous noise. Cetaceans were categorised into three functional hearing groups: cetaceans detecting low frequency noises in the range from 7 Hz to 22 kHz, cetaceans detecting mid-frequency noises in the range from 150 to 160 kHz and cetaceans detecting high frequency noises in the range from 200 to 180 kHz. For each functional group, criteria was developed for hearing damage, depending on the sound type and the sound pressure and sound energy received. This work established the basis for the development of regulatory guidelines which could be adopted and clearly applied. At the same time even the authors acknowledge that behavioural responses are strongly affected by the environmental conditions in which noise exposure occurred. Therefore environmental conditions should have equal or even greater importance in estimating the exposure severity. Ellison et al. (2012) proposed to develop an additional approach taking into consideration the context of exposure, which should enable more effective management of levels of chronic and acute exposure to noise.

No noise mitigation guidelines have been developed and adopted in Croatia. The impact of noise was never considered in practice, and no mitigation measures were undertaken in relation to any operations causing noise in the sea (seismic surveying, drilling and hydrocarbons extraction, blasting, construction, pile driving, etc). Protective measures taking into consideration the impact of sound on marine mammals have only been introduced once, for seismic surveying carried out in the Adriatic Sea in 2013. These measures were presented as a list of *ad hoc* rules without any scientific elaboration or operative description (MSES 2014), therefore their noise mitigation value was questionable. Based on the draft FPP it is evident that intensive hydrocarbon exploration and drilling/extraction operations are planned. Therefore, prior to commencement of any activities, a serious and well elaborated plan should be laid out for obtaining the missing data, monitoring the condition and mitigating the impacts A good example of responsible practice encouraging responsibility and minimising the impact of seismic surveys have been described by Nowacek et al. (2013).

The most suitable guidelines for use in the Adriatic sea were developed as part of the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic area (ACCOBAMS 2010) which Croatia has committed to implement. In addition, the Joint working group on noise of CMS/ASCOBANS/ACCOBAMS has further elaborated these practical guidelines to provide practical details on the processes for planning, assessing impacts and conducting marine seismic surveys (Joint NWG, 2014). An example method of monitoring the condition and mitigating impacts is provided in the Monitoring and mitigation plan for negative impacts of 4D seismic surveys developed by IUCN Western Gray Whale Advisory Panel (WGWAP) and Sakhalin Energy Company (WGWAP, 2014).

In addition to guidelines for noise mitigation, two new instruments require the development of noise monitoring and reporting on the status of protected species. Their application should also reflect on activities related to noise generated during hydrocarbon exploration and production.

Descriptor 11 (sound/energy) of the Marine Strategy Framework Directive (MSFD) 2008/56/EC requires that introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment. Commission Decision 2010/477/EU on criteria and methodological standards on good environmental status of marine waters (GES), established two indicators for marine waters within Descriptor 11, addressing low and mid frequency impulsive sound and low frequency continuous sound. In particular, it requires the creation of a noise register that should provide information on activities generating loud sounds (Dekeling et al., 2013). The generic source level (SL) threshold for inclusion in the register for non-impulsive sources is 176 dB re 1 μPa at 1 m, whereas the threshold for inclusion of impulsive sources is an energy source level (SLE) of 186 dB re 1 $\mu Pa^2 m^2$ s.

Under the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, parties have adopted the Ecosystems Approach (Decision 17/6) (ECAP) aiming at improving the way human activities are managed for the protection of the marine environment. Eleven Ecological Objectives (EO) are described through operational objectives and indicators for the Mediterranean (Decision 20/4). The parties agreed that EO 11 refers to achieving levels of energy in the environment (including underwater noise) which will ensure that noise from human activities no longer causes significant impacts on marine and coastal ecosystems. Although the ecological objectives were developed in accordance with the EU MSFD, an approach considering an even wider range of frequencies is proposed (ACCOBAMS, 2014).

8.3.2.4.1.2 Sea turtles and sound

The ear of sea turtles appears to be adapted to detect sound in water. The retention of air in the middle ear of sea turtles suggests that they are able to detect sound pressure. Morphological examinations of green and loggerhead sea turtles (Ridgway et al., 1969; Wever, 1978; Lenhardt et al., 1985) showed that the sea turtles have a typical reptilian ear with a few underwater modifications, supporting the proposal that fish hearing, rather than mammalian hearing, is the better model to use for sea turtles until there are much more data. The tympanum, on the surface of the head, is backed by a thick layer of subtympanal fat. The middle ear cavity is connected to the throat by a Eustachian tube (Wever, 1978; Lenhardt et al., 1985). The ossicular bones of the middle ear connect the tympanum to the inner ear. The bones consist of two elements, the columella and the extracolumella. For semi-aquatic turtles, the columella is the main pathway for sound input to the inner ear, and when the columella is clipped while leaving the tympanum intact, the animal displays a substantial decrease in hearing sensitivity (Wever and Vernon, 1956). The auditory sense organ within the inner ear of the sea turtle is the basilar papilla, and also possibly the saccule (Wever and Vernon, 1956). The basilar papilla is positioned opposite the round window and lies within the pathway of fluid displacement that results from motion of the columella in response to vibration of the tympanic membrane.

Electrophysiological studies on hearing have been conducted on juvenile green sea turtles (Ridgway et al., 1969; Bartol and Ketten, 2006; Piniak et al., 2012), juvenile Kemp's Ridleys (Bartol and Ketten, 2006), and on juvenile loggerheads (Bartol et al., 1999; Lavender et al., 2012). Ridgway et al. (1969) obtained an AEP audiogram to aerial and vibrational stimuli that extended from below 100 Hz to 2000 Hz with the lowest threshold at 400 Hz. Other studies using AEPs found similar low-frequency responses to vibrations delivered to the tympanum for the loggerhead sea turtle (Bartol et al., 1999) (Bartol et al., 1999) and to underwater sound stimuli for the loggerhead and green sea turtles (Bartol and Ketten, 2006; Bartol and Bartol, 2011; Lavender et al., 2012).

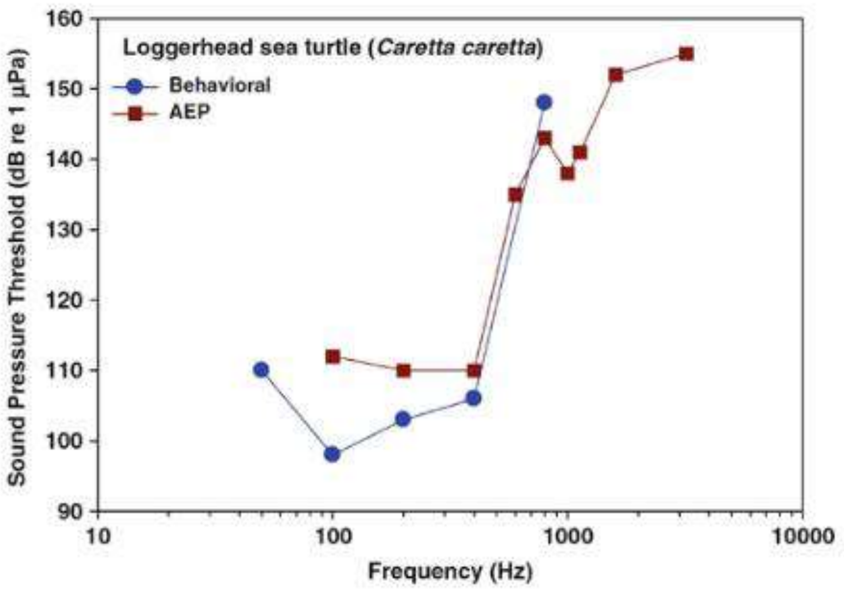


Figure 8.4 Behavioural and auditory evoked potential thresholds in loggerhead sea turtles (source: Martin et al., 2012.)

Martin et al. (2012) measured underwater thresholds in the loggerhead sea turtle by both behavioural and AEP methods. Behavioural sensitivity showed the lowest thresholds between 100 and 400 Hz, with thresholds at about 100 dB re 1 μPa. AEP measurements on the same individual were up to 8 dB higher. However, both techniques showed a similar frequency response and a high- frequency loss of sensitivity above 400 Hz of about 37 dB per octave (Figure 8.4). Other preliminary measures of hearing in sea turtles indicated that the hearing range was 50 - 1200 Hz (Lavender et al., 2012).

8.3.2.4.1.2.1 Effects of anthropogenic noise on sea turtles

Man-made noise may have a diverse range on effect on the animal. Popper et al. (2014a) classify these effects in the following categories: death and injury, effects on hearing, effects on behaviour; and population-level effects on fitness and survival.

8.3.2.4.1.2.1.1 Physical damage

Death and injury can result from exposure to very high amplitude sounds (Carlson and Johnson, 2010). Rapid change of pressure because of impulsive, intense sounds or forced change in depth may cause separation of gases from the blood, which leads to barotrauma (Stephenson et al., 2010; Halvorsen et al., 2011) (Halvorsen et al., 2011; Halvorsen et al., 2012b).

Because of their rigid external anatomy, it is possible that sea turtles are protected from direct mortality caused by impulsive man-made sounds, at least with regard to pile driving and seismic airguns, but the data are lacking (Popper et al. 2014a). It is possible that seismic airgun exposure would mortally injure sea turtles that are very close to the source, although preliminary data suggest that sea turtles are highly resistant to high intensity explosives (Ketten et al., 2005). Furthermore, until recently, it was thought that sea turtles efficiently manage gas exchange and decompression through anatomical, physiological and behavioural adaptations. New results provided evidence for the existence of decompression sickness (DSC) in sea turtles. A study of (García-Párraga et al., 2014) evidenced DSC-like lesions in loggerhead turtles following behavioural disturbance by high-powered acoustic sources. Similar effects were found in by-caught animals, and gas embolism in vital organs was also noted. Compositional gas analyses of intravascular bubbles showed to be consistent with DCS, which provided a definitive diagnosis of DSC in sea turtles (García-Párraga et al., 2014).

8.3.2.4.1.2.1.2 Effects on hearing

Effects of man-made noise on hearing are displayed as permanent or temporary hearing loss, and as masking of sound. Permanent loss of hearing may be a consequence of the death of the sensory hair cells in the ear or damage to the innervating auditory nerve fibres (Liberman, 2015). Temporary hearing loss (temporary threshold shift, TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. TTS results from temporary changes in sensory hair cells of the inner ear and/or damage to auditory nerves innervating the ear (Smith et al., 2006; Liberman, 2015). Unlike in the auditory receptors of mammals, sensory hair cells are constantly added in fishes (e.g., (Corwin, 1981, 1983; Popper and Hoxter, 1984; Lombarte and Popper, 1994) and also replaced when damaged (Lombarte et al., 1993 ; Smith et al., 2006 ; Schuck and Smith, 2009) . Therefore, when sound-induced hair cell death occurs in fishes, its effects may be mitigated over time by the addition of new hair cells (Smith et al., 2006; Smith et al., 2011; Smith, 2012, 2015). No studies have examined hearing loss or the impact of loud noise on hearing in sea turtles. Nothing is known about TSS in sea turtles. There have been no studies to determine if the hair cells in the basilar papilla of turtles are lost during exposure to intense sounds or if turtles can recover hair cells lost through exposure to intense sounds (Popper et al., 2014a).

Masking is a hearing impairment with respect to the relevant sound sources normally detected within the soundscape. However, the consequences of masking for sea turtles have not been fully examined. It is likely that increments in background sound within the hearing bandwidth of sea turtles may render the weakest sounds undetectable, render some sounds less detectable, and reduce the distance at which sound sources can be detected. Energetic and informational masking may increase as sound levels increase, so that the higher the sound level of the masker, the greater the masking. Masking will occur only as long as the masker is present. A very short period of masking, such as from a single pulse of sound, or widely separated pulses, may not affect fitness. However, if impulsive sounds are generated repeatedly by many sources over a wide geographic area then there is the possibility that the separate sounds may merge and the overall background noise be raised (Popper et al. 2014a). No information exists on the effect of masking on sea turtles. However, it is expected that there are circumstances under which TTS could occur for sea turtles, as it does for all other vertebrates investigated (Popper et al., 2014a).

8.3.2.4.1.2.1.3 Effects on behaviour

An action or activity becomes biologically significant to an individual animal when it interferes with normal behaviour and activity, or affects the animal's ability to grow, survive, and reproduce. Such effects may have consequences at the population level and may affect the viability of the species (NRC, 2005). In case of man-made noise as a driver of behavioural changes, this may include changes in behaviour and distribution, including moving from preferred sites for feeding and reproduction, or alteration of migration patterns. However, this behavioural effect does not include effects on single animals or small changes in behaviour such as a startle response or minor movements, but refers to substantial changes in behaviour for a large proportion of the animals exposed to a sound (Popper et al., 2014a).

A range of behavioural responses to man-made sounds have been observed in marine mammals and fish, but very few information exist for sea turtles. Weir (2007) monitored sea turtle avoidance of sound during active seismic survey and observed fewer sea turtles near airguns as they were firing (as opposed to silent airguns). The source of agitation could not be identified; the turtles may have reacted to the ship and towed equipment rather than specifically to the airgun (Weir, 2007). It has not yet been investigated how man-made noise, particularly impulsive and intense sounds, can affect behaviour of torpid (lethargic) sea turtles in wintering habitats or dynamic of seasonal movements. However, avoidance as a behavioural response of sea turtles to low frequency tones has been demonstrated in caged animals (Lenhardt, 1994). O'Hara and Wilcox (1990) found that sea turtles in a canal will avoid an area with an airgun, although the received level at the sea turtles was not measured. Moein et al. (1994) monitored the behaviour of penned loggerhead turtles exposed to airguns firing at 175–179 dB re 1 μPa at 1 m. Avoidance of airguns was observed at first exposure, but the sea turtles habituated to the sound over time. Behavioural responses by sea turtles, including rising to the surface and altered swimming patterns, have been elicited in caged animals exposed to an airgun at received levels of 166 dB (rms) re 1 μPa (McCauley et al., 2000).

8.3.2.4.1.2.1.4 Impact on fitness and survival on the population level

From a conservation perspective, the immediate impact of man-made noise on an individual animal is less important than the long term chronic impact on populations, either alone or in combination with other anthropogenic stresses, such as e.g. interactions with fisheries (Popper et al., 2014a). As explained above, noise as a stressor may alter normal behaviour and activity of resident populations, affecting coordination and orientation of animals, migratory patterns, swimming performance, speed and direction of movements, diving intervals and behaviour, predator detection, and foraging behaviour, including foraging range, time, path and success (Parrish, 2004; Breitburg and Riedel 2005; Popper et al., 2014a). Behavioural changes and non-fatal injuries in turn affect growth and survival of individuals, decreasing individual fitness and, hence, fitness and viability of whole populations. It should be stressed that man-made noise would present an additional stressor to sea turtles resident in the Adriatic Sea, on top of all anthropogenic threats described above.

8.3.2.4.1.3 Elasmobranchii and sound

8.3.2.4.1.3.1 The impact of anthropogenic noise on Elasmobranchii

There is a little literature on the behavioural effects of air gun emissions on fish species. Generally, fish species dive deeper and move away from the source of explosions. However little is known about the effects of human generated sounds on elasmobranch species.

Generally, it is believed that elasmobranch fish are less susceptible to noise than teleost fish species (Casper et al., 2012). Results from captive studies suggest that the hearing bandwidth for elasmobranchs is from ~20 Hz up to 1 kHz (Casper and Mann, 2009). As elasmobranchs do not have an air-filled cavity they are less susceptible to changes in pressure related to noise production in the marine environment. However, effects could be felt in the ear which has a unique construction having a direct connection from the saccular chamber to the outside environment (Casper et al., 2012). It is therefore possible that strong noise could lead to masking or temporary threshold shifts in hearing. Research carried out by the US Navy revealed that low-frequency, erratically pulsed sounds broadcasted in the water could attract coastal and oceanic sharks from a distance of several hundreds of meters (Myrberg Jr, 2001). Other studies found that the sudden onset of loud sounds (20–30 dB above ambient noise levels) played when a shark approached a location would result in a startle reaction and it would turn away. In most studies examining the attracting and repelling of sharks with noise, habituation occurred after a few trials, and no initial reaction was observed (Casper et al., 2012). In addition, elasmobranchs have sensors throughout the skin and especially along the lateral line that could be sensitive to pressure changes, which may have an effect on predator avoidance, prey detection, courtship and spawning. However, there has been little research undertaken into the effects of noise on elasmobranchs and to date there have been no demonstrations of damage due to man-made noise sources (Normandeau Associates Inc, 2012; Popper et al., 2014b).

While there may be limited effect on the adult specimens of elasmobranch species, there are potential population-wide effects on eggs and larvae of all fish species. These stages of development are particularly vulnerable due to limited mobility and size (Popper et al., 2014b). Damage to eggs and developing embryos includes deformation and compression of membranes, displacement within the embryonic sac and disruption of the vitalline membrane (Popper et al., 2014b). It is therefore important to identify areas considered as important for spawning populations of all fishes (including elasmobranch species) and protect those areas at the appropriate time of year.

Since there is a significant lack of information on the range, numbers and potential impacts of noise primarily on sea turtles and cetaceans, the impact of noise cannot be explicitly defined at this time. Studies in experimental/induced conditions, as well as monitoring of accompanying occurrences, indicate that there is a potentially negative impact which has not been confirmed in natural conditions. Noise caused by seismic surveying and well drilling is limited in duration, and there are interactions with other permanent sources of noise in the marine environment. In order for an impact to be acceptable, suitable mitigation measures must exist which can be prescribed to mitigate the impact..

After implementing the measures prescribed by this Study, it will be possible to determine whether suitable noise impact mitigation measures can be prescribed.

Impact	Positive/	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	
Noise impact on cetaceans	-	✓	✓	✓	✓	✓	✓	✓	✓
and turtles Impact of production platforms on cetaceans and	+	✓	⊘	✓	⊘	✓	⊘	⊘	✓

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.4.2 Cartilaginous fishes

8.3.2.4.2.1 Impact of 2D and 3D seismic surveying

A study was carried out in experimental conditions (McCaulley et al., 2003) on *Pagrus auratus,* species belonging to the same class (ray-finned fishes) as the hake (*Merluccius merluccius*), a commercially profitable specias of the Adriatic. The study showed that during exposure to seismic impacts of 180 dB hearing damage occurs, with no evidence of repair even after 58 days from the exposure to noise. Fish with impaired hearing have reduced fitness and are more susceptible to predators. In addition, there is a possibility they are unable to locate their prey, and if they use their hearing for communication, it becomes hindered. It should be noted that the studied fish were kept in cages during the study and could not escape the seismic impact. Sensory hair cells are constantly added in fishes (e.g., (Corwin 1981, 1983; Popper and Hoxter 1984; Lombarte and Popper 1994) and also replaced when damaged (Lombarte et al. 1993 ; Smith et al., 2006 ; Schuck and Smith, 2009)

. Therefore, when sound-induced hair cell death occurs in fishes, its effects may be mitigated over time by the addition of new hair cells, and it is presumed that a longer time period is required to renew the hair cells (Smith et al. 2006; Smith et al. 2011; Smith 2012, 2015).

Changes in fish behaviour, changes in schooling patterns and distribution, changes in migration patterns, etc. with longer or shorter spatial and temporal impact have been identified by several sources (Popper et al., 2003; Popper et al., 2004; Slabbekoorn et al., 2010; Fewtrell and McCauley, 2012; Løkkeborg et al., 2012; Mooney et al., 2012). According to a study carried out in 1996 (Engas et al.), fish species dive move away from the source of seismic impact.

A study on the European seabass (*Dicentrarchus labrax)* showed that there was no pathological impact on the observed fish. The study included airguns producing 256 dB at 1 µPa ·m 0-p s in impulses every 25 seconds over a duration of 2 hours. The minimal distance between the observed subject and the source was 180 meters. Blood samples were collected 6 hours after exposure and a difference was found beteen the control group and the exposed subject in the levels of cortisol, glucose and lactate, known indicators of stress in fishes. All three elevated values returned to their initial levels within 72 hours (Santulli et at., 1999). The same study demonstrated that during exposure to sound waves at a distance of 180 m schools of fish group in the middle of the cage and show increased activity. Such changes in behaviour lasted for 2 hours, after which behaviour returned to normal.

Impact ranking:

The impact is **negligibly negative due to impact mitigation measures.**

8.3.2.4.2.1 Impact of dispersed hydrocarbons (exploratory and production drilling stage; accompanying activities)

Hydrocarbons dispersed in the water column may damage the tissues of gills and the digestive system. Nevertheless, the majority of fish succeed in avoiding the polluted area. Impact on fish is often mediated by the impact on the plankton they consume. Due to hydrocarbon pollution, the plankton may migrate or accumulate pollutants, both of which will have a negative impact on fishes (Luyeye, 2005). As natural fish populations are mobile, the impact of dispersed hydrocarbons is expected to be **negligibly negative.**

8.3.2.4.2.2 Impact of accompanying activities (tankers)

Larvae of potentially invasive species of fishes may be transported in ballast waters of cargo vessels such as tankers. Seeing as regulations are in place for cargo vessel transport which lay down procedures to prevent the spreading of invasive species, the impact is assessed as **negligibly negative.**

8.3.2.4.2.3 Impact of light pollution from platforms

During night-time, platform lights may attract zooplankton and ichthyoplankton (fish larvae) and turtle hatchlings. However, the impact of light emissions will be limited to the area surrounding the platform, therefore the impact is considered to be **negligibly negative.**

Impact	Positive/	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	Synergistic
Impact of 2D and 3D seismic	-	🗐🗐🗋	⦸	⦸	🗐🗐🗋	⦸	⦸	⦸	⦸
surveying Impact of dispersed	-	🗐🗐🗋	🗐🗐🗋	⦸	⦸	🗐🗐🗋	⦸	⦸	⦸
hydrocarbon s Impact of accompanyin g activities	-	🗐🗐🗋	⦸	⦸	⦸	⦸	🗐🗐🗋	🗐🗐🗋	⦸
(tankers) Impact of light pollution	-	🗐🗐🗋	⦸	⦸	⦸	⦸	🗐🗐🗋	⦸	⦸

Key: + positive impact, - negative impact, 🗐🗐🗋 applicable, ⦸ not applicable

8.3.2.4.3 Birds (seabirds and passage migrants)

8.3.2.4.3.1 Impact of 2D and 3D seismic surveying

Seismic surveying could have a direct impact on the birds feeding below water in the immediate vicinity of sonic cannons. As the seismic airguns are deployed at 10 m water depth and directed towards the ground, in the first 10 m of the water column the noise is lower (Caldwell, Dragoset, 2000). Therefore the impact is estimated to be **negligibly negative**.

8.3.2.4.3.1 Impact of exploratory drilling (presence of platforms)

Open sea platforms have 3 main impacts on migratory birds: they serve as stopover sites, disorient nocturnal passage migrants and cause bird deaths through collision.

Birds flying across seas undergo major physiological stress, particularly during springtime when their fat stores are depleted. Excessive accumulation of lactic acid, failure of the nerve-muscle junction, or disturbances of central nervous coordination may occur. Resting on platforms, from several hours up to several days, and even feeding in cases of some species (depending on available food sources), provides the birds with an opportunity to recover. Passage migrants are very selective in their choice of stopover sites, and individual species select specific platform microhabitats (Russell, 2005). This represents **a positive impact.**

It has been noted that platforms attract nocturnal passage migrants which use the Moon and the stars for orientation. This happens more frequently on overcast nights, when platform lights are the only visual cue. Attracted by the lights, birds circle the platforms for up to several hours, which causes unnecessary expenditure of energy and increases the likelihood of collisions between the birds, as well as the birds' collisions with the platform. Collisions with the platform are most common during fall migrations (Russell, 2005). The impact can be reduced by using suitable lighting on platforms, therefore the impact can be described as

negligibly negative due to impact mitigation measures.

Production platforms often maintain a high level of subsea biodiversity since they act as artificial reefs which are rapidly populated by various marine organisms. Such conditions may attract birds feeding on those organisms (Russell, 2005) and have a **positive impact** on their populations.

8.3.2.4.3.2 Impact of well testing (hydrocarbon flaring)

Nocturnal passage migrants may be attracted to the light from platform flares, which can cause temporary disorientation, or injury and death in case of collision. As flaring operations last for 1 to 2 days per well, the impact is **negligibly negative**.

8.3.2.4.3.3 Impact of hydrocarbon residue

Hydrocarbon residues from process water discharged into the surrounding sea in concentrations permitted by the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) can have a negative impact on birds foraging at sea, even in very small quantities. Hydrocarbons strip the water repellent layer from the birds' plumage, resulting in thermal insulation disturbance (Ellis, 2013). Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms, the quantities of hydrocarbons discharged and the presence of birds in the process water impact zone, in order to give a precise estimate of this impact. The impact is **negligibly negative**

due to impact mitigation measures.

8.3.2.4.3.4 Impact of accompanying activities – logistics

Helicopters operating between platforms, exploratory vessels and land may disturb birds, in particular colonies nesting on the coast and the islands. If the standard helicopter routes avoid the locations of known seabird nesting sites, which could abandon their nests in case of disturbance, the impact can be described as **negligibly negative due to impact mitigation measures**.

Impact	Positive/	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	
Impact of 2D and 3D seismic	-	✓	⦸	⦸	✓	⦸	⦸	⦸	⦸
~~seismic~~ surveying (stopover	+	✓	⦸	⦸	⦸	✓	⦸	✓	⦸
sites) Platform (disorientation)	-	✓	⦸	⦸	⦸	✓	⦸	✓	⦸
Presence of	-	✓	⦸	⦸	⦸	✓	⦸	✓	⦸
platforms (collision) Presence	+	⦸	✓	⦸	⦸	⦸	✓	✓	⦸
subsea biodiversity)									
Impact of well testing (hydrocarbon flaring)	-	✓	⦸	⦸	✓	⦸	⦸	⦸	⦸
Hydrocarbon residues on the surface	-	✓	⦸	⦸	⦸	✓	⦸	✓	⦸
Impact of accompanying activities – logistics	-	✓	⦸	⦸	⦸	✓	⦸	✓	⦸

Key: + positive impact, - negative impact, ✓ applicable, ⦸ not applicable

8.3.2.4.4 Invertebrates

Impacts arising from the planned hydrocarbon exploration and production operations will affect a number of marine invertebrates. Notable impacts arise from mud discharges into the sea, hydrocarbons on the surface and in the water column, and seismic surveying. As the sea is populated by organisms belonging to all classes within the informal group of invertebrates, this section presents the impacts on select groups only (corals, bivalves, cephalopods, crustaceans), both for reasons of readability and due to the lack of impact data for individual groups.

8.3.2.4.4.1 Impact of 2D and 3D seismic surveying

Noise in the marine enviroment produced during seismic surveying can have a negative impact on the development of coral and bivalve larvae, as was experimentally demonstrated by Aquilar de Soto (2013), while no impact was noticed in crustaceans

(La bella et al., 1996; Christian et al., 2003, 2004). It can also affect adult invertebrates, possibly damaging cephalopod statocysts which may lead to disorientation or death (André, 2011). The potentially negative impact on larvae and adult individuals is most prominent at the site directly exposed to sound, which constitutes a smaller part of the total plankton biomass, and considering the short reproductive cycle of invertebrates, the impact is **negligibly**

negative due to impact mitigation measures.

8.3.2.4.4.2 Impact of discharge of drilling mud and well cuttings

Significant impact on benthic invertebrates results from the discharge of drilling mud and well cuttings in the vicinity of the well. Mechanical impact on benthic organisms is to be expected considering the large quantities of discharged drilling mud and well cuttings, as well as the toxic effect of additives in the mud after a longer period of time (Bjørgesæter A., 2008.). Mud and well cutting depositions cause secondary pollution of the benthic communities due to the presence of heavy metals and the accumulation of clay. Barium from the mud will mostly appear in the sediment in the form of insoluble $BaSO_4$ (due to high concentrations of sulphates (SO_4) in the marine environment). Chronic exposure to drilling mud containing barium leads to slower growth or even death in certain cases (Cranford et al., 1999), and also has a negative impact on bivalve gill tissues (Barlow M.J, Kingston P.F, 2001). It has been noted that the presence of barium may alter the composition of benthic communities (Strachan 2010). Communities are covered and anoxia occurs, with lethal effects on seabed fauna (Dodge, 1982). Mechanical impacts on rare benthic communities (coralligenous communities) can be reduced by prescribing a measure which requires that operations are moved away from such habitats. Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms, the type and quantities of drilling mud discharged into the sea, the quantities and composition of well cuttings discharged into the sea, and give a precise estimate of these mechanical and chemical impacts. The impact is **negligibly negative due to impact mitigation measures.**

8.3.2.4.4.3 Impact of platform and pipeline installation and drilling

If located in coral habitats, exploratory wells and production platforms and pipelines have a negative impact on the organisms as their renewal takes several decades, even under the most favourable conditons. Pipeline installation could have a negative impact on benthic organisms living under the pipelines and anchors, and cause water turbidity in the immediate vicinity of the pipelaying site. In general, one kilometre of pipelay is estimated to affect 0,32 ha of the seabed (Cranswick, 2001) The impacts are likely to last for several years. The actual surface affected by anchoring depends on water depth, sea currents, cable lenght, anchor and cable size, anchor step, etc. Considering the total area of mud and sand flats in relation to the area covered by the pipeline or the platform, the share of benthic habitats which will be converted is negligible. In the case of coral communities, as already indicated, a measure to move the operations away from the habitats will be prescribed as part of the Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network for the Licensee's Programme, therefore the impact is **negligibly negative due to impact mitigation measures.**

8.3.2.4.4.4 Platform removal impact

Production platforms, being present in the marine environment for several decades, become populated by various organisms very soon after installation, and gradually transform into articifial reefs (Rigs to Reefs) which maintain a high level of biodiversity, implying a **positive impact** on invertebrates. Over time, platform legs are overgrown with organisms, i.e. artificial reefs are formed. Growth is periodically removed from the legs so that their weight would not disturb platform stability. Previous experience shows that the presence of marine growth on the legs declines with water depth. According to the overview of growth on the Ivana A platform carried out by experts from the Faculty of Science (Bakran-Petricioli et al., 2007), the growth which developed on the underwater portions of the platform is still dominated (in terms of biomass) by the Mediterranean mussel (*Mytilus galloprovincialis*) and, to a smaller extent, the European flat oyster (*Ostrea edulis*). On the cleaned portion of the platform, at 8 m water depth, the biomass amounts to 30 to 40 kg wet mass/m^2, while at deeper portions of the platform (24.5 m) it is around 30 kg/m^2. On parts that have not been cleaned since the platform's installation, there are fewer larger mussels than before, at both depths. On parts that were cleaned, from the sea surface up to several meters of depth, mussels are forming again after the cleaning. None of the tested samples contain pre-mutagenic and/or mutagenic xenobiotics, therefore the area surrounding Ivana A can be considered free of pollution (Bakran-Petricioli at al., 2007) Fish are present around the platform in numbers up to 10 times higher than at open sea (Stanley and Wilson, 2000).

If fixed platforms are used, they cover an average of 10 m^2 of the seabed, and the level of impact depends on the types of organisms inhabiting the seabed.

8.3.2.4.4.5 Impact of hydrocarbon spills during exploratory drilling and production

Adult bivalves are organisms that primarily feed by filtering sea water, and as such they are susceptible to bioaccumulation of harmful substances. Hydrocarbons created as a byproduct in oil production are dissolved in sea water and accumulate easily in the organs of bivalves, causing disturbances in respiration and filtration, as well as other physiological disturbances (Malins, 1977). Dispersed hydrocarbons can also have a negative impact on octopus larvae (Longa, 2002). Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms, the type and quantities of hydrocarbons discharged into the sea, and give a precise estimate of this impact on invertebrates. The impact is **negligibly negative due to impact mitigation measures.**

8.3.2.4.4.6 Impact of accompanying activities

The increased number of vessels, especially tankers, increases the possibility of arrival of invasive species that propagate in ballast waters. As regulations are in place for vessel transport which lay down procedures to prevent the spreading of invasive species, the impact is assessed as **negligibly negative**.

8.3.2.4.4.7 Platform and pipeline removal impact

After platform production stops, platforms are removed, thereby also removing the communities growing on them. If the underwater portions of the platform are not removed, and if removal is not performed using explosives, this impact is **negligibly negative due to impact mitigation measures**. During pipeline removal, pollutants are emitted into the water and the seabed is disturbed once again (Scandpower Risk Management Inc., 2004), therefore pipelines should be cleaned and left in their position, resulting in **negligibly negative impact due to impact mitigation measures.**

Impact	Positive/	Indirect	Direct	Remote	Short-term	Medium-term	Permanent	Cumulative	
Impact of 2D	-	▯	⊘	⊘	▯	⊘	⊘	⊘	⊘
and 3D seismic surveying of drilling mud well cuttings	-	▯	⊘	⊘	⊘	⊘	▯	⊘	⊘
Impact of platform installation drilling	-	▯	⊘	⊘	⊘	▯	⊘	⊘	⊘
Presence of platforms	+	▯	⊘	⊘	⊘	⊘	▯	⊘	⊘
Impact of hydrocarbon spills during drilling	-	▯	⊘	▯	⊘	⊘	▯	⊘	⊘
production Impact of platform pipeline	-	▯	⊘	⊘	⊘	⊘	▯	⊘	⊘
Impact of accompa nying activities	-	⊘	▯	⊘	⊘	⊘	▯	▯	⊘

Key: + positive impact, - negative impact, ▯ applicable, ⊘ not applicable

8.3.2.4.5 Plankton

8.3.2.4.5.1 Impact of installation of an exploratory drilling platform

The main impacts from installation of exploratory drilling platforms are seabed disturbances and partial use of habitats. Considering that plankton moves freely in the pelagic zone, no significant impact on this group of organisms is expected Therefore the installation of exploratory drilling platforms has a **negligibly negative impact** on plankton.

8.3.2.4.5.2 Impact of installation of a production platform and pipelines

As the main impact of this activity is related to seabed disturbances and the use of habitats by sedentary species, no impact on plankton is expected as they inhabit the pelagic zone. Therefore, the installation of production platforms and pipelines has a **negligibly negative impact** on plankton.

8.3.2.4.5.3 Impact of exploratory and production drilling

During hydrocarbon exploration and production, specifically during exploratory and production drilling, drilling mud and well cuttings (sludge) are discharged into the area around the well. The larger part of the mud and well cutting mixture deposits on the seabed, while a portion of the particles disperses in the water column. The discharge of drilling mud and wall cuttings (sludge) has an impact on plankton populations if light levels are reduced as a result of dispersion of mud particles, thereby disturbing the daily vertical distribution of the plankton. If substantial water turbidity occurs as a result of the mud discharge, this can lead to reduced growth of phytoplankton (the reduced quantity of light has a negative impact on their ability to photosynthesize) (Luyeye, 2005). Nevertheless, considering the local nature of impact and the total plankton population, no major impact on this group of organisms is expected. In conclusion, the impact of exploratory and production drilling on plankton is **negligibly negative**.

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term term	Medium-term	Long-	Cumulative	Synergistic
Impact of installation of an exploratory and production drilling platform	-	🗐	⊘	⊘	🗐	⊘	⊘	⊘	⊘
Impact of exploratory and production	-	🗐	⊘	⊘	⊘	🗐	⊘	⊘	⊘

Key: + positive impact, - negative impact, 🗐 applicable, ⊘ not applicable

8.3.2.4.6 Habitats

8.3.2.4.6.1 Impact of exploratory drilling

Circalittoral sands and muds are the most common type of habitats present in blocks foreseen by the FPP. The habitats cover a large area, and the organisms inhabiting it are more or less dispersed. During exploratory and production drilling a portion of the habitat is directly occupied, but seeing as wells have a diameter around 1 m, in relation to the total area covered by the habitat such impact is considered **negligibly negative**.

Coralligenous communities are characterized by high diversity, but unfortunately their exact distribution in the Adriatic is not known, which hinders their protection. Due to the localised nature and much higher richness of species per unit of area in comparison with circalittoral sands and muds, these habitats are more vulnerable (Natura 2000 poster, Habitat 1170, Reefs), and can be negatively affected by drilling in the area or in the immediate vicinity. Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms and coralligenous communities, and define platform locations which will avoid those communities. The impact is **negligibly negative due to**

impact mitigation measures.

The same impacts apply to deepwater corals communities in the bathyal zone. Drilling, installation of platforms and anchoring on coralligenous communities directly occupies a portion of the habitat. Well cuttings and drilling mud inhibit photosynthesis in autotrophic organisms and prevent heterotrophs from feeding. The impact of hydrocarbons on coralligenous organisms is described in full in the section relating to impact on invertebrates.

8.3.2.4.6.2 Impact of discharge of drilling mud, well cuttings and hydrocarbon residues

Drilling mud and hydrocarbon residues from exploration and production may sink deep into sediments and persist for many years, causing negative impacts on organisms inhabiting it and the food chain (Effects of Oil on Wildlife and Habitat, 2010). The drilling of exploratory and production wells requires occasional discharge of drilling mud and well cuttings into the sea in the vicinity of the well. .   Deposits of mud and well cuttings and the presence of bentonite, barite and heavy metals in the mud have a negative impact on benthic communities. Even mud which is very low in toxicity (water-based drilling mud) affects the seabed communities by causing anoxia. Barium has a tendency to bioaccumulate in macroalgae. Elevated concentrations of barium have been found in species *Sargassum* ssp. (Neff J.M., 2002). Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms, the type and quantities of drilling mud discharged into the sea, the quantities and composition of well cuttings discharged into the sea, and give a precise estimate of these mechanical and chemical impacts. The impact is **negligibly negative due to impact mitigation measures.**

Drilling mud and well cuttings, as well as formation water, can also have a negative impact on species of **seagrasses**, if discharged in their immediate vicinity. One of the consequences is the reduced level of photosynthesis in seagrasses, which threatens the development of their communities. As seagrass communities inhabit shallow waters (0 - 35 m), the distance from exploratory and production areas is such that there would be no negative impacts indicated above, i.e. the impact is **negligibly negative**.

8.3.2.4.6.3 Impact of production platforms

Production platforms are soon overgrown with different marine organisms and transformed into artificial reefs, which further attracts many other organisms, such as predatory species of fish and birds. The creation of a new type of habitat maintaining a high level of biodiversity represents a **positive impact**.

8.3.2.4.6.4 Impact of pipeline installation

Pipeline installation could have a direct negative impact on benthic organisms living under the pipelines and anchors, and cause water turbidity in the immediate vicinity of the pipelaying site. In general, one kilometre of pipelay is estimated to damage 0,32 ha of the seabed (Gaurina-Međimurec, 2014), As circalittoral sands and muds cover the most part of the Adriatic seabed, the area covered by a single platform (10m^2) or a series of platforms is insignificant in relation to the total size of the area, therefore the impact on this type of habitat is **negligible**. Pipeline laying over coralligenous communities would have a significant negative impact, which can be mitigated by changing the route, therefore the impact is **negligibly negative due to impact mitigation measures**.

8.3.2.4.6.5 Impact of accompanying activities (increased number of tankers)

The increase in marine traffic increases the possibility of arrival of invasive species on anchors and in ballast waters. There are several invasive species of algae in the Adriatic which compete with indigenous species and marine flowering plants. Nevertheless, as regulations are in place for vessel transport which lay down procedures to prevent the spreading of invasive species, the impact is assessed as **negligibly negative.**

Impact	Positive/ Negative	Direct	Indirect	Remote	Short Term	Medium Term	Permanent	Cumulitive	Synergistic
Impact of exploratory drilling (circalittoral)	-	✓	×	×	×	×	✓	×	×
Production drilling	-	✓	×	×	×	×	✓		×
Exploratory production drilling (coraligenous)	-	✓	×	×	×	×	✓	✓	×
Discharge of drilling mud well cuttings and hydrocarbon residue	-	✓	×	×	×	✓	×	×	×
Presence of production platforms	+	✓	×	×	×	×	✓	×	×

Pipeline installation	-	✓	✗	✗	✗	✗	✓	✓	✗
Accompanying activities (increased number of tankers)	-	✗	✓	✗	✗	✗	✓	✓	✗

Key: + positive impact, - negative impact, ✓ applicable, ✗ not applicable

8.3.2.4.7 Protected areas

8.3.2.4.7.1 Nature monuments

The Framework plan and programme foresees operations to be undertaken in the vicinity of two geological nature monuments: the island of Brusnik and the island of Jabuka. Since the main reason for protection of these areas is their geological structure, being made entirely of igneous rocks, FPP operations will have no impact on the protection goal. Impacts on geological structures could occur during drilling of exploratory and production wells, however, wells planned in the FPP are drilled in the seabed, and the risk of damage to the geological structures of Jabuka and Brusnik is negligible. 2D and 3D seismic surveying, marine traffic, drilling mud discharges and platform operations have no impact on the geological structures of the islands.

8.3.2.4.7.2 National parks and nature parks

Marine habitats in the national parks of Kornati, Mljet and Brijuni and the nature parks of Lastovo Archipelago and Telašćica are one of the reasons for protection of these areas. The areas concerned are located at a distance of 6 kilometres or more from the borders of the FPP project area (Table 3.26), reducing the risk of negative impacts. The most significant remote negative impact on marine habitats identified in the Strategic Study refers to the deposits of drilling mud and other waste water during the operation of exploratory and production platforms. The distance of the protected areas is sufficient enough to dismiss the remote impacts of the FPP.

FPP operations could have a negative impact on the protected marine macrofauna and seabirds inhabiting the national parks and nature parks listed in Table 3.26. All impacts on marine macrofauna and seabirds are discussed in detail in chapters 8.3.2.4 Biodiversity and 6. Main Assessment.

8.3.2.4.7.3 Significant landscapes

The implementation of the FPP does not present a threat to the significant landscapes of Ravnik and Pakleni Islands, considering the nature of their protection status.

8.3.2.5 Ecological network

8.3.2.5.1 Change of breeding colony conditions due to noise level increase during FPP operations

The noise impact can result in altered or unfavourable breeding conditions. During 2D and 3D surveys and in case of traffic increase, especially increase of helicopter flights, a more significant negative impact is possible for breeding colonies of yelkouan shearwaters (*Puffinus yelkouan*) and Cory's shearwaters (*Calonectris diomedea*) (Sultana, J. and Borg, J. J. 2006). Remote islands and isles (Sv. Andrija, Svetac, Kamnik and Palagruža) are the breeding sites for the only population of yelkouan shearwaters and Cory's shearwaters in Croatia, and impacts resulting from the implementation of FPP could endanger them to the extent that they abandon their breeding sites permanently. This impact is estimated to be **unacceptably negative** and an alternative solution is proposed, as described in chapter 9.

8.3.2.5.2 Increased concentrations of floating hydrocarbons during normal platform operations

Hydrocarbon residues from process water discharged into the surrounding sea in concentrations permitted by the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) can have a negative impact on birds foraging at sea, even in very small quantities. Hydrocarbons strip the water repellent layer from the birds' plumage, resulting in thermal insulation disturbance (Ellis et al., 2013). However, the concentrations of these compounds are so small that their impact at open sea is

negligibly negative.

8.3.2.5.3 Animal deaths in helicopter collisions

Collisions with birds are possible during helicopter flights. As areas of highest risk for collisions have been identified in the Strategic Study, negative impact can be avoided by implementing the mitigation measures prescribed in chapter 10. The impact is therefore estimated as **negligibly negative due to impact mitigation measures.**

8.3.2.5.4 Use of platforms for migratory bird stopovers

Birds flying across seas undergo major physiological stress, particularly during springtime when their fat stores are depleted. Excessive accumulation of lactic acid, failure of the nerve-muscle junction, or disturbances of central nervous coordination may occur. Resting on platforms, from several hours up to several days, and even feeding in cases of some species (depending on available food sources), provides the birds with an opportunity to recover. Passage migrants are very selective in their choice of stopover sites, and individual species select specific platform microhabitats. This represents **a positive impact.**

8.3.2.5.5 Disturbance of usual migration routes

It has been noted that platforms attract nocturnal passage migrants which use the Moon and the stars for orientation. This happens more frequently on overcast nights, when platform lights are the only visual cue. Attracted by the lights, birds circle the platforms for up to several hours, which causes unnecessary expenditure of energy and increases the likelihood of collisions between the birds, as well as the birds' collisions with the platform. Collisions with the platform are most common during fall migrations. The impact is therefore estimated as **negligibly negative due to impact mitigation measures**.

8.3.2.5.6 Hydrocarbon flaring during well production capability testing

During testing of well production capability, hydrocarbons are burned off on the platform, and the flare-shaped flame rises above the platform. Hydrocarbons are never fully combusted and the unburned components of hydrocarbons end up in the sea. Seabirds can mistake these amorphous masses for food and ingest them, which may result in poisoning (Wanless and Harris, 1997, Velando et al., 2005), The impact is therefore estimated as **negligibly negative due to impact mitigation measures** and monitoring prescribed in chapters 10 and 11.

8.3.2.5.7 Swallowing and entanglement in inadequately disposed waste

Animals frequently swallow pieces of plastic and plastic bags or get entangled in floating waste as they come into contact with waste in the sea accidentally, while searching for food or out of curiosity. The negative impacts of waste affect individual fitness. Waste can become affixed to their extremities or remain undigested in their digestive system, which can ultimately lead to increased mortality of the population. Marine mammals, turtles and birds are at highest risk. There are no measures that could mitigate this impact, as they are already prescribed by law, but waste ends up in the sea nevertheless. The intensity of this impact is not high and it is considered to be **negligibly negative**.

8.3.2.5.8 Increased levels of noise caused by airgun operation

During 2D and 3D surveys airguns are used which produce short but intense sound pressure waves. This can result in physiological and behavioural changes in affected individuals of marine macrofauna, in higher or lower intensity and with various negative consequences. A direct link between the impacts of airgun noise and mortality of individuals has not been established, therefore the impact is considered to be **negligibly negative due to impact mitigation measures**.

8.3.2.5.9 Platform operation reduces the attractiveness of an area

When operating, platforms generate increased levels of noise, mud, process water, formation water and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and process water reduce the abundance of fish (Patun, 1999; Mario, 2002) and the diversity of benthic communities which consequently affects quantities of prey and foraging success (seabirds, sea turtles and marine mammals). Heavy metals contained in the mud tend to bioaccumulate through the food chain (Gbadebo A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators.

The noise from the hydrocarbon extraction and drilling of wells can temporarily cause the sea fauna to move off, but eventually the organisms adapt to the new circumstances.

Based on the analysis conducted, the impact is estimated as **negligibly negative due to impact mitigation measures**.

8.3.2.5.10 Presence of production platforms

Sedentary organisms typical for shallow seas grow on the submerged portion of the platform. The creation of new colonies of sedentary organisms ("artificial reefs") leads to the development of new food chains which are atypical for the open sea, increasing the diversity of organisms in their surroundings. This represents **a positive impact.**

8.3.2.5.11 Accompanying activities causing increased marine traffic and noise

Collisions with vessels and an increased level of noise due to increased marine traffic have a negative impact on marine macrofauna (Nowacek, S. M. et al., 2001), but on account of the slight increase in marine traffic in comparison with the existing traffic and the rare occurrences of such events the impact is considered to be

negligibly negative.

8.3.2.5.12 Disturbance of natural environment by platform installation

Installation of platforms produces certain levels of noise and introduces a new element into an area, which can temporarily reduce the area's attractiveness. As a result of the biological processes in the sea, balance will be re-established and the impact is therefore considered to be **negligibly negative**.

8.3.2.5.13 Disturbance of natural environment by platform removal

As in the case of platforms installation, certain levels of noise will be produced and initial environmental conditions will be altered. Since platform removal can be performed using explosives at the base of the piles, the impact is considered to be **negligibly negative due to impact mitigation measures** prescribed in chapter 10.

Impact	Positive/	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	
Changed conditions breeding colony conditions due to noise level increase during FPP operations	-	✓	⊘	⊘	⊘	⊘	✓	⊘	⊘
Increased concentrations of floating hydrocarbons during normal platform	-	⊘	✓	⊘	⊘	✓	⊘	⊘	⊘
operations Animal deaths in helicopter	-	✓	⊘	⊘	✓	⊘	⊘	⊘	⊘
collisions Use of platforms for migratory	+	✓	⊘	⊘	⊘	✓	⊘	⊘	⊘
bird stopovers Disturbance of usual migration	-	✓	⊘	⊘	⊘	✓	⊘	⊘	⊘
routes Hydrocarbon flaring	-	✓	⊘	⊘	✓	⊘	⊘	⊘	⊘
Swallowing a n Swallowing and	-	⊘	✓	✓	⊘	✓	⊘	⊘	⊘
Increased levels of caused noise by operati	-	✓	⊘	⊘	✓	⊘	⊘	✓	⊘
on Platform reduces the attractiveness	-	✓	⊘	⊘	⊘	✓	⊘	⊘	⊘
of an area	+	✓	⊘	⊘	⊘	✓	⊘	⊘	⊘
Accompanying activities causing increased marine traffic and noise	-	✓	⊘	⊘	✓	⊘	⊘	✓	⊘
Disturbance of natural environment by platform installation	-	✓	⊘	⊘	✓	⊘	⊘	⊘	⊘
Disturbance of natural environment by platform removal	-	✓	⊘	⊘	✓	⊘	⊘	⊘	⊘

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.6 Marine and seabed pollution

8.3.2.6.1 Impact of discharging mud into the sea

Discharge of drilling mud and well cuttings in the vicinity of the well can impact the seabed and the sea, as the mud discharged into the sea contains certain levels of heavy metals. Concentrations of some toxic metals (e.g. cadmium, copper, lead, mercury and zinc) may be elevated within several hundred meters from the well site. Given its composition, the use of synthetic drilling mud poses a threat for the quality of the marine environment (synthetic muds are emulsions of synthetic compounds such as linear α-olefins, poly-α-olefins, linear alkylbenzenes, ethers, esters or acetals). Discharges of synthetic mud into the sea would alter the quality of the seabed and the sea.

On the basis of the assessment of impact of drilling mud on the quality of the seabed and the sea, it can be concluded that the implementation of FPP can cause pollution of the seabed and the sea, but assuming the mitigation measures are implemented the impact could be reduced to **negligibly negative impact due to impact mitigation measures**.

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term term	Medium-term	Long-	Cumulative	Synergistic
Impact of discharging mud into the	-	✓	⊘	⊘	⊘	✓	⊘	✓	⊘

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.7 Economic characteristics

8.3.2.7.1 Fisheries

8.3.2.7.1.1 Impact of increased marine traffic

Fishing vessels mostly operate in the internal waters and to a much lesser extent in the territorial waters (Figure 3.78). Vessels that may be significantly affected include purse seiners, tuna purse seiners and bottom trawlers, while other vessels fish in the internal waters. The operation of these vessels may be interrupted by activities related to hydrocarbon exploration and production in the designated blocks. The highest purse seiner activity can be expected along the west coast of Istria, the island of Lošinj, Dugi Otok and Kornati, while bottom trawlers mostly circle the broader area of the Jabuka Pit. In accordance with the Ordinance on tuna (*Thunnus thynnus*), swordfish (*Xiphias gladius*) and Mediterranean spearfish (*Tetrapturus belone*) fishing, farming and trade (OG 11/14, 20/14, 61/14, 66/14 and 94/14), tuna purse seiners harvest tuna from 26 May until the quota is fulfilled (by 24 June at the latest) in the wider area of the Jabuka Pit (block 12).

It may be concluded from the above that fishing activity could decrease during the implementation of FPP as a result of increased marine traffic, but as the number of additional vessels is relatively low, the impact is estimated to be

negligibly negative due to impact mitigation measures.

8.3.2.7.1.2 Seismic surveying noise impact

According to the data available, operations related to 2D and 3D seismic surveying impact the physical condition and the behaviour of fishes. Physical effects (mortality, changes in hearing) caused by seismic surveying are described in chapter 8.3.2.4.2.1. Behavioural changes in fish exposed to sounds from seismic surveying vary greatly and are species-dependent. They range from mild agitation and reduced reaction to other stimuli to much stronger responses, such as modified swimming speed and direction and changes in vertical distribution /Blaxter et al., 1981, Pearson et al., 1992). Different fish species have different sensitivity and therefore a different response to sounds produced during seismic surveying. It has also been noted that fish with different living patterns had different responses. Fish species inhabiting the seabed reacted to sounds by withdrawing into hiding places, and no difference in vertical and horizontal distribution was noticed (Skalski et al., 1992, Wardle et al., 2001). Unlike these species that stay close to the seabed, fish belonging to species *Gadidae* (e.g. *Merlangius merlangus* and *Micromesistius poutassou*), whose living patterns are similar to the hake's (*Merluccius merluccius*) in that they undertake significant vertical migrations, reacted to seismic noise by withdrawing to greater depths and moving away from the source of noise. Based on the above, it may be concluded that seismic surveying can have a negative impact on fisheries in the surveyed area as the fish tend to move away from the source of noise (Slotte et al., 2004). On account of such fish behaviour, greater fishing efforts will have to be made for the same amount of catch, which has a negative impact on the economic feasibility of fishing.

The majority of fishing operations in the Adriatic take place year-long in the following blocks:

- purse seiners:
  West coast of Istria (blocks 1 and 2), Lošinj
  Archipelago (block 4),

  the area from Dugi Otok to Kornati (blocks 6, 8 and 10)

- bottom trawlers:
  the area surrounding the Jabuka Pit (blocks 10, 11, 12, 13, 14, 15, 16, 17 and 19),
  areas of South Adriatic (blocks 23 and 28)

- tuna purse seiners:

the area surrounding the Jabuka Pit (block 12).

It can be assumed from the overview above that fishing operations could be reduced due to seismic surveying, but seeing as the surveying operations are limited in duration, it can be assumed that after they are performed, in compliance with the mitigation measures prescribed in this Study as well as those that will be defined during the Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network, the situation in a certain area will return to its original condition. Therefore the impact is estimated as **negligibly negative due to impact mitigation measures.**

8.3.2.7.1.3 Impact due to platform and supporting infrastructure installation and exploratory and production drilling

The physical presence of platforms, as well as noise and light associated with the drilling operations, will impact the populations of fish species in the vicinity. Impact on fisheries as a branch of the economy will be evident through the reduction of areas where fishing is permitted. The majority of fishing operations take place year-long in the following blocks (Figure 3.78):

PURSE SEINERS:

- West coast of Istria (blocks 1 and 2),
- Lošinj Archipelago (block 4),
- the area from Dugi Otok to Kornati (blocks 6, 8 and 10),

BOTTOM TRAWLERS:

- the area surrounding the Jabuka Pit (blocks 10, 11, 12, 13, 14, 15, 16, 17 and 19),
- areas of South Adriatic (blocks 23 and 28),

TUNA PURSE SEINERS:

- the area surrounding the Jabuka Pit (block 12).

Pipeline installation will have a negative impact on benthic organisms, including benthic fish species. Water turbidity in the immediate vicinity of the pipelaying site will have a negative impact on fish populations. As a consequence of the above, fish inhabiting the affected area will move away from the impact site. These activities will have an impact on fisheries in the affected area. The installation of pipelines will limit the possibility of fishing operations in the immediate vicinity of the installed infrastructure, thereby reducing the area where fishing operations can be carried out. On the other hand, fishing pressure will increase in areas where fishing operations are allowed.

Vessel anchoring and deepwater fishing is prohibited in safety zones surrounding platforms up to a distance of 500 m. The ban on fishing inside safety zones, if located inside one or more of the significant fishing areas, will have a negative impact on fisheries as it will reduce fishing pressure and increase pressure in other areas where fishing is allowed. However, if the measures described in chapter 10 are carried out, this impact is to be assessed as **negligibly negative due to**

impact mitigation

8.3.2.7.1.4 Platform removal impact

✓Positive impact on fisheries is expected after platform removal due to restored availability of fishing areas. By opening the areas for fishing, the pressure on neighbouring areas caused by the ban on fishing will be removed.

Positive impact is expected due to the restored availability of fishing areas.

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term	Medium-term	Long-	Cumulative	Synergistic
Impact of increased marine traffic	-	✓	⊘	⊘	⊘	⊘	✓	⊘	⊘
Seismic surveying noise impact	-	✓	⊘	⊘	✓	⊘		⊘	⊘
Impact due to installation of platforms and accompanying infrastructure, and exploration	–	✓	⊘	⊘	⊘	⊘	✓	⊘	⊘
Impact due to pipeline and supporting infrastructure	-	✓	⊘	⊘	⊘	⊘	✓	⊘	⊘
Impact of platform removal	+	✓	⊘	⊘	⊘	⊘	✓	⊘	⊘

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.7.2 Tourism

8.3.2.7.2.1 Impact of platforms on "sun and sea" tourism

The negative impacts of FPP on the "sun and sea" tourism could primarily manifest in landscape features being disturbed by the installation of platforms in areas of very high tourist appeal. Tourist perception of hydrocarbon production platforms is mostly negative and the visibility of platforms from the mainland is perceived as disturbing the view which may significantly reduce an area's attractiveness for the tourism.

During the Environmental Impact Assessment, potential negative impacts of platforms on the landscape and tourism must be analysed in detail, in particular in relation to their visibility from beaches and tourist settlements. Provided that measures described in chapter 10 are carried out, this impact is assessed as **negligibly negative due to impact mitigation measures**.

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term	Medium-term	Long-	Cumulative	Synergistic
Impact of platforms on	-	✓	⊘	✓	⊘	⊘	✓	⊘	⊘

Key: + positive impact, - negative impact, ✓ applicable, ⊘ not applicable

8.3.2.7.2.2 Impact of platforms on nautical tourism

The negative impacts of FPP on nautical tourism could primarily manifest in landscape features being disturbed by the installation of platforms in areas of very high appeal for nautical tourism. This primarily implies the areas of national parks

"Kornati", "Krka" and "Mljet", nature parks "Telašćica" and "Lastovo Archipelago", as well as areas of high appeal for nautical tourism such as the wider areas of the islands of Žirje, Šolta, Brač, Hvar, Korčula, Vis, Lastovo and the area connecting them. The attractiveness of the area for nautical tourism is closely linked to landscape features, which is why the installation of platforms, mostly perceived as negative by the nautical tourists, may cause them to avoid the areas where platforms are visible.

During the Environmental Impact Assessment, potential negative impacts of platforms on nautical tourism must be analysed in detail, in particular in relation to their visibility from points of highest nautical appeal and from the busiest nautical routes. However, if the measures described in chapter 10 are carried out, this impact is to be assessed as **negligibly negative due to impact mitigation.**

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term term	Medium-term	Long-	Cumulative	Synergistic
Impact of platforms onnautical	-	■	⦸	■	⦸	⦸	■	⦸	⦸

Key: + positive impact, - negative impact, ■ applicable, ⦸ not applicable

8.3.2.7.3 Maritime shipping, maritime transport and waterways

8.3.2.7.3.1 The impact of FPP implementation on shipping, maritime transport and waterways

In terms of impact on maritime transport and vise versa, hydrocarbon exploration and production can be an activity covering larger areas in a certain period of time (exploration vessel surveys), an activity carried out for a period of time at the same location (exploratory drilling), or long-term occupation of an area during hydrocarbon production, considering that no other operations are allowed in the 500 m zone surrounding the platform. In accordance with the FPP, the exploration stage can have a duration of up to 5 years (option extended for another year), and the production stage a maximum of 25 years.

When operating and surveying, exploration vessels navigate across an area defined in advance, using low speeds (up to 5 knots) and a long towing line, usually between 3 – 8 km or even longer. Exploratory drilling is performed by rigs which remain at the same location for a longer period of time. As a rule, such units must not be forced to abandon the exploratory drilling site. Interference with transport routes may occur during exploration. In this regard, drilling which takes place in the immediate vicinity of longitudinal routes according to the FPP is a sensitive matter, considering that a large number of vessels operate on the route and have large amounts of kinetic energy, and harmful consequences can occur in case of impact.

During the planned operations of the FPP requests will be submitted for modifications of transport routes in the Adriatic, and the bodies competent for their approval will find them acceptable, therefore the impact on shipping, maritime transport and waterways is estimated as **negligibly negative due to impact mitigation measures.**

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term term	Medium-term	Long-	Cumulative	Synergistic
The impact of FPP implementation on shipping, maritime transport and waterways	-	■	⦸	⦸	⦸	■	⦸	■	⦸

Key: + positive impact, - negative impact, ■ applicable, ⦸ not applicable

8.3.2.8 Waste management

Waste products, such as mud and well cuttings, waste and formation water, will be discharged into the sea during the exploration drilling. However, as these waste products undergo a purification process before being discharged into the sea, which is governed by applicable national and international regulations, their significant impact on marine pollution is not expected. This impact is therefore defined as a **negligible negative impact**.

However, one may expect that during the exploration and production period in each block awarded to the concessionaire under the contract one or more wells will be drilled, thus making the quantity of mud and well cuttings discharged into the sea, as well as the seabed surface on which mud and well cuttings will precipitate, proportional to the number of wells. This will result in changes of the seabed contours, barium concentrations and, potentially, concentrations of other metals. These changes occur primarily within the area approximately 500 m around each drilling platform and can last for several years.

In order to maintain good quality of marine environment concentrations of heavy metals in marine environment during the execution of these activities should be monitored. Chapter 11 defines mandatory monitoring of pollutants in the marine environment in order to monitor possible impact of waste products discharged into the sea.

Impact	Positive/negative	Direct	Indirect	Remote	Short-term	Medium-term Permanent		Cumulative	Synergistic
The impact of exploration and production	-	■	⦸	⦸	⦸	⦸	■	⦸	⦸

Legend: + positive impact, - negative impact, ■ impact with such feature, ⦸ impact without such feature

8.3.2.9 Socioeconomic characteristics

8.3.2.9.1 Financial model in the Republic of Croatia

Under the Regulation on the fee for the hydrocarbon exploration and production (Official Gazette no. 37/14 and 72/14), the Croatian Government opted for a model based on the production distribution. The Regulation lays down the method of determining, the amount and distribution proportion of the fee for hydrocarbon exploration and production. The total fee includes seven components, six of which are payable in the form of pecuniary fee, while one is based on the production distribution.

The components of the total fee for hydrocarbon exploration and production, or the financial model applicable in Croatia, are:

1. a pecuniary fee for approved block area defined by the entry in the registry of blocks with the ministry responsible for mining, established under the provisions of applicable mining acts, in the amount of HRK 400.00 / km2 per year,
2. a pecuniary fee for production field area defined by the entry in the registry of production fields with the ministry responsible for mining, established under the provisions of applicable mining acts, in the amount of HRK 4,000.00 / km2 per year,
3. a pecuniary fee for the conclusion of a contract between the investor and the Croatian Government under the issued license - it cannot be less than HRK 1,400,000.00, and it is also one of the elements of the work programme covered by an overall assessment of the investor's offer in a bidding process,
4. a pecuniary fee for recovered amounts of hydrocarbons – 10% of the market value of the total amount of recovered hydrocarbons,
5. an additional pecuniary fee for the realised hydrocarbon production – for the realised production of oil: HRK 1,400,000.00 at the recovery beginning and HRK 1,400,000.00 for each 50,000 barrels, up to the cumulative production amount of 200,000 barrels; for the realised production of gas: HRK 900,000.00 at the recovery beginning and
   HRK 900,000.00 for each 25,000 barrel equivalents, up to the cumulative production amount of 100,000 barrel equivalents,
6. a pecuniary fee for administrative costs – HRK 600,000.00 during the first year of the license and contract period, with a 4% annual increase,
7. the distribution of the recovered amounts of hydrocarbons – the distribution of the recovered amounts of hydrocarbons in percentage after the reimbursement of investor's costs, within the descending scale, depending on the calculated R-factor.

R-factor is calculated according to the formula "R = X/Y", whereby:

"X" refers to the amount of realised cumulative net income of an investor from recovered amounts of hydrocarbons under an issued license and concluded contract between the Croatian Government and the investor in the previous quarter. Net income is the total pecuniary amount earned by the investor for the reimbursement of costs and its share of income from the distribution of recovered amounts of hydrocarbons under the issued license and concluded contract, net of operating costs.

"Y" refers to the amount of cumulative capital costs from recovered amounts of hydrocarbons under an issued license and concluded contract between the Croatian Government and the investor in the previous quarter. Cumulative capital costs refer to all development and production costs under the issued license and concluded contract.

The percentage of the recovered amounts of hydrocarbons' distribution to which the investor is entitled shall be calculated according to the following table (Table 8.8):

Table 8.8 The percentage of the recovered amounts of hydrocarbons' distribution to which the investor is entitled

R-factor value	The percentage to which the investor is entitled
0 < R < 1.0	90%
1.0 < R < 1.5	80%
1.5 < R < 2.0	70%
R > 2.0	60%

8.3.2.9.2 An example of financial benefits for the Republic of Croatia (source: Croatian Hydrocarbon Agency)

The selected financial model in the Republic of Croatia is the basis for the inflow of funds into the Croatian budget. As the amount of recoverable reserves and the number and location of wells, as well as the profile, duration and other characteristics of production cannot be determined at such early stage, an illustrative example of one block for the whole Adriatic explains the possible financial impact of exploration and production. The above example has been developed in accordance with the provisions of the draft Contract on the exploration and hydrocarbons' production distribution, published on the website of the Croatian Hydrocarbon Agency (www.azu.hr), Regulation on the fee for hydrocarbon exploration and production (Official Gazette no. 37/14 and 72/14) and applicable tax regulations.

The analysis included a block in the Central Adriatic, with an average sea depth of 200 m, an area of 1,300 m2 and a production field area of 200 km2. In order to achieve the total income of HRK 5 billion from the production in that block, the field with recoverable reserves of hydrocarbons amounting to 10 million barrels of oil equivalents should be produced. The calculation has been made for a period of 20 years (5 years of research work, 15 years of production), at the assumed price of USD 83.00 per oil barrel, or USD 51,00 per barrel of oil equivalent for gas respectively. Total investment in one block will generate a cash flow of over HRK 2.75 billion (total income from production amounting to HRK 5 billion net of estimated capital and operating costs amounting to HRK 2.25 billion), whereby the Republic of Croatia will earn 58% of the total cash flow, or HRK 1,6 billion respectively. The benefits for the Republic of Croatia primarily refer to the payment of pecuniary fee for the recovered amounts of hydrocarbons amounting to 10% of the total value of recovered hydrocarbons, as well as the benefits in terms of the production distribution (the Contract on the exploration and hydrocarbons' production distribution defines the model of production distribution in such a way that the appropriate percentage of the remaining recovered amount of hydrocarbons, after the deduction of the pecuniary fee for the recovered amounts of hydrocarbons and the reimbursement of the investor's costs in accordance with the provisions of the contract, is distributed between the investor and the Republic of Croatia).

Explanation of the model (Figure 8.5):

Total income: the market value of the total amount of recovered hydrocarbons, at the assumed price of USD 83.00 per oil barrel, or USD 51,00 per barrel of oil equivalent for gas respectively.

Capital costs: include all infrastructure costs providing benefits during a number of years, and not only in the year the investment was made. Capital costs refer to well drilling, equipment installed on well for the purpose of production, connecting pipelines of mining facilities for the collection and transport of hydrocarbons, buildings and facilities used for mining operations and all other investments for the purpose of hydrocarbons production.

Operating costs refer to the costs of maintaining current production and work flow.

All fees, except the fee for recovered amounts of hydrocarbons, include the following fees laid down by Regulation on the fee for hydrocarbon exploration and production (Official Gazette no. 37/14 and 72/14) – a pecuniary fee for approved block area, a pecuniary fee for production field area, a pecuniary fee for the conclusion of a contract between the investor and the Croatian Government under the issued license, an additional pecuniary fee for the realised hydrocarbon production, a pecuniary fee for administrative costs.

The fee for recovered amounts of hydrocarbons refers to 10% of the market value of the total amount of recovered hydrocarbons.

Cost reimbursement: costs reimbursed to the investor out of the value of the remaining production, after the deduction of the amount of the fee for recovered production amounts, taking into account the upper limit of cost reimbursement in the amount of 50%.

Corporate income tax: the tax which companies pay on the profit, i.e. the difference between revenues and expenditures.

Withholding tax: payment of dividends or shares in profits to non-resident legal entities from the profits.

Total cash flow of an investment: the difference between the total income from the production and capital and operating costs of the investment.

The cash flow of the Republic of Croatia: the sum of all benefits for Croatia from the investment (the fee for the recovered amounts of hydrocarbons, other pecuniary fees defined by the Regulation, a share in profits from the production, taxes).

Investor's cash flow: the difference between all positive (cost reimbursement and a share in profits from the production) and negative cash flows (capital and operating costs, other pecuniary fees defined by the Regulation, taxes).

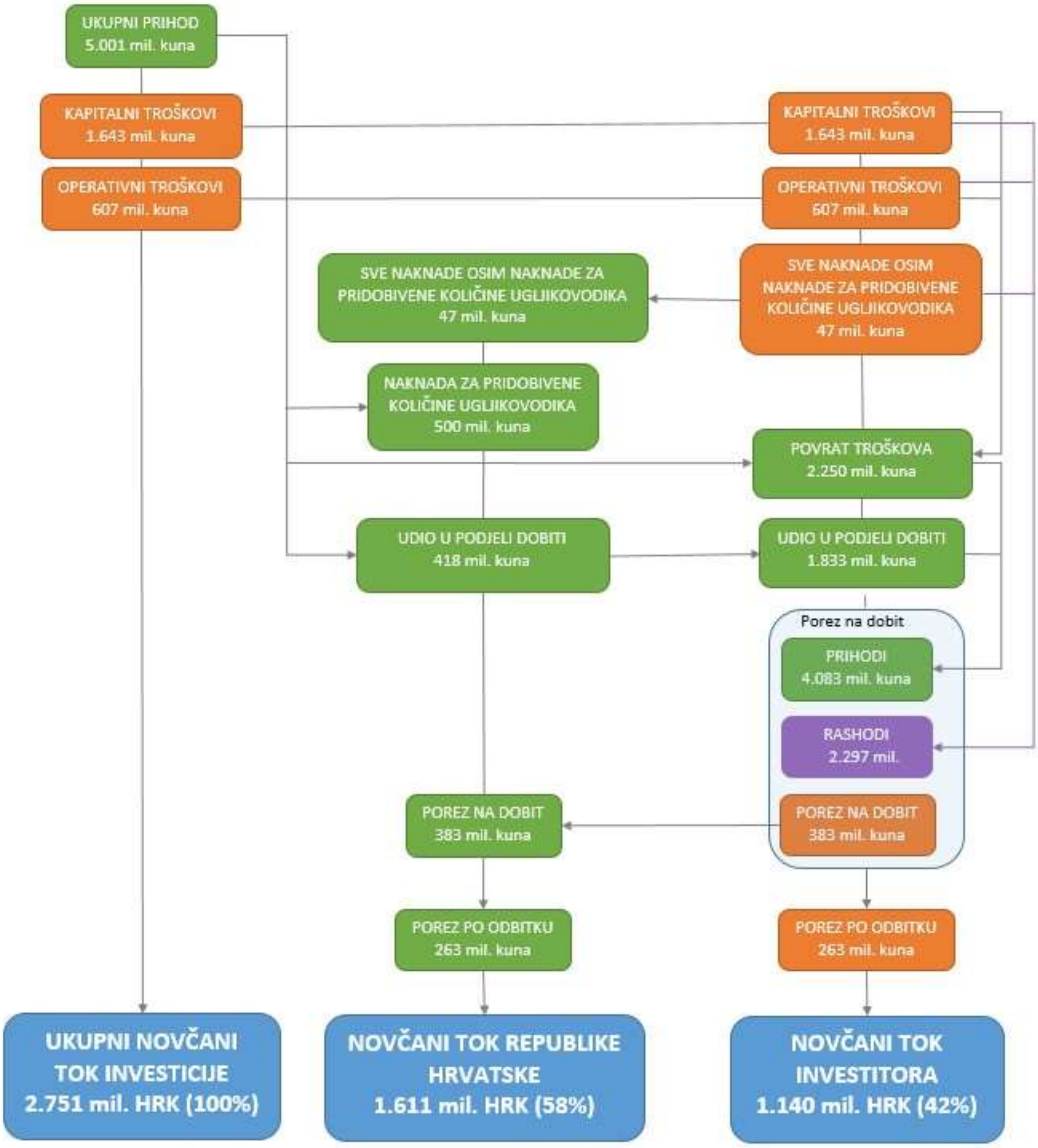


Figure 8.5 An example of a financial model with recoverable reserves of hydrocarbons amounting to 10 million barrels of oil equivalents

with the project period from 2015 to 2035 (source: Croatian Hydrocarbon Agency)

Furthermore, the financial benefits for the Republic of Croatia include budgetary income from direct taxes and the payment of other fees prescribed by Regulation on the fee for hydrocarbon exploration and production, including the pecuniary fee for approved block area, the pecuniary fee for production field area, the pecuniary fee for the realised hydrocarbon production and the pecuniary fee for administrative costs.

Following all of the above, taking into account that the Republic of Croatia does not bear the costs of exploration, development and production of hydrocarbons, estimated total direct financial benefits for the Republic of Croatia amount to 58% of the total profit from the project. Or, as shown in the example, to HRK 1.6 billion in the period between 2015 and 2035, of the total profit from the project amounting to HRK 2.75 billion. Also the indirect impact on the state budget from value added tax, the impact of taxes and contributions from and on earnings of workers employed by the investor, and other fiscal and quasi-fiscal payments and other fees, cannot be neglected.

8.3.2.9.3 Economic impacts

Economic impacts of hydrocarbon exploration and production differ in various implementation stages, but as they refer to foreign direct investments, their impact on the gross domestic product of the state is important, as well as the contribution to the overall modernization of the economy of the country receiving the investment. Foreign direct investments have the clearest impact on growth in the manufacturing and related services sector and contribute to increasing the productivity of the economy and the introduction of new business processes, the transfer of technology and know-how, management skills and training employees.

Based on the experience and current costs of offshore hydrocarbon exploration and production, investments during the exploration and production at the research stage can amount to HRK 300 million to 1.1 billion, and to several dozen billion at the hydrocarbon development and production stage, depending on the form of the final solution for the production and plant type. The final production method and selection of production plant type for each block will be based on various factors such as sea depth, distance from shore, fluid characteristics, the existing infrastructure, the amount of resources, shape and size of fields, techniques for production improvement and the availability of local resources and workforce.

8.3.2.9.3.1 Direct economic impacts

The direct impacts of exploration and production can be expected in industries directly related to hydrocarbon exploitation, but also in indirectly related industries. Certain activities during hydrocarbon exploration and production affect gross domestic product and employment differently. Each stage of hydrocarbon exploration and production process has a specific impact on the economy of a state where activities are performed.

8.3.2.9.3.2 Direct economic impacts in the hydrocarbon exploration period

Based on global practices and applicable comparisons, at the exploration stage the necessary investment can amount to HRK 300 million to 1.1 billion in each block. The exploration stage economic impact is primarily reflected in the development in logistic and industrial support to seismic surveys and exploration drilling in the Adriatic. Offshore exploration will thus result in the development of the port and other transport infrastructure, greater utilization of maritime and shipping services, and have positive effects on employment.

During seismic surveys and other possible analyses, as well as exploration drilling one or more supply bases in an Adriatic port, strategically located in relation to blocks, should be established. It will include logistic support offices, a port for supply and crew ships, a storage area for pipes and other equipment, storage tanks for fuel and liquids, telecommunications stations, installations for the supply of special cement materials and mud, a helicopter base for transporting staff to and from a drilling plant, waste disposal systems, food preparation services, cleaning, etc.

8.3.2.9.3.3 Direct economic impacts in the hydrocarbon production field development exploration period

The development stage is the most intense part of the hydrocarbon production process due to the engagement of the largest number of workers and supporting activities related to the functioning of the process. Therefore, its effects have a significant impact on employment, as well as gross domestic product, resulting in significant benefits for the Croatian economy. Taking into account experienced and highly skilled workforce, available port facilities, shipbuilding experience and a long tradition of hydrocarbon production in the Republic of Croatia, a significant part of needs for the purpose of hydrocarbon exploration and production are expected to be met in Croatia.

The example of the development of a medium-depth block in the Adriatic shows that the investments necessary for the installation of two fixed production and processing jacket platforms with eight legs fixed to the seabed, and the hydrocarbon transportation system, can amount to approximately HRK 18.5 billion, based on global practices in developing installations at similar depths and current market prices. Such plant is intended for the case of medium reserve quantities and includes underwater installations, fixed steel platforms, floating production systems and installations for loading hydrocarbons onto tankers. According to examples of developed industrial countries and countries with a long history of hydrocarbon production, the best practice would be to retain up to 60% of total investments within the Croatian borders, meaning that up to HRK 11.1 billion of investments could be directly channelled into the Croatian economy for the development of a medium hydrocarbon field.

In order to support the construction of mining facilities in the Adriatic and the merging stage during the development activities, additional office and storage facilities should be established in the country. When such plants become operational, the storage will be used for storing new supplies and spare parts. Office facilities will become an operational location for providing support and a place for employees in charge of daily operations.

8.3.2.9.3.4 Direct economic impacts in the hydrocarbon production period

The production stage is extensive in the first part during the construction of production plants which engage human resources and shipyard infrastructure, thus having a positive impact on gross domestic product. The later phases of the production stage are less intensive, but still including favourable impact on employment.

The above examples of the financial model show that the cumulative income of the Republic of Croatia in the production period from the fee for recovered amounts of hydrocarbons, the production distribution, the fees laid down by Regulation on the fee for hydrocarbon exploration and production and direct taxes, will exceed HRK 1.5 billion in case of only one block (at the assumed hydrocarbon production amount of 10 million barrels of oil equivalent, at the price of USD 83.00 per oil barrel, or USD 51,00 per barrel of oil equivalent for gas respectively during the production period from 2021 to 2035). The supply base will also be used to transport equipment and supplies to offshore mining facilities. Besides logistical needs, it is realistic to expect that the income of industries producing parts and performing overhaul of hydrocarbon production plants, will increase due to the activities in the Adriatic. Needs for various types of equipment and services (electrical, construction, telecommunications, metal processing, etc.) are part of the activities required during the construction of the hydrocarbon production plants. Operating costs (the cost of processing fluids, transport costs, power supply, fuel, the maintenance of production platforms' fixed structures, the maintenance of production equipment at wells, lubricants, etc.) during the production may amount to additional HRK 1.5 billion per year according to the example of the plant from the chapter on the development.

8.3.2.9.3.5 Indirect economic impacts

Indirect economic impacts are also significant, although more difficult to measure. They are reflected primarily in the benefits for suppliers and industries directly related to the hydrocarbon exploration and production activities in the Adriatic. Within this category an increase in demand for power supply, construction materials and the construction of steel structures, fuel, petrochemical products, etc., can be realistically expected. Indirect impacts also include the increase in purchasing power resulting from income growth from the hydrocarbon exploration and production activities, resulting in greater demand for consumer goods and other services. A possible decrease of energy costs in the Republic of Croatia resulting from lower transport costs of hydrocarbons recovered in the Adriatic to destinations within Croatia should also be mentioned. Since the hydrocarbon market has been liberalised, it is important to note that the production growth is unlikely to result in a decrease in the price of raw materials, but the proximity of its location results in lower transport costs to final destination, thus reducing the energy costs for the end consumer. Lower energy costs may be very beneficial to the state's general economy in terms of competitiveness growth and the reduction of end-user prices of services and goods.

8.3.2.9.4 Public opinion

In the period from 29 August 2014 to 29 September 2014. there was an online public consultation about the Decision on the Development of the Framework Plan and Programme for Works on Hydrocarbon Exploration and Production in the Adriatic and the Decision on Conducting Strategic Environmental Assessment of the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic. Twenty parties who agreed to make their opinions public, participated in the consultation. Private individuals oppose hydrocarbon exploration and production in the Adriatic on the grounds that it is the economic activity which threatens biodiversity, clean sea and harms other economic activities. Comments from associations, besides the explanation of possible adverse impact, include complaints about the deficiencies in the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic, as well as the content deficiencies in the Strategic Study and the Decision on Conducting Strategic Environmental Assessment of the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic.

During the course of strategic assessment and following the decision of the expert commission the Strategic Study will be published for public debate. At that stage it is realistic to expect public comments and suggestions, which can be incorporated into the final version of the study and become an integral part thereof. Then, a table with public attitude on the FPP will be possible.

The impact	Positive/negative	Direct	Indirect	Remote	Short-term	Medium-term Permanent		Cumulative	Synergistic
Income increase	+	🗐	🗐	⊘	⊘	🗐	⊘	🗐	🗐

Legend: + positive impact, - negative impact, 🗐 impact with such feature, ⊘ impact without such feature

8.3.2.10 Impact of the physical characteristics (waves and sea currents) on the FPP implementation

8.3.2.10.1 Meteorological and oceanographic environmental aspects

Meteorological and oceanographic elements and phenomena also include environmental elements, relating to air and sea pollution from exhaust gases, waste products (petroleum, fuel oil , oil), and in cases of ship accidents with harmful substances (petroleum, fuel oil, oil, various chemical compounds and others) as cargo or damage and fires in the port terminal facilities or in the area of waterway terminals, ports and navigable routes, and of course including undesirable consequences on and around sea platforms.

Ships as atmosphere pollutants are mentioned the least because they navigate "somewhere far away" and more importance is attributed to the problem of petroleum, fuel oil and oil discharge into the sea.

Dopants spread in different ways. Gasification (diffusion) occurs in stable stratified sea at extremely weak sea currents. In such case dopants spread the least, while the largest amounts (concentrations) of dopants will occur near discharge source. Strong horizontal currents transmit pollutants downstream, i.e. there is advection. In such case the amount (concentration) of dopants will decline rapidly while moving away from the discharge source (thus increasing at a so far "clean" location) and the dopants will spread downstream. The retention time or concentrations of certain dopants are not equal (from several hours to several months). Some dopants in the air come in contact with the Earth's surface with precipitation, thus causing pollution, others decompose with time, while many of them very effectively attack and decompose certain important constant air or water ingredients by chemical processes. Fuel combustion consumes large amounts of oxygen, thus violating ecological balance.

Winds, waves, sea currents and changes most directly determine the direction and speed of the spread of any contamination, which depends on the particular case at hand. Sea currents which largely occur in enclosed seas such as the Adriatic are an example. In case of maritime disaster, vast areas of the Adriatic are threatened by pollution. Then, the knowledge of sea currents is very helpful. If several large tankers carrying petroleum or similar cargo navigate the Adriatic every day, the risk of accidents will be significant. Similar applies to a well on which technical difficulties and the discharge or breakthrough from the depth/seabed of oil may occur.

In case of sea pollution from waste products (petroleum, fuel oil, oil, different chemical substances and other), their spreading depends on meteorological and oceanographic elements and phenomena, except in degradation processes. We should not forget that people often consider the sea a waste dumping area! Environmental issues are often neglected on open seas and oceans. They are still left to the natural processes of degradation of certain waste products. In case of waste products (oil slicks) moving close to shores, they are collected, neutralised or destroyed. At that point meteorological and oceanographic analyses and forecasts allow monitoring of the pollution, including appropriate advice for its removal.

8.3.2.10.2 Impact of waves

Big waves may affect platforms and associated ships. Waves, especially higher than 2 or 3 m, affect the ships by changing the speed and direction of ship navigation, heavy slant and overloads on board, including direct damage. Sharp decline and sudden prance, including extreme tilting, are the most dangerous and obvious. A wave will not have the same effect on a little or big ship, meaning a ship will behave differently in small or big waves. This means that there is a connection between waves of certain properties (wave height, length, period, wave refraction, direction and speed, etc.) affecting a ship of certain properties (shape and dimensions of underwater and above water parts of the ship, speed, cargo, etc.) depending on the depth of the sea (or rather shallow water) and the shape of the coastline and islands near waterways. Thus, 2 to 4 meter waves represent a major threat to small ships, while big, a hundred or more meters long ships, almost do not feel their impact. On the other hand, several hundred meter high waves cause big difficulties to the big ship, while the small one navigates easily through them. Wavelength plays a very important role, especially when it is of the same order of magnitude as ship length. If a ship's bow and stern are supported by two wave peaks, while the middle part of the ship is in the valley of the wave, or when the bow and stern are in the valley, and the middle part of the ship is at the peak, there will be large loads to and transverse bending of the ship. Such overloads and bending will probably go unnoticed on a new ship, but microcracking still occurs and after some time, it becomes more obvious, even resulting in ship fractures.

Waves reduce a ship's speed depending on the height and direction of the waves. The speed decreases as waves grow bigger. A ship navigating towards oncoming waves loses speed much faster than in case of waves hitting the ship on the side. The least loss is when the waves hit the ship on the back. It is worth mentioning that the ship starts to navigate slightly faster when small waves, up to 1 meter high, hit it on the back.

In general, the waves do not facilitate, but to a greater or lesser extent hinder navigation. Due to the complexity of waves' actions on the ship, for each ship there are certain recommendations and regulations for ship management in cases of high seas. The basic principle of navigation is to reduce the speed of the ship and point its bow towards the oncoming waves. In case the bow cannot be pointed towards the oncoming waves, the stern may also be pointed towards them. The worst, and even dangerous, thing to do is to expose the ship's side to the oncoming waves. Sometimes the bow can be lean away from the direction of the oncoming waves, but not more than 10 to 20 °. This is done in case of resonance phenomena on-board the ship. Namely, by reducing (and only exceptionally by increasing) the ship's speed and slight turning away from the direction of the oncoming waves resonant phenomena should be mitigated. Otherwise, the speed needs to be reduced, and sometimes the ship needs to stop (engines need to be turned on), but it is important to keep control of the ship, i.e. one should "listen" to the ship's rudder.

If stormy weather with high waves is expected to hit and there is no access to the protected part of a port, a larger ship at berth or at anchor should set sail, as this reduces the risk of direct damage to the ship.

Platforms are in a way part of the land or ship. It all depends on how they are designed (anchored) and their location at sea. In this case the Northern Adriatic is referred to as shallow sea (20 – 150 m), while the Southern Adriatic is referred to as deep sea (200 – 1233 m). During several days of jugo wind blowing relatively high waves of 3 to 5 m may develop. The highest waves recorded so far at open sea were 10.8 meter high. It occurred on a platform in the Northern Adriatic. Although bura wind is known for its high speed, due to the blowing on the coast, waves are not so high. The highest waves recorded in the North Adriatic were 7.2 meter high. Statistically, during the centennial return period in the Adriatic the height of the highest wave is 13.5 m. Besides the height, there are other characteristics of the waves.

The waves on platforms have similar effects as the ones onshore. Protection includes removing all items and fixing them reliably. It should be noted that the height of the working space at a platform must meet the specified wave hits (besides wind). The height should preferably be above the wave reach height, which is not always easy to implement, both technically and financially.

8.3.2.10.3 Impact of sea currents

Sea currents in the Adriatic, either surface or deep, are not especially strong, but the transfer of certain substances may still occur, and if those are pollutants, the situation will not be harmless to the environment.

Sea currents generally occur at the surface or in the depth. Along the eastern coast of the Adriatic there is incoming (NW) current, more pronounced in winter, bringing water from the Levantine Sea, while along the western coast the outflow of water is more pronounced in summer. These surface currents are related to the distribution of the thermohaline properties of water (temperature, salinity), i.e. density, but there is also a common impact of wind changing direction. In summer mistral (NW wind) is important, and in winter jugo wind. A closed circuit in the southern part of the Adriatic, where the sea is the deepest, should be mentioned. Speed of surface currents is 0.55 to 0.80 ms^{-1}, while the largest exceeds 1.0 ms^{-1} along Kamenjak (in the south of the Istrian peninsula). The above is essential for transmission of pollution, regardless of whether it includes solid or liquid substances. Gases, less dense than water, come out into the atmosphere and spread through other processes (wind, diffusion, etc.). The density of solid or liquid substances in relation to water means that less dense substances float at or near the water surface and are transmitted by surface currents together with diffusion processes. Solid or liquid substances more dense than water, sink quickly or slowly carried by currents in the depths of the sea. Certain proportion of reaches the bottom of the sea, where it precipitates, and another proportion moves farther where it either precipitates or "dissolves" in water, which becomes contaminated. Therefore, deep way water flows play an important role.

In the deeper layers of the Adriatic the flow is influenced by thermohaline gradients. Along the eastern coast there is the entry into the Levantine waters of high salinity, while in layers along the bottom of the Strait of Otranto there are outflows of south Adriatic water. Thick north Adriatic water flows to the Central and Southern Adriatic in the bottom layer, at speeds up to 0.20 m/s, changing the thermohaline properties of the Central and Southern Adriatic.

8.3.2.11 8.3.2.11 Accidents

Potential accidents during hydrocarbon exploration and production which should be considered are (1) oil spills and (2) discharge of hydrogen sulphide (H2S). Oil spills may occur at any stage of hydrocarbon exploration and production. Potential sources are: oil spills resulting from blowout, (2) diesel fuel spills, (3) oil and synthetic mud spills and (4) fluid leakage from seismic cables.

Crude oil spill resulting from blowout

Crude oil spill may occur as a result of blowout. A blowout is an uncontrolled flow of layer fluids in a wellbore, and sometimes even to the surface. The fluid flowing out of the well uncontrollably may consist of salt water, oil, gas, condensate or a mixture thereof. During drilling, each well is equipped with a blowout preventer (BOP), mounted on the mouth of the well to prevent leakage of oil or gas under high pressure. Blowout risk may be estimated on the basis of global statistics concerning the occurrence of blowouts during offshore drilling. According to Holand (1997), the average frequency of blowouts during drilling in the Gulf of Mexico is 0.0059 blowouts per drilled well or one blowout in 169 drilled exploratory wells. Similarly, between 1996 and 1999 there were approximately 5 blowouts in 1,000 wells or 1 blowout in 200 wells in the Gulf of Mexico (MMS, 2001). In case of the North Sea, the frequency is 0.00629 blowouts per drilled well or 1 blowout in 159 drilled exploratory wells (Holand, 1997). Most blowouts do not result in crude oil spills. For example, out of 151 blowouts in the Gulf of Mexico between 1971 and 1995 only 18 (i.e. 12%) resulted in crude oil spill. During those blowouts approximately 159 m3 (1000 bbl) of oil and condensate were spilled (MMS, 2001). Between 1964 and 1999 almost all crude oil spills which occurred during drilling and production of the US continental shelf (94%) were less than or equal to 0.159 m3 (1 bbl) (Anderson and LaBelle, 2000).

Data for the Gulf of Mexico and the Norwegian and British waters are generally better documented than for other areas of the world and Table 8.9 presents an overview of blowouts by operational phases 237 blowouts which occurred in the period from 1 January 1980 until 1 January 2008.

Table 8.9 The number of blowouts during different operations (source: http://www.sintef.no/home/projects/sintef-technology-and-society/2001/SINTEF-Offshore-Blowout-Database/)

Area		The Gulf of Mexico		The Norwegian and British waters		Total	
Exploratory drilling		53	30.6%	9	14.1%	62	26.2%
Development drilling		50	28.9%	31	48.4%	81	34.2%
Non-conventional drilling		–	–	2	3.1%	2	0.8%
Completion		12	6.9%	6	9.4%	18	7.6%
Maintenance		35	20.2%	9	14.1%	44	18.6%
Production	External cause*	6	3.5%	1	1.6%	7	3.0%
	Without external cause*	10	5.8%	2	3.1%	12	5.1%
Wirelining		2	1.2%	–	–	2	0.8%
Unknown		5	2.9%	4	6.3%	9	3.8%
Total		173	100%	64	100%	237	100%
*External causes mainly refer to storm, military activity, ship collision, fire and earthquake.							

So far there is no database at the European level for the collection and exchange of data on different types of accidents. However, there are many databases in different Member States of the EU developed mainly due to legal requirements, containing data on accidents in their continental shelves.

The table below indicates the number of wells entered into the SINTEF database and frequency of blowouts during offshore hydrocarbon exploration and production. SINTEF is not a regulatory body, but the largest independent research organization in Scandinavia which supports law enforcement in Norway. SINTEF Offshore Database includes 573 blowouts which have occurred during offshore hydrocarbon exploration and production across the world since 1955. Data refer to the North Sea and the Gulf of Mexico, and can be applied to other areas of the world (source: International Association of Oil& Gas Producers, Blowout frequencies, Report No. 434-2, March 2010).

Table 8.10 The frequency of blowouts during different operational stages

Operation	Blowout frequency			Unit
	Average	Gas	Oil	
Exploratory drilling (13,762 wells)	3.1×10^{-4}	3.6×10^{-4}	2.5×10^{-4}	Per well
Development drilling (22,833 wells)	6.0×10^{-5}	7.0×10^{-5}	4.8×10^{-5}	Per well
Completion (20,328 wells)	9.7×10^{-5}	1.4×10^{-4}	5.4×10^{-4}	Per operation
Wirelining (358,941 operations)	6.5×10^{-6}	9.4×10^{-6}	3.6×10^{-6}	Per operation
Coiled tubing	1.4×10^{-4}	2.0×10^{-4}	7.8×10^{-5}	Per operation

Snubbing	3.4×10^{-4}	4.9×10^{-4}	1.9×10^{-4}	Per operation
Workover (19,920 operations)	1.8×10^{-4}	2.6×10^{-4}	1.0×10^{-4}	Per operation
Producing wells (including external causes) (211,142 well years)	9.7×10^{-6}	1.8×10^{-5}	2.6×10^{-6}	Per well year

The data shown in the table can be used for risk assessment. For example, for a hypothetical platform with 8 producing oil wells, with one workover and two wirelinings per year, the blowout frequency is calculated as follows:

(8 wells x 2.6×10^{-6}) + (1 workover x 1.0×10^{-4}) + (2 wirelinings x 3.6×10^{-6}) = **2.44×10^{-5}**.

Regardless of the low frequency, accidents occur, risks exist and need to be controlled. In this context, special attention should be paid to blowouts, fires, explosions causing serious consequences and rare events with considerable consequences. Examples of major offshore accidents according to total/serious damage to platforms, the number of fatalities or amount of spilled oil include accidents on platforms (Christou and Konstantinidou, 2012): Alexander L. Kielland (the North Sea, 1979), Ixtoc I (the Gulf of Mexico, 1979), Piper Alpha (the North Sea, 1988), Ekofisk B (the North Sea, 1988), Adriatic IV (Egypt, 2004), Montara (Australia, 2009) and Deepwater Horizon (the Gulf of Mexico, 2010).

Historical data show that the two largest accidental oil spills were caused by a blowout (Table 8.11).

Table 8.11 10 biggest accidental oil spills in the last 50 years (COM (2011))

Tanker/platform	Location	Type	Year	Spilled oil (in tonnes)
Deepwater Horizon	USA – the Gulf of Mexico	Blowout	2010	666,400
Ixtoc 1	Mexico	Blowout	1979	476,000
Atlantic Empress	Trinidad and Tobago,	Tanker	1979	287,000
Nowruz Oill Field	Iran	Blowout	1983	272,000
ABT Summer	Angola	Tanker	1991	260,000
Castillo de Bellver	South Africa	Tanker	1983	252,000
Amoco Cadiz	France	Tanker	1978	223,000
Haven	Italy	Tanker	1991	144,000
Odyssey	Canada	Tanker	1988	132,000
Torrey Canyon	UK	Tanker	1967	119,000

The disaster of Deepwater Horizon platform in 2010, during the drilling of Macondo 252 well in the Gulf of Mexico is so far the last of many tragedies, blowouts and oil spills. Macondo 252 well was supposed to be an exploratory well at approximately 1,500 m, and at the same time it was designed as a producing well in case of proof of sufficient hydrocarbon reserves. Unfortunately on 20 April 2010, following a series of bad decisions, human errors and non-functioning security barriers, gas found its way to the surface and caused an explosion and fire. The consequences were dramatic: 11 fatalities and 17 injured. As the firefighting efforts were not successful, the platform sank in the morning of 22 April 2010. All attempts to close down the well were unsuccessful so the oil was spilling on the seabed lasted another 87 days. Approximately 795 m3 (210,000 gallons) of oil was spilling every day, and in just three days it covered 1,502 km2. Subsequent analyses determined direct causes which could and should have been prevented on time, and which led to the accident at Deepwater Horizon platform. The direct causes of the accident (Tinmannsvik et al., 2011; BP, 2010; Øien & Nielsen, 2012) are: (1) the cement outside the production casing and at the bottom of the well (at the “shoe track”) did not prevent influx from the reservoir,

(2) the crew misinterpreted the result of the negative pressure test and considered the well as being properly sealed, (3) the crew did not respond to the influx of oil and gas before hydrocarbons had entered the riser, (4) the crew routed the hydrocarbons to the mud gas separator instead of diverting it overboard, (5) the fire and gas system did not prevent ignition, (6) the BOP did not isolate the wellbore and the emergency methods available for operating the BOP also failed. The underlying causes of the Deepwater Horzion accident (Tinmannsvik et al, 2011, Commission President, 2011) are:

(1) (1) ineffective leadership, (2) compartmentalisation of information and deficient communication, (3) failure to provide timely

procedures, (4) poor training and supervision of employees, (5) ineffective management and oversight of contractors, (6) focus on time and costs rather than control of major accident risks, (7) failure to appropriately analyse and appreciate risk, (8) inadequate use of technology/instrumentation. After the accident, the above causes were studied in detail, lessons were learned) and measures to avoid similar accidents improved (Christou and Konstantinidou, 2012). Dissemination of information about what went wrong with offshore operations, regardless of location, is the key to avoiding such errors in the future (Commission President, 2011).

In November 2012, BP entered into a settlement with the Ministry of Justice of the United States assuming the blame. Under that settlement BP accepted the government's four-year supervision over its security measures and procedures, and the Environmental Protection Agency announced that BP would receive a temporary ban on the conclusion of new contracts with the US government. BP also agreed to pay record damages in the amount of USD 4.5 billion. Those costs are still not final because of the payments under the Clean Water Act and National resource Damage assessment, and by February 2013 they amounted to USD 42.2 billion.

In November 2014, a US District Court ruled that BP bore sole responsibility for the oil spill due to negligence and reckless behaviour. This ruling could mean the payment of additional penalties in the amount of USD 18 million.

In the four years since the spill many activities for the return of the damaged environment to its original state have been undertaken. According to the BP report, the results are visible today. Certain areas in the Gulf have reached the income from tourism at the level of the period before the accident (or even above), sport fishermen have returned, most of the coast has been cleaned, and there are strong indications that the environment is recovering.

And most importantly, damaged beaches have been cleaned to the depth of five meters using mechanical equipment for sieving residual oil and other pollution residues, while clean sand has been returned to beaches.

Other beaches and ecologically important areas have been cleaned manually up to 20 cm deep, or deeper in places where it had been possible and approved by the Coast Guard.

Oily wetland areas have been treated with different techniques in order to enhance their self-cleaning capacity.

In October 2014 the decision to launch 44 additional projects in the Gulf area, with the estimated value of USD 627 million, was passed. Those projects are aimed at the restoration of habitats and natural resources in the following states: Texas, Louisiana, Mississippi, Alabama and Florida, as well as at improving recreational use of natural resources. Environmental projects include the restoration of dunes, the habitats of sea grasses, algae and oysters, the restoration of coastal islands protecting the coastline from wave and tide erosion, as well as creating

"live coasts" - made from organic materials protecting the coastline from erosion and providing additional habitats. Projects to improve the recreational use of these areas include the creation of new recreational opportunities, better access to natural resources, and creating better conditions to enjoy them.

After the disaster in the Gulf of Mexico, the European Commission responded in 2010 with the communication "Facing the challenge of the safety of offshore oil and gas activities" and the Proposal for a Regulation of the European Parliament and of the Council on safety of offshore oil and gas prospection, exploration and production activities (COM, 2011). There is unanimous agreement of all parties concerned that the exchange of information about past accidents and incidents is of paramount importance for the prevention of similar events in the future. In this context, Articles 22 and 23 of the proposed document require the exchange of information and transparency in the behaviour of operators in terms of ensuring the safety of conducting all operations, and Annex IX provides a common form to be used to enter the information.

Environmental and socio-economic consequences of crude oil spills may vary considerably, depending on the volume of spilled oil, its chemical properties, oceanographic and meteorological conditions at the time of the blowout, and the effectiveness of measures to prevent the spread of pollution. At the very least, spilled oil may affect the quality of water due to the creation of oil slicks on the sea surface and increased concentration of hydrocarbons because of solutes and small drops of oil. Oil spills may affect air quality in the vicinity of the spill due to the evaporation of volatile organic compounds (VOCs). Subsurface blowout may affect benthic habitats by re-suspending and dispersing sediments within a diameter of about 300 m (MMS, 2007b). Oil spills may have a negative impact on marine mammals, sea turtles, shore and sea birds in a variety of ways: through direct contact, inhalation of oil or volatile distillates, oil ingestion (directly or indirectly, through consuming oiled prey) and decreased feeding. If spilled oil reaches the shore, it may adversely affect coastal resources, including beaches where turtles nest, protected marine areas, coastal bird population, recreation and tourism. Cleaning activities of oil-polluted areas in coastal and offshore waters may interfere with local fishing and maritime activities.

Platforms and ships compliant with MARPOL a must have on-site a *Shipboard Oil Pollution and Emergency Plan - SOPEP* which contains the required reporting procedures and actions necessary to control the spilled oil and the necessary steps to initiate an external response to any spill. Modelling trajectories of oil spills in order to predict the spread of oil slicks at various places in the approved block, identifying potentially vulnerable natural resources and determining the minimum response time to any spill to be taken into account when planning interventions, are recommended. Oil slicks which may appear on the surface should be removed mechanically. If this is not possible, then the use of dispersants from the list prescribed by the Contingency Plan for Accidental Marine Pollution will be allowed.

Direct consequences of possible accidents on the life and health of workers, environmental pollution and adjacent coastal areas and direct economic damage can be easily estimated, but it is difficult to estimate indirect economic damage and consequences of the accident on security of energy supply. The indirect economic damage may include losses from falling prices of a company shares after an accident (BP shares fell by 50% in June 2010 after the Deepwater Horizon accident). Statistically, the vast majority of reported major accidents in Europe have not resulted in significant oil spills, especially not in the quantities that have been spilled during the disaster in the Gulf of Mexico, but the number of fatalities and/or damage is considerable, as is the case of the Piper Alpha platform accident (Table 8.12).

Table 8.12 Significant damage to platforms in the North Sea (Marsh Property Risk Consulting, 2009)

Platform	Location	Type	Date	Cause	Damage (USD)	Fatalities
Piper Alpha	UK – the North Sea	Platform	6.7.1988.	Explosion	1.6 billion	167
Ekofisk	Norway – continental shelf	Unmanned platform	4.6.2009.	Collision	750 million	0
Sleipner A	Norway – continental shelf	Deep water concrete structure	23.8.1991.	Structure damage	720 million	0
Ocean Odyssey	UK – the North Sea	Semisubmersible	23.8.1988.	Blowout	98 million	1

Diesel fuel spills

Diesel fuel spill is an accident which may occur at any stage of hydrocarbon exploration and production. Potential sources are ship collisions or strandings, cracked tanks or a cracked hose during offshore refuelling operations. Big spills, resulting from cracked diesel fuel tanks are extremely rare. Their probability has not been estimated, but historical data for areas with intense hydrocarbon exploration and production activities (the Gulf of Mexico) show that there were no such accidents between 1981 and 1999 (Anderson and Labelle, 2000, MMS, 2007b). Historical data show that in most cases less than 0,159 m3 (<1 bbl) of diesel fuel was spilled, while in all other cases, the mean amount of spilled oil was 0.795 m3 (5 bbl) (MMS, 2000).

Stranding and collisions of ships are a common cause of spills in the Mediterranean. In the period from 1981 to 2000 there were 273 ship accidents in the Mediterranean Sea, of which 123 accidents (45%) resulted in oil-pollution of the sea (Alexopoulous and Dounias, 2005). During the last part of that period (from 1994 to 2000) strandings and collisions were the primary causes of oil spills. Tankers and bulk carriers are responsible for oil spills in almost 77% of cases, mainly due to accidents during terminal operations. An accident occurred because of cracked or leaking pipes, damaged mooring ropes, disconnected or split hoses, faulty valves, etc.

Environmental and socio-economic consequences of diesel fuel spills depend on the size of the spill, oceanographic and meteorological conditions at that moment and the effectiveness of measures taken to prevent the spread of pollution. In general, spilled diesel fuel will be subject to sudden dispersion, wear, evaporation and dissipation through a water column. This will affect air quality in the vicinity of the spill due to the evaporation of volatile organic compounds (VOCs). Diesel fuel spills affect local water quality because there will be an increase in the concentration of hydrocarbons in water. Spilled diesel fuel may affect plankton and fish in the water column in the vicinity of the spill because it is very toxic. Adult and young fish can actively avoid large oil slicks, but planktonic eggs and larvae cannot avoid contact. Fish eggs and larvae will die if exposed to certain toxic fractions of spilled oil. Diesel fuel spills are not expected to affect benthic communities because hydrocarbons are not expected to reach the seabed. In addition, it is unlikely that a small amount of diesel fuel will affect the quality of water on the coast or coastal habitats because the minimum distance of individual blocks from the coast ranges from 6 to 11 km. A significant impact on coastal habitats, protected areas, recreation and tourism, and coastal communities is highly unlikely, except in case of large diesel fuel spills near the coast.

Oil-base drilling mud spills

The base of synthetic mud is synthetic oil mixed with other ingredients for mud preparation. In the Gulf of Mexico in the period from 2001 to 2004 there were 53 synthetic mud spills (MMS, 2007b). In most cases less than 7.95 m3 (50 bbl) of synthetic mud was spilled, and in three cases more than159 m3 (1000 bbl). Two of three large spills been were the result of emergency disconnection of risers, and the third synthetic mud spill was caused by damage on the risers. For the purpose of an impact analysis of synthetic mud spills, it can be assumed that a small synthetic mud spill may occur at a well location in the approved block. Spilled synthetic mud is expected to sink to the bottom (Boland et al., 2004). The seabed on which synthetic mud settles, will be the most affected. Impacts will be similar to those previously described for the discharge of well cuttings from synthetic mud, including increased concentrations of organic carbon and localized anoxia (oxygen shortage) (Continental Shelf Associates, Inc., 2006).

Fluid leakage or spills from seismic cables

Seismic cables towed by ships for seismic surveys typically contain a light aliphatic hydrocarbon (similar to kerosene) for electrical insulation and neutral buoyancy. Broken cables are rare and usually occur when sea currents wrap cables around a fixed structure (e.g. a platform). Big fish bites may also occasionally result in seismic cable cracking. If fish damage a seismic cable or if it starts to leak, a small amount of fluid from the cable may leak into the sea. In most cases, the volume of just one part of the cable will be spilled, or approximately 100 to 200 litres of fluid (Continental Shelf Associates, Inc., 2004). The spilled liquid is expected to evaporate and be diluted in seawater quickly. An area likely to be affected by liquid spills from the seismic cable ranges from a few meters to several dozen meters from the cable. Spilled liquid creates a shine on the sea surface, and there is short and localized impact on water quality. Impacts will be negligible. Newer cables do not contain fluids, but solid polymer foams which enable them to float on the surface, whereby avoiding the risk of fluid spills (Continental Shelf Associates, Inc., 2004).

Discharge of hydrogen sulphide

The discharge of hydrogen sulphide (H2S) is an accident which may occur during exploration or production. Recovered natural gas containing H2S is treated prior to transport to the mainland in order to reduce its corrosivity. H2S undergoes separation from natural gas in amine units at an exploration platform. Environmental, health and safety aspects related to the discharge of H2S are: irritation, injury and mortality in humans and animals, as well as corrosion of equipment and pipelines. However, the risk is very localised. Mechanisms of dispersion in the atmosphere (wind, etc.) cause quick dispersion of natural gas leakage and the associated discharge of H2S. According to MMS (2007b), for a very large facility (with a capacity of 2.8 x 106 m3/d (100 MMcfd) of produced natural gas) with high levels of concentration (of the order of magnitude of 20 000 ppm) and in conditions of very weak winds (speed <1 m/s), the level of H2S is reduced to 500 ppm at the distance of 1 km from the source, while at the distance of several kilometres from the source H2S level decreases to 20 ppm. The risk of significant impacts on the water column is weak because H2S is very soluble in water, and oxidises in one hour (MMS, 2007b). It can be concluded that accidental discharge of H2S may have significant localised impacts on air quality, human health and biodiversity. The degree of risk will depend on the size and concentration of discharged H2S and meteorological conditions in the environment. In cases of significant risks of H2S discharge during operations, the concessionaire should be required to submit an "H2S Contingency Plan".

Marine accidents (casualties)

Marine accidents (term below includes marine accidents and marine casualties as determined by the Ordinance on the investigation of marine casualties (OG 09/07), include all unwanted events which threaten human lives, cause material damage, or pollution of the marine environment. Marine accidents generally do not include accidents at facilities for offshore exploration and production, and since the nature of accidents at such facilities is very similar to accidents on ships below, they will be considered jointly below.

Marine accidents with regard to facilities for offshore exploration and production are divided into:

- events caused by the characteristics and operation of a structure itself (internal causes),
- events caused by environmental factors (natural causes),
- events caused by actions of other participants in maritime transport (external causes).

Fires and explosions are the most important events caused by internal causes in scope of speed and speed. Fire and/or explosion, regardless of the order of occurrence, cause extensive material damage and may cause a number of human casualties and large and even catastrophic pollution. Such events are extremely rare, primarily due to the extremely high levels of technological security embedded into facilities for offshore exploration and production.

Events caused by environmental factors are the result of natural forces, primarily wind and waves. Large scale damage or pollution caused by natural forces is unlikely (all experience with such events dates back to the last century).

Events caused by actions of other participants in maritime transport are events in which improper operation, or technical failure in another vessel may cause damage to a facility for offshore exploration or production and consequently marine pollution. In sense of intensity, a collision with facilities for offshore production, or explosion or fire transferred from another ship or vessel, stand out.

A collision means any event in which other craft or ship hits a facility for offshore production, whereby causing permanent transformation of the structure. A collision with ships which stay nearby the facility as part of their regular operation should be distinguished from a collision with ships coming to the immediate vicinity of the platform due to force majeure, failure or officer error. Also, ships using own drive for navigation should be distinguished from ships navigating on wind and sea currents. In the latter case, contact speeds are very small (typically up to ½ node), and except in case of ships with larger displacement, possibilities of significant collision energies are very small.

Collisions with ships which stay nearby the platform as part of their regular operation or are tied to it occur in most cases due to human error (in approximately 45% of cases), due to a malfunction of propulsion or other devices (in approximately 33% of cases) and for other reasons (in approximately 22% of cases), whereby the influence of weather conditions is the most common.

Given the technological organization, ships access facilities primarily for the transport of people, supply delivery and maintenance. Consequently, smaller and slower ships are expected and it is estimated that they will not have sufficient kinetic energy that could cause serious damage. According to available data, ships weighing up to 80 tons, with collision energy to 4 MJ are expected.

Finally, ships that will provide technological support cannot cause exceptional damage in the event of collision at full speed (smaller facilities are usually considered to be able to withstand collision energies up to 4 MJ, and larger ones up to 15 MJ, depending on the structural properties).

Passing ships navigate much faster, and generally they weigh more (including the extra weight) and can achieve impact collision that are significantly above the assumed resistance of facilities to collisions with navigating ships. Given the navigation structure in the Adriatic, it is assumed that at least 80% of ships navigating the primary longitudinal waterway have enough kinetic energy to cause serious damage to a platform.

The likelihood of transmission of fire and explosion from navigating ships or from other facilities and the likelihood of other adverse impacts from adjacent facilities or navigating ships are small and can be ignored.

Legislation

Accidents are avoided by maintaining operational security of wells and collection and transmission systems through prescribed supervision and maintenance, and in accordance with recognized professional standards. All workers on a platform must be familiar with hazards and procedures in emergency situations. Instructions on procedures in emergency situations must be in plain sight. Emergency drills must be regularly performed (at least monthly). Records about performed drill should be kept. A platform must be equipped with mining documents, mining projects, drive records, records, certificates, reports, marine documents and environment protection contingency plan.

The big ecological disaster caused by an oil spill in the Gulf of Mexico in April 2010 was the reason for the adoption of a new, specific regulatory framework at EU level in order to increase safety standards and environmental protection measures in order to protect European sea and prevent the occurrence of such accidents in the future. In June 2013 the Directive 2013/30/EU of the European Parliament and of the Council of 12 June 2013 on safety of offshore oil and gas operations, was adopted. The Directive is aimed at preventing the occurrence of accidents associated with offshore oil and gas activities and limiting the consequences of such accidents should they occur so as to ensure rapid response in order to minimise the consequences. The Directive itself is primarily aimed at ensuring the protection of marine environment and coastal economies against pollution. The Directive sets out the conditions for safe offshore exploration and production of oil and gas and at the same time improves risk management mechanisms.

The Directive defines a major accident as:

- an incident involving an explosion, fire, loss of well control, or release of oil, gas or dangerous substances involving, or with a significant potential to cause, fatalities or serious personal injury;
- an incident leading to serious damage to the installation or connected infrastructure involving, or with a significant potential to cause, fatalities or serious personal injury;
- any other incident leading to fatalities or serious injury to five or more persons who are on the offshore installation where the source of danger occurs or who are engaged in an offshore oil and gas operation in connection with the installation or connected infrastructure; or
- any major environmental incident resulting from the above incidents.

For the purposes of the Directive 'offshore oil and gas operations' means all activities associated with an installation or connected infrastructure, including design, planning, construction, operation and decommissioning thereof, relating to exploration and production of oil or gas, but excluding conveyance of oil and gas from one coast to another, while 'offshore' means situated in the territorial sea, the Exclusive Economic Zone or the continental shelf of a Member State within the meaning of the United Nations Convention on the Law of the Sea.

Offshore oil and gas industry is developed in many regions of the Union, and in the offshore waters of Member States there are potentials for new regional development, since the development of technology allows drilling in more demanding conditions. Production of offshore oil and gas is an important factor for the security of energy supply in the Union.

Risks associated with large offshore oil and gas accidents are significant. By reducing the risk of pollution of offshore waters, this Directive should therefore contribute to ensuring the protection of the marine environment and in particular to achieving or maintaining good environmental status by 2020 at the latest.

Although general authorizations in accordance with Directive 94/22/EC guarantee exclusive rights of exploration and production to holders of authorizations in areas to which it applies, offshore oil and gas activities in this area shall be subject to continuous expert regulatory monitoring of Member States in order to ensure the establishment of effective controls in order to prevent major accidents and limit their effects on people, the environment and security of energy supply.

During hydrocarbon exploration and production there are mobile and stationary offshore units. Mobile offshore drilling units in transit are typically ships, while platforms, especially for production are usually considered stationary offshore units. Operations of mobile offshore units are regulated by international maritime conventions. **According to MARPOL 73/78 ships, including ships for exploratory drilling must have a contingency plan in emergency situations occurring during oil pollution.**

The Directive on safety of offshore oil and gas operations contains detailed terms and conditions with respect to documentation that an operator (concessionaire) must prepare and submit to the competent national regulatory authority for the purpose of performing offshore oil and gas operations. Thus, for example, the operator must submit to the competent regulatory authority the following documentation: **corporate major accident prevention policy, safety and environmental management systems, a report on major accidents, internal emergency response plan, reports on well operations, etc. In addition, operators shall establish appropriate monitoring systems and periodic reviews of these reports at least every five years.**

Member States should ensure that the competent authority is legally authorized and has sufficient resources to undertake effective, proportionate and transparent implementation measures, including, if necessary interruption of operations if operators and owners do not achieve satisfactory results in terms of safety and environmental protection.

Safety and environmental aspects associated with licenses

In proceedings to assign or transfer licenses for performing operations related to offshore oil and gas, Member States shall comply with additional requirements when assessing the capability of an applicant. In particular, when assessing the technical and financial capability of the applicant for a licence, due account shall be taken of the applicant's financial capabilities, including any financial security, to cover liabilities potentially deriving from the offshore oil and gas operations in question including liability for potential economic damages where such liability is provided for by national law. Before granting or transferring a licence for offshore oil and gas operations, the licensing authority shall consult, where appropriate, the competent authority. A licence shall not be granted unless the applicant presents evidence that they have made or will make adequate provision to cover liabilities potentially deriving from the applicant's offshore oil and gas operations. A licensee shall maintain sufficient capacity to meet their financial obligations resulting from offshore oil and gas operation liabilities.

The licensing authority or the licensee shall appoint an operator (i.e. entity) which (directly) performs offshore oil and gas operations. Where the operator is to be appointed by the licensee, a prior approval of the licensing authority should be obtained. If the licensing authority objects to issue such approval or if during the performance of activities the operator is found to be non-compliant with the requirements of the Directive, the licensee shall be required to appoint a suitable alternative operator or assume the responsibilities of the operator under this Directive.

When assessing the technical and financial capability of the applicant, due account shall be taken of all ecologically sensitive marine and coastal environments, in particular, for example, marine protected areas or areas covered with Natura 2000 network, etc.

Liability for environmental damage

The key requirement of the Directive for Member States is to ensure that the licensee is financially liable for the prevention and remediation of environmental damage as defined in the Directive on environmental liability (Directive 2004/35/EC), caused by offshore oil and gas operations carried out by, or on behalf of, the licensee or the operator. Thus, the licensee without the status of the operator remains responsible under the Directive on environmental liability. Furthermore, the Directive amends the legal definition of water damage contained in the Directive on environmental liability in a way that the present definition now covers EU Member States marine waters. In other words, responsibility for the environment pursuant to the provisions of the Directive on environmental liability was extended and applies to marine waters.

Independent regulatory authority

The Directive requires the appointment of a national independent authority in charge of a series of regulatory functions such as assessing and accepting reports on major hazards, assessing design notifications, and assessing notifications of well operations, overseeing compliance by operators and owners with this Directive, including inspections, investigations, making annual plans, etc.

For the purpose of preventing conflicts of interest Member States are generally required the regulatory functions of the competent authority to be carried out within an authority that is independent of any of the functions of Member States relating to the economic development of the offshore natural resources and licensing of offshore oil and gas operations, including the collection and management of revenues from those operations.

Obligation of reporting major accidents with offshore oil and gas operations conducted outside the Union

In accordance with the Directive, Member States shall require companies registered in their territory and conducting, themselves or through subsidiaries, offshore oil and gas operations outside the Union as licence holders or operators to report to them, on request, the circumstances of any major accident in which they have been involved.

Cooperation between Member States

Each Member State shall ensure regular exchanges of knowledge, information and experience, in particular, regarding the functioning of the measures for risk management, major accident prevention, reporting on major accidents with other competent authorities, inter alia, through the European Union Offshore Oil and Gas Authorities Group (EUOAG).

Preparedness measures and notifications in case of major accidents

Member States are required to prepare external emergency response plans covering all offshore oil and gas installations or connected infrastructure and potentially affected areas within their jurisdiction.

Furthermore, Member States shall ensure that the operator or, if appropriate, the owner notifies without delay the relevant authorities of a major accident or of a situation where there is an immediate risk of a major accident. In the event of a major accident, the operator or the owner shall take all suitable measures to prevent its escalation and to limit its consequences.

Also, the Directive contains specific provisions with respect to preparedness measures and information in the event of a major accident with transboundary effects on the environment in another Member State.

<u>The application and impact of new rules on Croatian legislation</u>

CONTINGENCY PLAN FOR ACCIDENTAL MARINE POLLUTION (Official Gazette no. 92/08) is a document of sustainable development and environmental protection, which defines the procedures and measures for predicting, preventing, restricting and preparing for and responding to accidental marine pollution and the unusual natural occurrences in the sea for the protection of the marine environment. The Plan complies with international agreements in the protection of the marine environment to which the Republic of Croatia is a party. Entities involved in the implementation of the Contingency Plan are: Headquarters for the implementation of the Contingency Plan, Maritime Rescue Coordination Centre - Rijeka and County Operational Centre.

Although existing, Croatian regulations for hydrocarbon exploration and production, in particular:

- Act on Exploration and Production of Hydrocarbons (Official Gazette no. 94/13 and 14/14),
- Mining Act (Official Gazette no. 56/13 and 14/14),
- Ordinance on main technical requirements on safety and security of offshore exploration and production of hydrocarbons in the Republic of Croatia (official Gazette no. 52/10)

lay down basic obligations and protection measures of nature and environment, health and safety of people and property in the performance of oil and gas exploration and production operations, further legislative changes to the existing or the adoption of a new legal framework in order to timely comply with all requirements and obligations under the Directive, will be required.

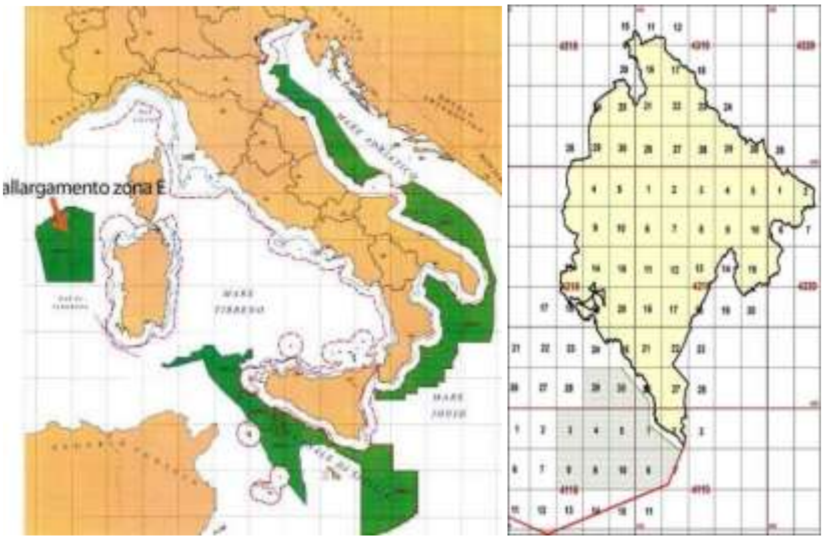
In general, Member States with access to the sea are obliged to transfer the provisions of the Directive into national law by 19 July 2015.

The Directive provides for the following transitional deadlines for compliance with national legislation transposing the provisions of Directive:

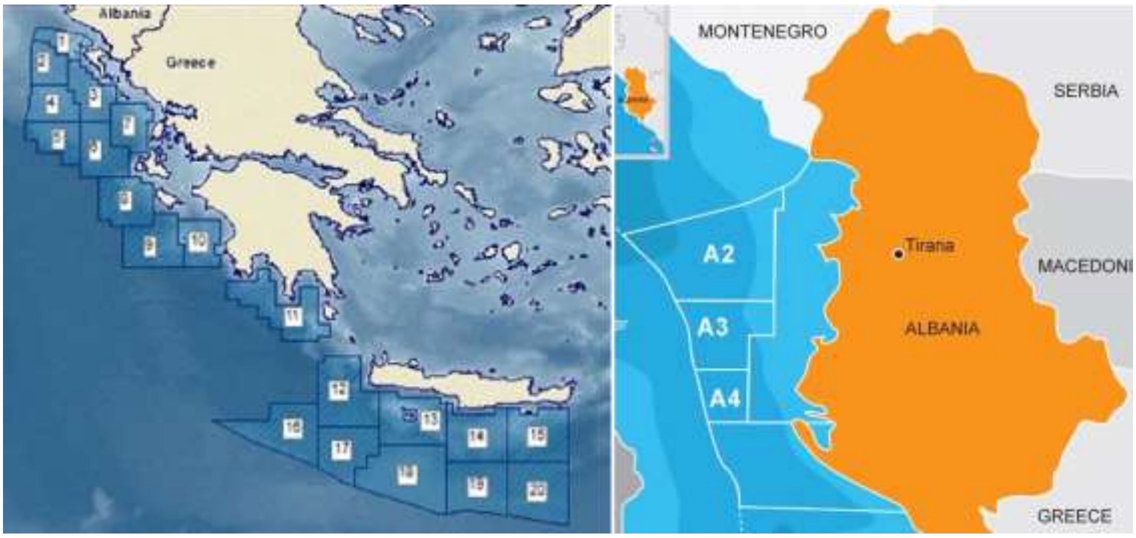
- **no later than 19 July 2016** in relation to owners, operators of planned production facilities and operators planning or carrying out well operations
- **no later than 19 July 2018** in relation to the existing plants.

Finally, in addition to operators INAgip d.o.o. (joint operating company established by INA d.d. and Italian oil company ENI) and Edina (established by INA d.d. and Italian company EDISON SPA) given the existing gas exploration and production operations in the Northern Adriatic, all selected tenderers who will be issued a license and granted a concession for hydrocarbon exploration and production in the Adriatic following the bidding procedure, will have to comply with the new rules and requirements of the Directive.

Countries in near and far surrounding are in various stages of preparation, or exploration and production of hydrocarbons as shown in the pictures below.



Italy (left) and Montenegro (right)



Greece (left) and Albania (right)

Review of the impact of possible accidents on the environmental components:

8.3.2.11.1 Chemical Characteristics

Accidents may happen in the course of hydrocarbon exploration and production which could significantly change the sea water pH, quantity of dissolved oxygen, nutrient or organic substance levels beyond acceptable or permissible limits. Rate, duration and result of oil transformation and degradation in the marine environment depend on oil characteristics and composition, spill parameters and environmental conditions.

Similar to live organisms, marine ecosystem also dissolves, metabolises and stores great quantities of hydrocarbon and converts them into environmentally safer substances. Distribution of the oil spill over the sea surface occurs under the influence of gravity, and it's controlled by oil viscosity and sea water surface tension. Only 10 minutes after the spill, the oil can disperse over the surface area of 50m in radius, thus creating a 10 mm thick spill. Within the first several days after the spill, a significant part of the oil converts to gas-phase. Apart from evaporable components, the spill quickly loses water soluble hydrocarbons. The remaining part, the most viscous fraction, slows down the spreading of the oil spill. Most oil components, such as aliphatic and aromatic hydrocarbons of low molecular mass, are to certain level water soluble. Polar components which are the result of oxidation of some fractions of oil in the marine environment are also water soluble. Compared to evaporation, compound decomposition lasts considerably longer. Hydrodynamic characteristics and physico-chemical conditions in surface waters have a large influence on the process rate. Emulsification of oil in the marine environment depends, first of all, on the oil composition and water mass mixing regime. The most stable water-in-oil emulsions contain 30 % to 80 % of water and appear mainly after strong storms in the zones where heavy oils with increased non-evaporable component contents (especially asphaltene) are spilled. These emulsions may subsist in the marine environment for more than 100 days, while their stability mainly grows with temperature decrease. Reverse emulsions, oil drops suspended in water, are much more unstable since surface tension forces quickly slow the oil dispersion down.

Oil chemical transformations on the sea surface begin a day after the oil enters the marine environment. This mainly refers to oxidation processes which often include photochemical reactions under the influence of ultraviolet waves. These processes are catalysed by trace elements, such as vanadium, and they are inhibited by sulphur compounds. End products of oxidation (hydro peroxides, phenols, carboxylic acids, ketones, aldehydes and others) mainly have a higher solubility rate in water, but some experiments show that they are more toxic. Reactions of photo-oxidation, especially of photolysis, initialise polymerisation and decomposition of the most complex molecules, which increases the oil viscosity and enhances the formation of solid oil aggregates.

In narrow coastal zones and shallow seas where there are many swimming components, and the sea water mixes intensely, from 10 % to 30 % of oil from oil spills adsorbs on suspended materials and settles on the seabed. In deeper zones, far away from coasts, oil sedimentation (except of heavy fractions) is very slow. Concurrently, the biosedimentation process occurs in which plankton filtrators and other organisms absorb emulsified oil. Suspended form of oil and its components in the water column undergoes an intense chemical and biological (especially biochemical) process of degradation. This condition radically changes when the suspended oil reaches the seabed. Numerous experimental studies and data indicate that oil degradation rate on the seabed sharply declines. Oxidation processes slow down in anaerobic environment on the seabed so that heavy oil fractions piled in sediments may remain conserved through several months or even years. The final destiny of the majority of oil components in the marine environment is determined by their transformation and degradation resulting from microbial activity. Approximately a hundred of known bacteria and fungi species may use oil components for their growth and development. In virgin areas, their presence does not exceed 0.1 – 1.0 % of the total amount of heterotrophic bacterial communities, while in the oil polluted areas their number reaches 1 – 10 %. Biochemical processes of oil microbial degradation include various types of enzyme reactions based on oxygenases, dehydrogenases and hydrolyses.

The biodegradation level and rate depend primarily on the structure of their molecules. Paraffin components (alkanes) have the capacity to biodegrade faster than aromatic and naphthenic components. Degradation rate usually increases in proportion to the increase of complexity of molecular structure (with the increase of the number of carbon atoms and the level of chain branching) and the molecular mass. Moreover, the degradation rate depends also on the physical state of oil, including the dispersion rate. The most important environmental factors affecting the hydrocarbon biodegradation include temperature, nutrient and oxygen levels, as well as the composition of species and the number of micro-organisms decomposing the oil.

All these complex and mutually related factors affecting the biodegradation, as well as vast differences in the oil composition, severely complicate the interpretation and comparisons of existing results on rates and levels of oil biodegradation in the marine environment. Due to all the above described processes, the oil in the marine environment quickly loses its original characteristics and degrades to hydrocarbon fractions of various chemical compositions and structures and of various motion rates. These fractions undergo radical transformations which slow down after thermodynamic balance is achieved with environmental parameters. Their quantity decreases because of dispersion and degradation. Finally, all original and resulting fractions dissolve to carbon dioxide and water. This form of marine environment self-cleansing inevitably occurs in water ecosystems, if the initial toxicity does not surpass acceptable limits.

8.3.2.11.2 Climate Characteristics

In case of an accident during FPP implementation, hydrocarbon explosions potentially have the most significant consequences for climate characteristics. Oil combustion, similar to what happens during well testing, leads to GHG emissions which affect global and local climate. Those influences are in proportion to the amount of combusted hydrocarbons. As a result of the combustion of 1 m^3 of crude oil, 0.59 kg of CO, 5.69 kg of nitric oxides, 1.19 kg of suspended matter, 19.49 kg of sulphur oxides and 0.04 kg of evaporable hydrocarbons (MMS, 2008) is considered to be released into the atmosphere. The impacts the hydrocarbon combustion caused by explosion has on the global climate are difficult to assess due to the complexity of processes affecting the climate. Another significant impact is that of a local character which can change the climate of an area affected by a smoke cloud for a shorter period of time. That impact depends on winds and is limited in time and space.

8.3.2.11.3 Biodiversity

MARINE MAMMALS, REPTILES AND CARTILAGINOUS FISH:

A direct impact of oil spills on Cetacean, sea turtles or large fish has rarely been recorded. Usually, the impact is measured through direct mortality of animals found dead. Birds and fur animals (otters, seals, etc.) are those mostly exposed (Rainer Engelhardt, 1983). Although it is generally considered that cetaceans could avoid areas where oil is spilled, their skin is less susceptible to catching oil and they absorb less oil as they are insulated with a thick layer of blubber (Rainer Engelhardt, 1983). However, impact differs from species to species. Smultea and Würsig (1995.) found out that for bottlenose dolphins, contact with oil largely depended on the type of oil spills and their possibility to detect them.

Contrary to these findings is the mortality recorded during the most recent devastating oil spill of the Deepwater Horizon platform in the Gulf of Mexico. More than 150 dolphins (mainly *T. truncatus*) and more than 600 sea turtles were found dead (NOAA Fisheries 2014). Although such a mortality could be regarded moderate taking into account that during two months around five million barrels of oil seeped into the sea from the depth of 1500 m, Williams et al. (2011) indicated that the actual mortality could be up to 50 times higher due to a large number of carcases not being recovered.

Even more concerning is the long term effect of pollution and the related “cryptic” mortality, i.e. deferred mortality affecting the population (Williams et al., 2011). A relatively well documented case is the one in which after the Exxon Valdez tanker oil spill, and due to the long-term impact, a loss of 30-40 % of animals in two populations of killer whales took place in the area of Prince William Sound, Alaska (Matkin et al., 2008). Also, vulnerability to pollution is larger in species living in coastal and relatively closed habitats (Fortuna et al., 2002) and resident populations with limited minimum home-range.

During oil spills, large volumes of oil could be released into the environment. As the oil composition depends on each particular event, the actual content of different contaminants will differ depending on the source. During the Exxon Valdez tanker oil spill in Alaska in 1989, high contents of phenanthrene (PHN), naphthalene (NPH) and polyaromatic hydrocarbons (PAHs) were found in the tissue of seals (Frost and Lowry, 1994). After oil spills from oil tankers Haven and Agip Abruzzo in the Ligurian sea (Marsili et al. 2001), more biopsy samples from a number of Cetaceans were analysed and it was found that in fin whales levels of PAH still reflected elevated PAH values a year and half after the incident. The risk from hydrocarbon and other toxic substance contamination is not always directly related to the actual contact during the oil spill. In days following the accident, inhalation of air containing high levels of evaporated toxic substances in the air close to the surface can occur. Toxic vapours can cause eyes and lungs irritation and different acute health problems (nausea, drowsiness, difficulty breathing, etc.).

After the spill, different types of dispersants, substances lowering the surface tension and solvents are released into the environment in order to disperse the oil spills. During the Deepwater Horizon platform oil spill, dispersants were not only used on the surface, as was the case in other similar incidents, but large quantities were also released under water (Mascarelli, 2010; Kujawinski et al., 2011). Their toxicity largely depends on their chemical composition and level. Finally, through ingestion of contaminated prey, animals can bioaccumulate large amounts of toxins that can cause health problems.

OTHER FISH GROUPS: The strongest influence an accident can have on fish during the hydrocarbon exploration and production is oil spill, and this is due to the fact that the oil spill could directly endanger their habitat. However, research showed that fish swim away from the pollution source thus decreasing the impact the pollution might have on them.

During the oil spill from the "Sea Empress" tanker, monitoring was carried out in order to determine the pollution level and spreading. No mortality was determined on observed subjects (*Cynoscion nebulosus* and *Salmo salar*). The level of aromatic hydrocarbons in the observed subjects was analysed and it was not significantly increased. The total level of aromatic hydrocarbons on the observed group was identical or smaller than the level of hydrocarbons measured in fish not exposed to pollution. Tested animals were not held in cages, but they moved freely and did not feed on the pollution site (Law and Kelly, 2004). Several researches showed that alkyl phenols easily enter the fish organism, but that they are eliminated from the organism within several hours or days.

BIRDS: The strongest impact an accident can have on birds during the hydrocarbon exploration and production is an oil spill into the sea which can then result in the direct impact or impact within the trophic network. Birds can consume and bioaccumulate harmful substances through food. The contact of feathers and oil causes the removal of protective hydrophobic layers and the birds lose the ability of thermoregulation and floating. Birds usually use their beaks trying to remove the oil from their feathers whereby they swallow it and expose themselves to a great risk of damaging digestive and nerve systems, liver, lungs and other internal organs. (The United States Environmental Protection Agency, EPA, Office of Emergency and Remedial Response: The Behavior and Effects of Oil Spills In Aquatic Environments)

INVERTEBRATES: The strongest impact an accident can have on sea invertebrates during the hydrocarbon exploration and production are spilling of oil and crude mud into the sea. Under the impact of oil spill, coral colonies increase sclerites, and the production of mucus which stimulates bacteria growth, bleaching occurs and covering with brown products as stress indicators. Reproductive systems are often damaged, the number of reproducing colonies is reduced, the number of ovaries per polyp is reduced and the number of planula (larvae). The expected larvae survival rate is reduced which is related to changes in behaviour caused by hydrocarbons in the environment. As a consequence to cell wall thinning, the growth rate is reduced and the tissue damage occurs. Parts of colonies or entire colonies die. (Loya, 1980)

Bivalves are mainly immobile or poorly mobile organisms which feed themselves by filtering, and each polluting substance can potentially accumulate in them. During the spill of crude mud or oil, directly exposed animals usually die (Burger 1994). Bivalves populating the coast during the oil spill accident are directly exposed to the large quantities of crude oil, while species living deeper in the sea are exposed to dissolved hydrocarbons which reduce their level of transpiration and filtration, and cause other physiological problems.

PLANKTON: Oil spills can negatively impact on the activity of phytoplanktons. The presence of oil on the sea surface causes a reduced or non-existent light penetration into the sea, which in turn makes the photosynthesis impossible. This reduces the total growth of phytoplanktons, which then impacts the development of other higher organisms (Luyeye, 2005). Oil spill can cause disturbances in the zoo plankton population. In some cases, the impact can be lethal, while in other, certain species of zoo planktons may ingest certain compounds present in the oil (e.g. PAH) and thus lead to bioaccumulation and biomagnification of certain toxic compounds. Oil spill on the sea surface causes the reduction in light penetration into the water column which influences the zoo plankton feeding, either by the reduced growth of phytoplanktons or by the change in the phytoplankton behaviour (disturbance in the daily vertical allocation of zoo plankton depending on the amount of light in the water) (Luyeye, 2005).

Discharge (leaking) of waste waters without the previous treatment may represent a large problem for the quality of sea water as a life medium since it causes hypoxia, which negatively affects the zoo plankton community development.

HABITATS: During the oil spill accidents, the most endangered habitats are those in the intertidal zone, which would be covered in oil in case the oil spill reaches the coast. All habitats containing photosynthetic organisms (settlements of Neptune Grass and algae) are endangered due to habitat shading. Data shows that exposure of Neptune Grass to petrochemicals leads to stress phenomena (Seagrasses: Biology, Ecology and Conservation), and that oil spillage causes the reduction in photosynthetic capacity in kelp *Macrocystis* (O'Brien, Dixon, 2007). In addition, the research recorded the weakening of the development of the *Zostera marina* species upon the exposure to petrochemicals (Seagrasses: Biology, Ecology and Conservation). A part of hydrocarbons is dispersed in the water column and in case of oil spill, most habitats, i.e. organisms populating them, at the accident site are potentially endangered. It is recorded that the oil can remain in the sediment up to 30 years (Effects of Oil on Wildlife and Habitat, 2010). When cleaning the oil, various dispersants are used which can make hydrocarbons more accessible within the food chain (Rico-Martínez, 2013).

AREAS OF PROTECTION: The impact of accidents on areas of protection is directly related to the distance from the pollution source and hydrocarbon type. Since the FPP does not provide information on the location of oil reservoirs and gas reservoirs, this strategic study has singled out all marine areas of protection as areas exposed to the highest risk. All these areas are indicated on the map below (Figure 8.6) and listed in Annex 7.

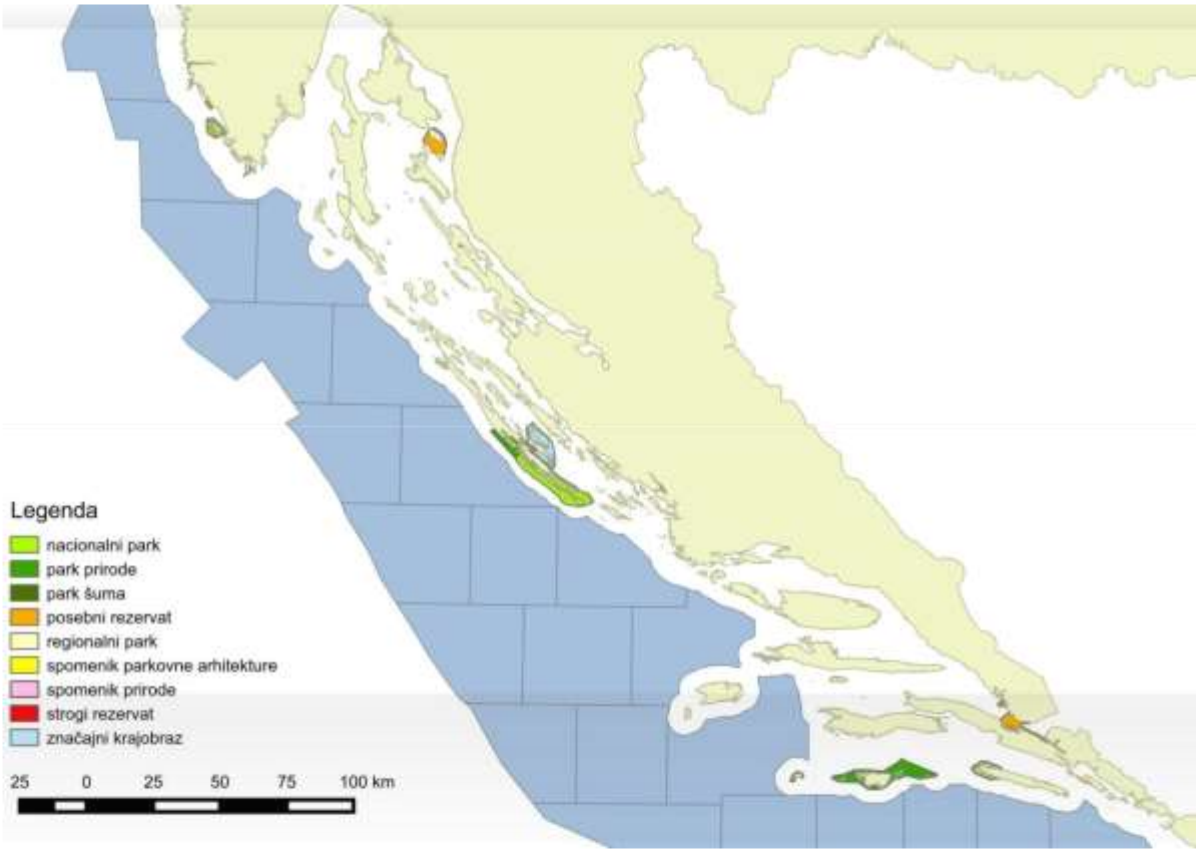


Figure 8.6 Areas of protection under the highest risk of accidents

8.3.2.11.4 Ecological Network

The main assessment recognizes the potential significant adverse impact of accidents on ecological network areas. Accidents are possible during hydrocarbon exploration and production, whereby two events are singled out based on the significance of their adverse influences:

- oil and gas spills,
- hydrogen sulphide (H_2S) discharge.

Oil spills and hydrogen sulphide discharge have an adverse impact on all organisms in the water column, seabed, sea birds and coastal habitats. Impact of accidents threatening organisms may be direct, whereby impact on specimens occurs (suffocation, poisoning) or impact within the trophic network (consummation and bioaccumulation of harmful substance through food). In birds, the contact of feathers and oil causes the removal of protective hydrophobic layers and the birds lose the ability of thermoregulation and floating. Birds usually use their beaks trying to remove the oil from their feathers whereby they swallow it and expose themselves to a great risk of damaging digestive and nerve systems, liver, lungs and other internal organs. In turtles and dolphins, what is more concerning is the long term effect of pollution ("cryptic" mortality), i.e. mortality affecting the population (Williams et al., 2011).

During the oil spill accidents, the most endangered habitats are those in the intertidal zone since they would be directly covered in oil in case the oil spill reaches the coast. Habitats containing photosynthetic organisms (settlements of Neptune Grass and algae) are endangered due to habitat shading. A part of hydrocarbons is dispersed in the water column and in case of oil spill, most habitats, i.e. organisms populating them, at the accident site are potentially endangered. It is recorded that the oil can remain in the sediment up to 30 years (Effects of Oil on Wildlife and Habitat, 2010).

The severity of impacts caused by oil spills and hydrogen sulphide discharge depends on the event location, the quantity of spilled liquid as well as the dynamics of the sea and atmosphere at that moment. Since FPP does not provide for detailed locations of the project, this chapter can only define risk areas on the basis of the general flowing direction of sea currents in the Adriatic which, due to the complexity of the processes causing the sea currents dynamics, do not represent the expected flowing direction of currents around the future wells. However, one rule can apply in this level of strategic assessment: closer areas of ecological network are under higher risk of adverse impacts than the more remote areas (Figure 6.14). The map below shows the distance of ecological network areas from exploration and production zones. The list of all areas shown is specified in Annex 6.

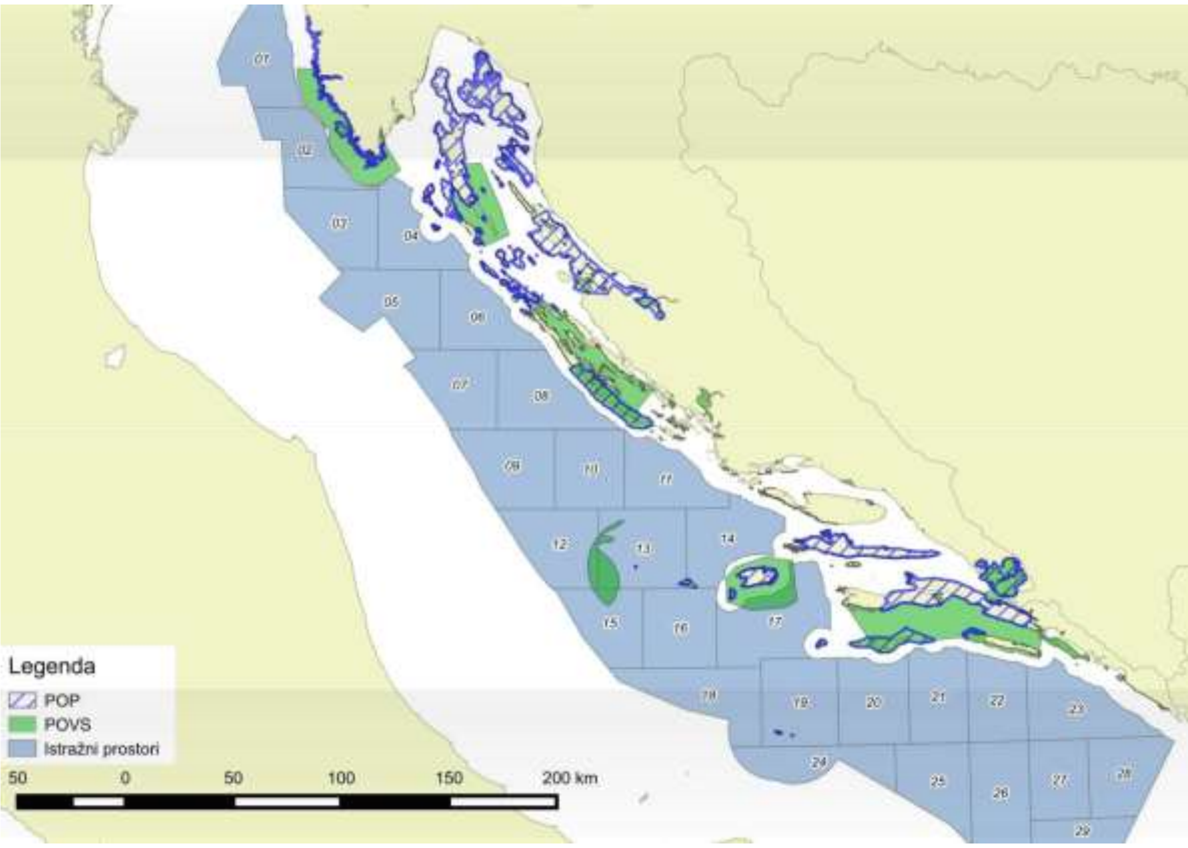


Figure 8.7 Areas of ecological network under the highest risk of accidents

8.3.2.11.5 Marine and Seabed Pollution

Accidents, such as oil spills, hydrogen sulphide discharges, ship accidents and discharging of crude mud and formation water into the sea, can contribute to marine and seabed pollution. Individual petrochemicals from the oil tend to bioaccumulate and biomagnify, while some compounds, including hydrogen sulphide, cause acute toxicity. The marine and seabed quality, with regards to the levels of heavy metals and stable organic polluting substances, could be reduced due to accidents. In addition, spilling of mud, formation water and/or oil, as well as ship accidents and hydrogen sulphide discharge can significantly affect the marine environment pollution.

Metal waste, such as welding electrodes and buckets, which is thrown into the marine environment by accident, can pollute the seabed around the well location.

8.3.2.11.6 Economic and Socio-economic Characteristics:

Accidents causing oil spills can potentially have significant consequences on the economy and business. Apart from the short-term consequences, such as the reduced possibility of using a part of the water area, long-term changes in people's perception is expected which can reflect mostly to tourism and fisheries. After the accident in the Gulf of Mexico (Deepwater Horizon), the sales of fish from the Gulf of Mexico significantly dropped because buyers considered it to be polluted, although it wasn't (M. Dolores Garza-Gil et al. 2006; Brent W. Ritchie et al. 2013). Similarly, the oil spill may adversely affect the perception of the Adriatic Coast and drop in tourism revenue.

8.3.2.11.6.1 Fisheries

Oil spill can severely damage fisheries and mariculture through physical pollution, pollution of organisms' natural populations, and reduced market values of commercial types of fish (Conversations for Responsible Economic Development, 2013). The nature and scope of impact on seafood production depends on characteristics of spilled oil, accident circumstances and types of fisheries or maricultural activities. In some cases, efficient protection measures and cleaning can prevent or minimize the damage. At the oil spill locations, mass mortality of economically important marine organisms could occur, while vagile organisms, such as fish, will migrate to less polluted areas, thus potentially increasing the fishing efforts. Marine organism nurseries often cannot be relocated from the pollution location. Organisms pertaining to the pollution area are often not safe for consummation, and don't taste well. Consumers refuse to buy food from the sea in the vicinity of which the oil spill happened, even if that food was not affected by the oil and is safe to eat, which damages the local economy in the long run by creating a negative perception of products from this area. Chemical dispersants are used to remove the oil which are often more toxic than the oil itself, and their impact on the majority of organisms is not known.

8.3.2.11.6.2 Tourism

Accidents, such as spilling of oil or other polluting substances into the sea, can have a significant adverse impact on tourism thus making the accident area unattractive to tourists, especially if the pollution ends up on beaches. After the accident of the Prestige tanker off the coast of Galicia (Spain) in 2002, the number of overnight stays in the region dropped by 5 million, while the tourism revenue dropped by 134 million euro, which is a drop of approx. 8%. The number of foreign tourists' visits reduced by 21 % which represented a revenue loss of 20 % (Garza-Gil et al., 2006).

Apart from direct impact of accidents on tourist areas (such as oil being washed over to the beach, unpleasant smell and other), the loss of reputation of tourist destination in the wider region or the entire country is also important. Destination perception is an important factor in deciding which country or region to visit. In the Gulf of Mexico, the adverse consequences of the explosion and oil leakage from the Deepwater Horizon platform on the tourism were also felt outside the parts directly affected by the pollution due to the prevailing public perception of the entire gulf as polluted (Conversations for the Responsible Economic Development, 2013). Two months after the accident, it was recorded that 26% of the people who had planned to visit Louisiana had cancelled the visit. In August of 2010, the Knowland Group carried out a public opinion poll in Louisiana, Alabama, Mississippi and Florida, which showed that the entire adverse impact of the accident on tourism was still noticeable two months after the accident. Although the hotel occupancy was good within a short period of time, it was shown that these were mostly workers working on the rehabilitation of accident consequences. The long-term effect, lasting for longer than two years, was mostly felt on accompanying activities related to tourism.

8.3.2.11.6.3 Maritime Shipping, Maritime Transport and Waterways

The oil spill is the most significant accident which can affect the maritime transport. When rehabilitating spill consequences, the number of vessels participating in the rehabilitation works (barrier installation, oil collection, chemical neutralisation…) will increase in the accident area. The existing maritime routes in the spill area will be temporarily rerouted in order to avoid the additional oil dispersion and collision of vessels (cargo ships, passenger ships..) and spill rehabilitation equipment.

8.3.2.11.7 Waste Management

In case of an accidental disposal of waste material into the sea (illegally disposed waste), it can harm the marine organisms, primarily marine mammals, turtles and birds. Metal waste (e.g. welding electrodes) may pollute the seabed around the well location. Oil spill could adversely affect the waste management, with regards to large quantities of hazardous waste discharged into the sea.

8.3.2.11.8 Human Health and Quality of Life

The human health includes the physical, psychological and socio-economic dimension. An accident such as oil spilling into the sea represents an accident which affects all three dimensions of the human health. High levels of certain compounds from oil may cause respiratory, liver, urinary, endocrine, neurological, haematological and other health issues, while even small levels of those compounds may cause mutagenic effects. Carcinogenic compounds represent the highest risk to human health, and they are benzene and polycyclic aromatic hydrocarbons. Many researches on the impact of toxic petrochemicals on the human health have recorded information on acute toxic symptoms, genotoxicity, etc. Besides, the oil spill accident also causes the occurrence of significant psychological diseases, such as PTSP, anxiety and depression. These health issues were most intense in the coastal areas directly affected by the oil. Inhabitants of those areas could no longer fish, but they spent months (sometimes even years) cleaning the polluted shores. The communities participating in the cleaning process also recorded the highest disease rate with regards to their direct exposure to toxic substances.

Psychological impact in communities which were not directly affected by the oil spill was strong due to the general slowing down of economic development and ruined environment perception in the pollution area.

Hydrogen sulphide released in the accident has a very adverse impact on the human health. The largest impact this toxicant has is on the nervous system. Exposure to lower levels may lead to eye irritation, nausea, problems with breathing and lung oedema. However, these symptoms usually disappear within several weeks. Prolonged exposure to a low level of hydrogen sulphide may lead to fatigue, loss of appetite, headache and dizziness. Short exposure to a high level of hydrogen sulphide may cause a person to stop breathing and may be lethal. In cases when the impact was not lethal, the high exposure to the hydrogen sulphide may lead to cortical necrosis and cerebral oedema.

Fires and explosions on platforms often result in serious injuries and even death of workers on platforms.

Recovery of community after the accident (the example of the oil spill in the Gulf of Mexico):

High depression rate lasted up to a year after the oil spill. Two years after the accident, approx. 20 % of the population was still depressed. Economic losses were the largest source of psychological health issues in the area which was, directly and indirectly, affected by the accident.

8.3.2.11.9 Infrastructure

When installing the infrastructure for exploratory wells, damage or complete disruption of the existing infrastructure or infrastructure being installed may occur. This impact will take place only if the installation is not carried out according to applicable regulations and at a stipulated distance from the existing infrastructure. When using production platforms, damage or infrastructure disruption may occur (pipelines and cables) due to accidents or improper handling.

8.3.2.12 Cross-border Impacts

Cross-border impacts are the result of certain activities which may cause a change in environment components in countries adjacent to the territory of the country where a certain activity is taking place. The Act on the Ratification of the Convention on Environmental Impact Assessment in a Transboundary Context (OG IT 6/96, entered into force with respect to the Republic of Croatia on 10 September 1997) defines the cross-border impact as a *"Transboundary Impact"* referring to any impact, not exclusively of a global nature, within an area under the jurisdiction of a Party caused by a proposed activity the physical origin of which is situated wholly or in part within the area under the jurisdiction of another Party.

The basic international treaty regulating the cooperation related to the cross-border environmental impact is the Convention on Environmental Impact Assessment in a Transboundary Context ("Espoo Convention"). The Convention sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries. At the European Union level, the Convention is complemented with the Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (as amended with the Directive 2014/52/EU), and Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment. Also, Directive No. 2013/30/EU on the safety of offshore oil and gas operations and amending Directive 2004/35/EC in one of its parts deals with the transboundary impact related to offshore exploration and production of hydrocarbons and defines that the Member State in which activities are planned, and if considered necessary, before the commencement of operations, forwards the relevant information to the potentially affected Member State and shall endeavour, jointly with that Member State, to adopt measures to prevent damage.

In case of the FPP for exploration and production in the Adriatic, the potential cross-border impact refers to the countries with which the Republic of Croatia shares the open sea area and the epicontinental belt. Those are Italy and Slovenia as EU Member States, and Montenegro which is not an EU Member State. FPP covers a number of various activities, at various sea depths (from 50 m to 1215 m) and in the area of various physical systems, so that cross-border impacts are possible, with regards to a certain type of activity, and their level can be assessed during the appropriate assessment for the ecological network / environment. For activities such as geomechanic testing of the seabed, laying of installation to the seabed or sailing of supply ships, the cross-border impact is not expected, while for activities such as seismic surveys and certain stages of well drilling as well as the hydrocarbon exploration itself, it is realistic to expect a cross-border impact.

In accordance to the above stated, a separate Appropriate Assessment of the impact on ecological network will be drafted for each project, Assessment of the need for an EIA and consequently, assessment of the cross-border impact as a part of procedures of Environmental Impact Assessment.

For the purposes of the assessment of the potential cross-border impact, exploration blocks defined in FPP overlap with Natura 2000 areas of Slovenia and Italy (Figure 8.7, Figure 8.8).

8.3.2.12.1 The Republic of Slovenia

In the part of the Republic of Slovenia ≈ 17 km away from the exploration block 1 there are four SCI areas - types and habitats (SI3000238 Strunjanske soline s Stjužo, SI3000247 Piranski klif, SI3000249 Med Izolo in Strunjanom – cliff and SI3000307 Med Strunjanom in Fieso) and an SPA area - birds (SI5000031 Strunjan) - Figure 8.7. With regards to the distance from the closest exploration block 1 point, the impact on the Natura 2000 areas in Slovenia is not expected. Cross-border impact is possible in case of accidents. The distance of the closest protection areas from the exploration block 1 is a bit less than 17 km, and impact on these areas is not expected (Figure 8.8).

8.3.2.12.2 The Republic of Italy

The perimeter of exploration blocks 1, 2, 3, 5, 7, 9, 12, 15, 18, 24, 25, 26 and 29 borders with the epicontinental belt of the Republic of Italy (Figures 8.9 and 8.10). Peripherally, in the northern part of the exploration block 1, there is a Natura 2000 area IT3330009 Trezze san Pietro e Bordelli (SCI) and a cross-border impact on that area cannot be excluded should the FPP implementation activities take place in the exploration block 1. In view of the above stated, before projects related to the exploration and production of hydrocarbons in the exploration block 1, consultations with the Republic of Italy should be conducted. Alternatively, it is suggested to reduce the surface of the exploration block 1 in its northern part. Perimeters of exploration blocks 18 and 24 are ≈ 22 km away from Natura 2000 areas IT911001 Isole Tremiti (SCI) and IT9110040 Isole Tremiti (SPA) - Figure 8.10. With regards to distance from exploration blocks, the cross-border impact on Natura 2000 areas in Italy is not expected, except in case of possible accidents. Protected sea areas in Italy are situated more than 20 km away from the exploration blocks (Figure 8.11) so that the cross-border impact thereon is not expected.

Figure 8.7 Natura 2000 areas in the Republic of Slovenia with respect to the exploration block 1

Figure 8.8 Protected sea areas in Montenegro

Figure 8.9 Northern part of the Adriatic Sea - Natura 2000 areas with respect to exploration blocks

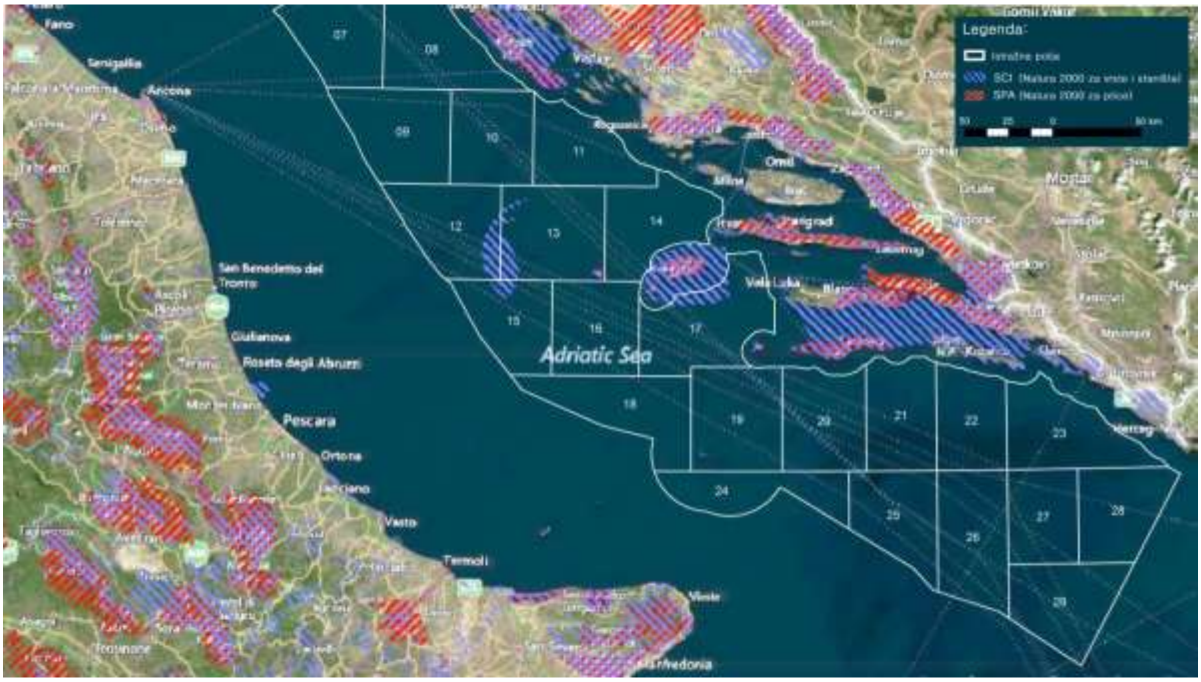


Figure 8.10 Southern part of the Adriatic Sea - Natura 2000 areas with respect to exploration blocks

Figure 8.11 Protected sea areas in the Republic of Italy

8.3.2.12.3 Republic of Montenegro

FPP exploration blocks 28 and 29 (Figure 8.10) border with the territorial sea of Montenegro. Inspecting the map of protected areas (Figure 8.12), as well as the Emerald Network (Figure 8.13) based on which ecological network areas will be established, it can be concluded that a significant cross-border impact on the protected areas or on the Emerald Network areas in Montenegro is not to be expected.

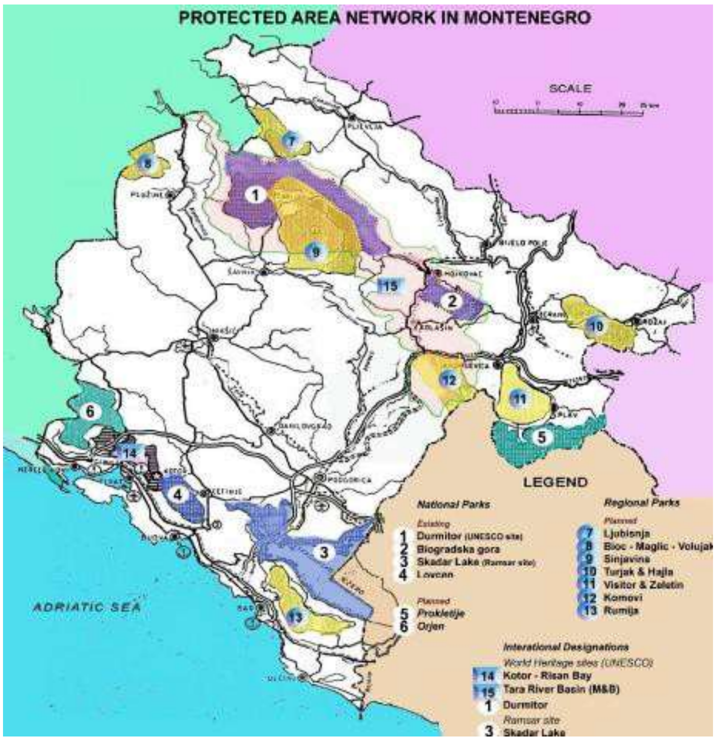


Figure 8.12 Areas of protection in Montenegro

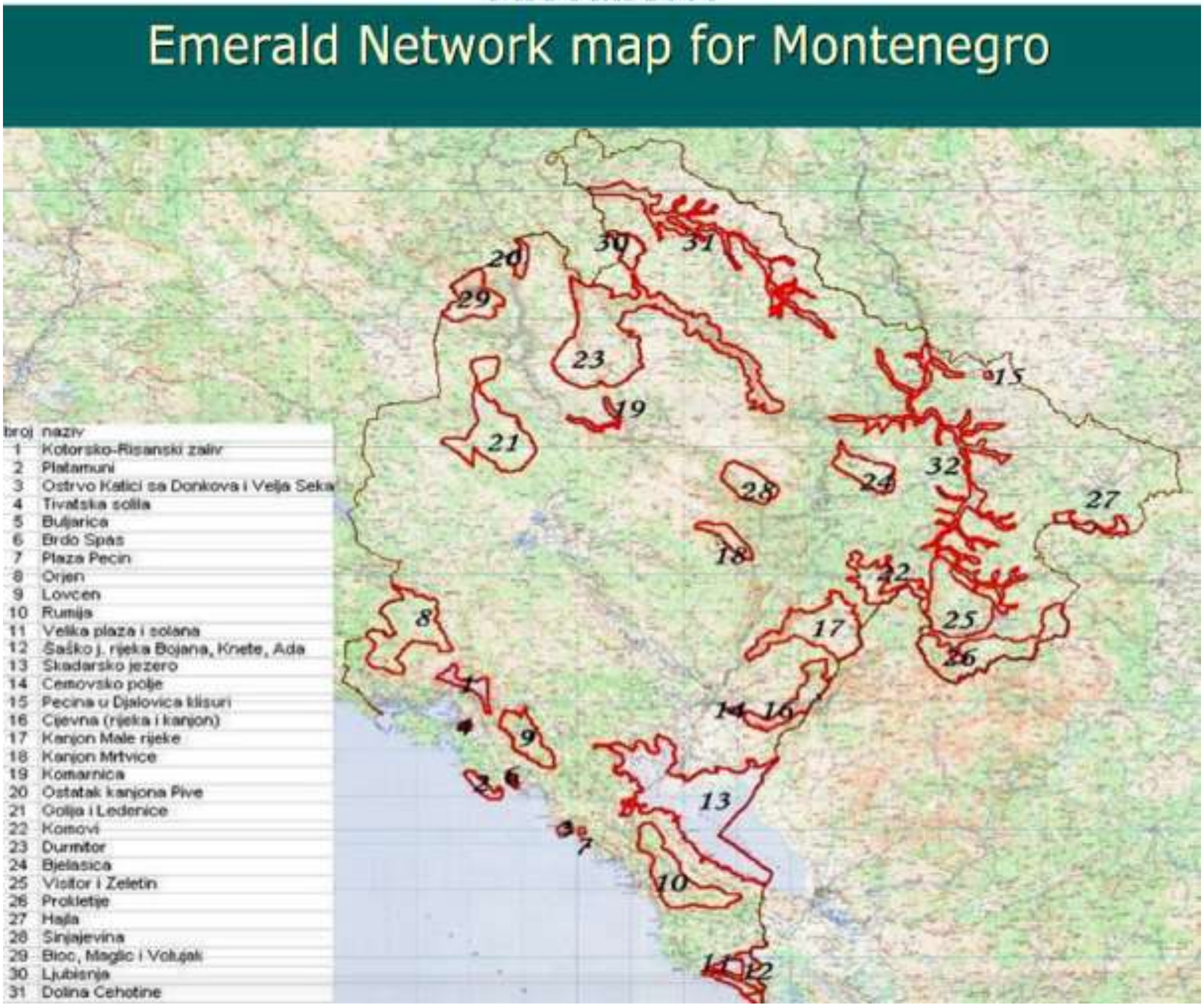


Figure 8.13 Montenegro Emerald Network

8.3.2.13 Assessment of the Fulfilment of Strategic Study Environmental Goals

Environment Component	Environmental Goal	Impact on the Fulfilment of Environmental Goal
Chemical Characteristics Noise Biodiversity Ecological Network Tourism Fisheries Marine and seabed pollution	Good condition of the sea and seabed	FPP implementation shall have multiple impacts on this environmental goal. All impacts range from insignificantly negative to positive, apart from the Ecological Network which in the part of a possible impact on birds shows an unacceptable negative impact. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions for impacts assessed as unacceptably negative.

Chemical Characteristics Noise Biodiversity Ecological Network Fisheries	Good condition of marine species and habitats with a special emphasis on marine mammals, turtles, fish, invertebrates and birds	FPP implementation shall have multiple impacts on this environmental goal. All impacts range from insignificantly negative to positive, apart from the Ecological Network which in the part of a possible impact on birds shows an unacceptable negative impact. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions for impacts assessed as unacceptably
Cultural and historical heritage Tourism	Protected submarine cultural heritage and natural landscape	From the tourism aspect, the FPP implementation will have an insignificantly negative impact with regards to this environmental goal due to the implementation of measures of impact mitigation. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions. The impact on the cultural & historical heritage was not analysed separately, but the Study defines an implementation measure within this environment component which in turn contributes to the increase of
Chemical characteristics Noise Fisheries Tourism Maritime Shipping, Maritime Transport and Waterways Waste Management	Harmonised implementation of the Programme with regards to other economic activities	FPP implementation shall have multiple impacts on this environmental goal. All impacts range from insignificantly negative to positive. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions.
Climate Characteristics	Preserving the existing air quality and climate conditions	FPP implementation shall have an insignificantly negative impact on this environmental goal. The strategic study suggests regular follow up of the air
Chemical Characteristics Human health and quality of life Waste Management Socio-economic characteristics Tourism	Preserving the human health and quality of life	FPP implementation shall have an insignificantly negative to insignificantly negative impact due to the implementation of measures of mitigation of impact on this environmental goal. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the

Chemical characteristics Climate characteristics Biodiversity Ecological network Marine and seabed pollution Fisheries Tourism Maritime Shipping, Maritime Transport and Waterways Shipping, marine Waste management Human health and quality of life	Mitigated accidents risk	Since it is not possible to define criteria for the assessment of impact of accidents on the environment at the level of assessment carried out by the Strategic Study, nor carry out the assessment of the impact on individual environmental components accordingly, the Study provides only an overview of potential accidents on individual environmental components, established based on the scientific data. It is expected that a detailed analysis of accidents' impact on environment for individual hydrocarbon exploration and production projects will process, during further procedures, assessments of the project impact on the environment/Appropriate assessment of the project impact on the ecological network. However, the Strategic Study has defined FPP improvement measures with the purpose of increasing positive impacts of the FPP implementation, and it also suggests regular follow up of various environment component conditions, which altogether contributes to

8.3.2.14 Cumulative Impacts

With regards to described impacts possible in the course of FPP implementation, it can be concluded that carrying out of activities on all exploration blocks would cumulatively have a significant negative impact on the environment. This would especially be seen should the activities in the blocks be carried out simultaneously. Based on available data, the optimum number of exploration blocks in which implementation of operations would not significantly impact the environment cannot be precisely determined. However, with regards to the Adriatic sea being a closed sea, as well as with regards to possible impacts, the framework assessment is that exploration (seismic exploration, well drilling) should not take place on more than three exploration blocks simultaneously. For hydrocarbon production operations, an assessment of the impact on the environment shall be carried out for each project within which a Study of the project impact on the environment will be developed which will assess the cumulative impact in relation to implemented operations in the exploration phase as well as in relation to a potential number of exploratory wells.

9 Alternative solutions

Although the FPP proposal does not include alternative solutions, they have been devised based on the analysis of the potential impact on environment components during the preparation of this Study. The proposed alternative solution represents one of the ways to solve potential conflicts between the objectives of implementing FPP and the environment and nature protection objectives in the most sensitive areas. In order to avoid the identified potential conflicts, a redefinition of blocks covered by such areas has been proposed so as to exclude the areas of specific interest for other activities or for nature protection. On a strategic assessment level covering the pelagic zone up to the continental shelf border, when locations, time schedules or exploration methods to be used when implementing FPP are all unknown, the alternative solutions can be proposed on the level of identified conflicts of FPP with individual environment components. By implementing the proposed protection measures, as well as acceptability assessment procedures for the ecological network / environment, additional mitigation measures will be foreseen for the defined activities based on the identified potential conflicts.

9.1 Block corrections arising from conflicts with nautical tourism

The extended water area of the islands of Žirje, Šolta, Brač, Hvar, Korčula, Vis, Lastovo is particularly essential for nautical tourism, which is an important, thriving branch of economy. Installation of platforms and other facilities for petroleum production within this water area in a way that they are visible from the most used nautical passageways could be detrimental to the landscape features and change the existing perception of the area concerned, thus decreasing its appeal for nautical tourism. This is why this alternative solution proposes to modify certain parts of blocks 14 and 17 so as to exclude the areas which are highly appealing for nautical tourism, especially around the island of Vis, and block 11 in agreement with the Ministry of Tourism will be adjusted and the petroleum operations will be coordinated with nautical tourism activities.

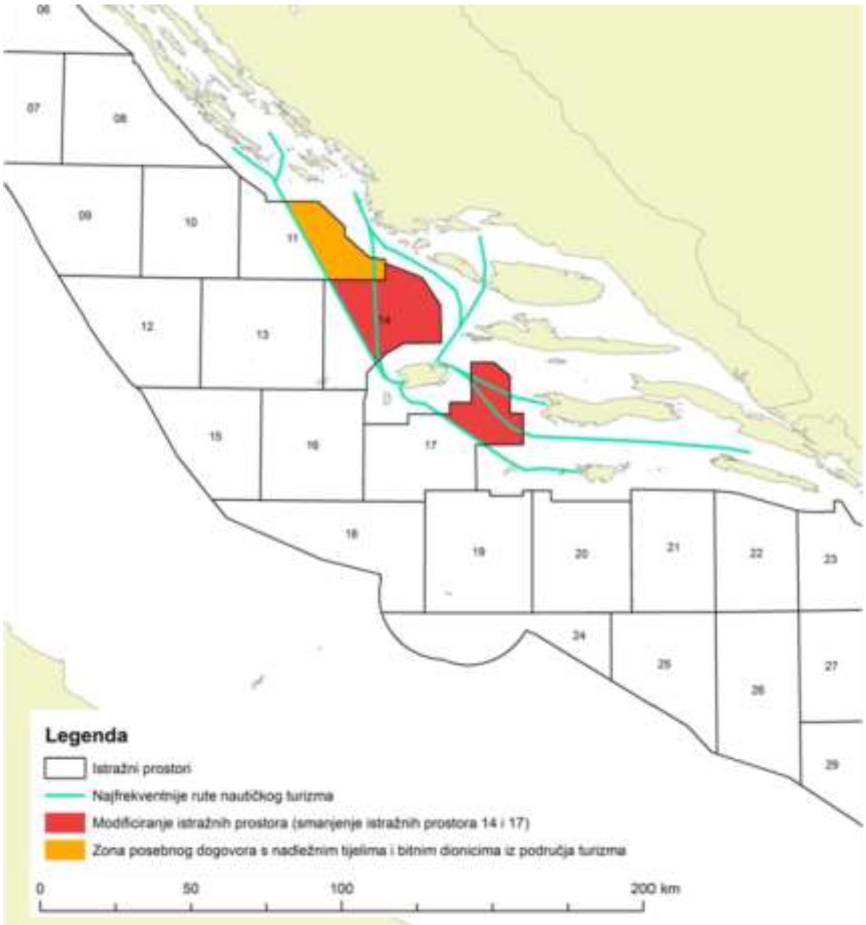


Figure 9.1 Alternative solution proposal regarding block modification in order to prevent conflicts between FPP and nautical tourism

9.2 Block and permitted activity corrections arising from conflicts with fishery

Impacts on fishery are possible in different phases of FPP implementation. Based on the baseline studies analysis regarding fishing vessels, areas specifically important for fishery have been defined. The immediate area of Jabučka kotlina (surrounding the island of Jabuka) is particularly sensitive, as well as its surrounding area where, in order to protect this extremely important fishery resource area, a zone of prohibition regarding trawling is planned to be implemented, as well as a no-take zone. The boundaries of this area have been determined based on the scientific research conducted by Croatian and Italian scientists. The known impacts on fishery regard the impact created by noise during seismic surveys, the impact of platform installations and of exploratory and production drilling, the impact arising from installing pipelines and the accompanying infrastructure, as well as the impact from platform removal.

No petroleum production is to be carried out in the immediate area of Jabučka kotlina (surface area of 305.38 square kilometres), while seismic surveys and exploratory drilling shall not be carried out during the spawning and recruitment of fish species (parts of blocks 12, 13 and 15). In the surrounding area of Jabučka kotlina (a future no-take zone, parts of blocks 10, 11, 12, 13 and 15), FPP activities involving a possible impact on fish spawning shall be carried out in agreement with the Department of Fisheries at the Ministry of Agriculture. In other areas economically important for fishery, FPP activities shall be carried out in agreement with the competent authorities and important stakeholders from the area of fishery (parts of blocks 1, 2, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23, and 28).

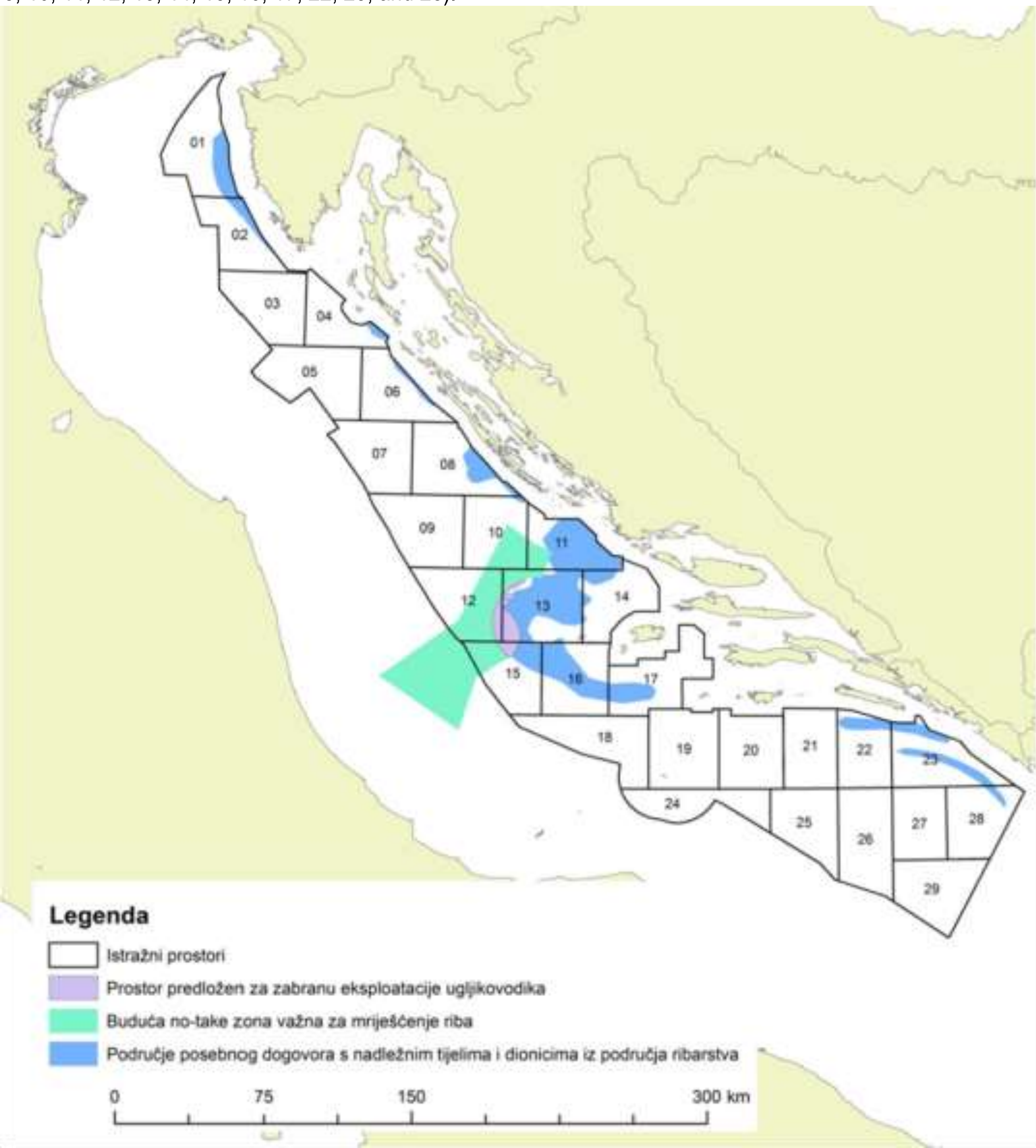


Figure 9.2 Areas important for fishery in relation to blocks

9.3 Block corrections necessary for the protection of conservation objectives of the NATURA 2000 ecological network

The analysis of potential impacts helped recognise a potentially significant negative impact on the nesting population of seabirds and Eleonora's falcon (-2). Pučinski otoci (Pelagic islands and islets) (sv. Andrija, Svetac, Kamnik and Palagruža) are the only nesting locations of populations of the *Puffinus yelkouan* (Yelkouan shearwater) and *Calonectris diomedea* (Cory's shearwater) species in Croatia, as well as the majority of the *Falco Eleonorae* (Eleonora's falcon) population which could be endangered by the impacts caused by the FPP implementation to such an extent that they permanently leave the nesting area. Therefore, this alternative solution proposes to transfer the activity zone 1 km further from the concerned part of the area comprising the Pučinski otoci (Pelagic islands) ecological network which includes these species to be conserved (Figure 9.4, Figure 9.5, Figure 9.6).

Figure 9 Figure 9.4 Alternative solution proposal regarding block modification in order to protect the conservation objectives of the NATURA 2000 ecological network

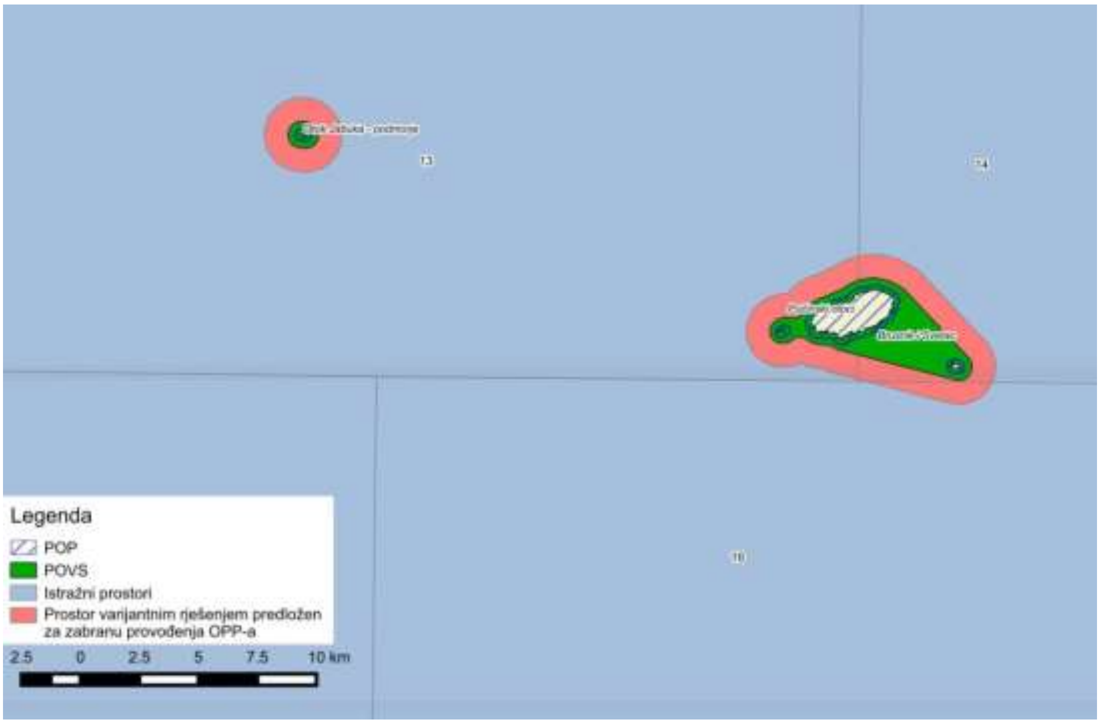


Figure 9.5 Alternative solution proposal regarding block modification in order to protect the conservation objectives of the NATURA 2000 ecological network in the following areas: island of Jabuka – underground, Pučinski otoci (Pelagic islands), as well as the islands of Brusnik and Svetac

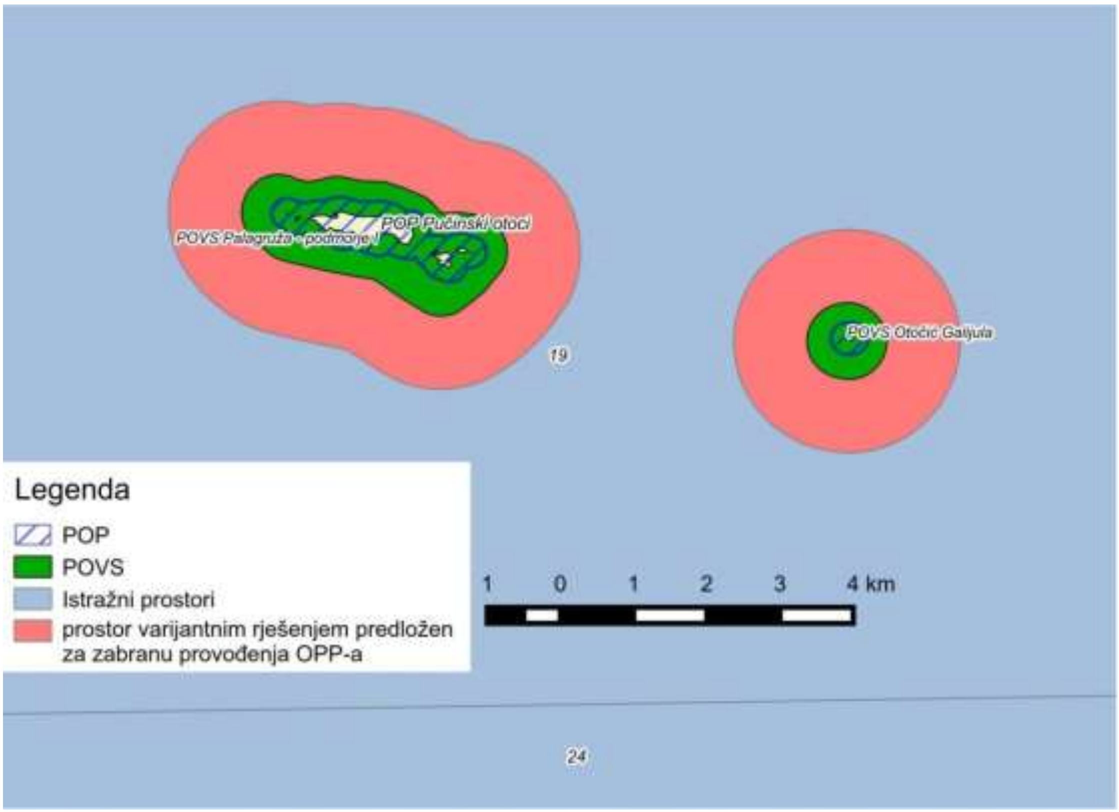
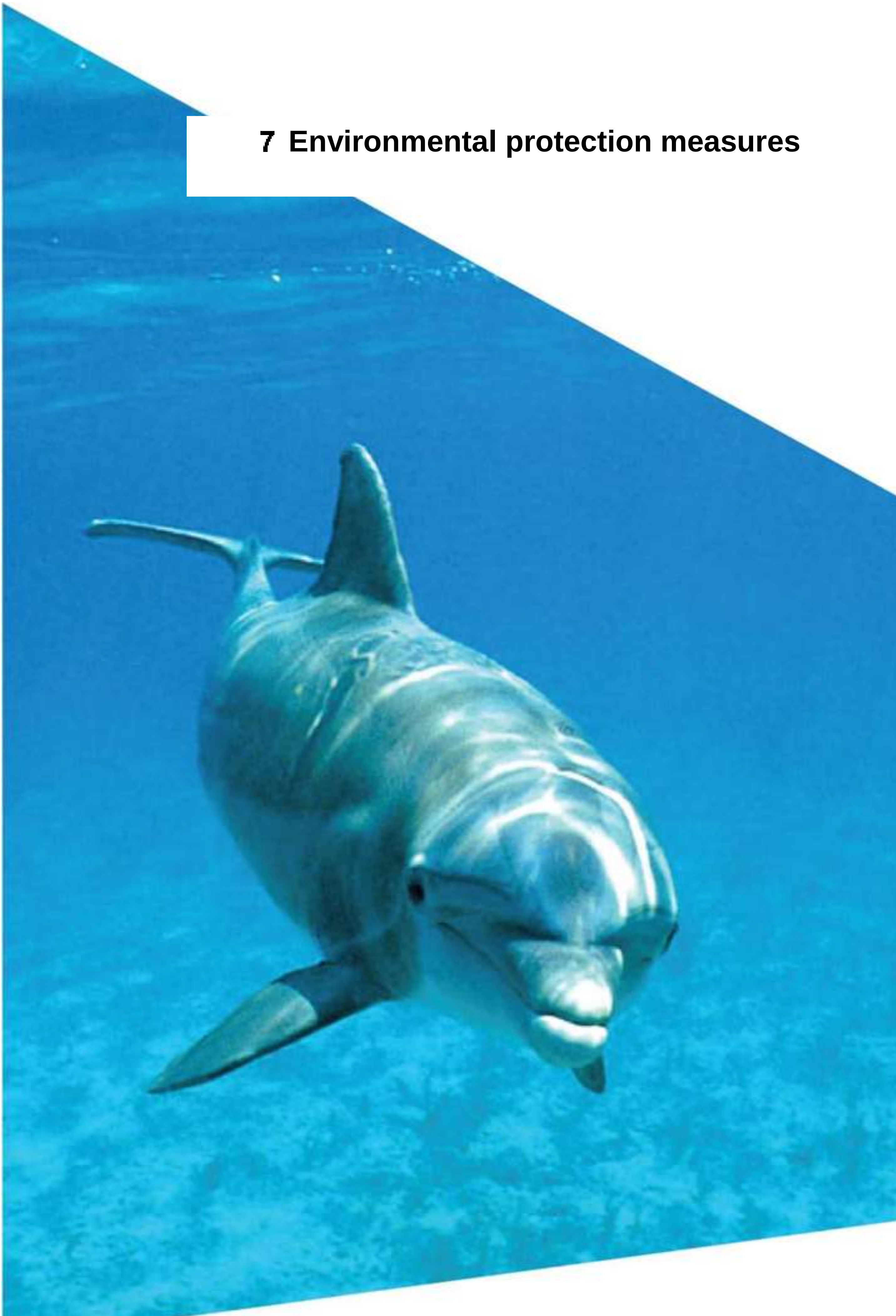


Figure 9.6 Alternative solution proposal regarding block modification in order to protect the conservation objectives of the NATURA 2000 ecological network in the following areas: island of Palagruža – underground, Pučinski otoci (remote islands) and the Galijula islet

7 Environmental protection measures



Component	Impact	FPP mitigation and improvement measures	Justification of the measure
Chemical properties	Changes in sea water pH, oxygen saturation, sea water nutrient and organic concentration levels resulting from the hydrocarbon exploration and production operations	1 In the area affected by the FPP implementation, in order to measure sea water pH, oxygen, nutrient and organic substance levels in the environment prior to the commencement of the operations, and to ensure their continuous monitoring during the operations and, in the case that the set parameter values are outside the estimated permitted interval, additional mitigation measures need to be established.	As it may be concluded from previous monitoring results, the largest fluctuations of sea water dissolved oxygen and nutrient salt concentrations and pH were observed at stations with direct anthropogenic effects; in the immediate vicinity of exploration and production platforms, it may be expected that the values of these parameters will change.
Noise	Noise level increase	1 In the area affected by the FPP implementation, in order to build a noise dispersion model which takes into account the expected noise level and frequency caused by the FPP implementation as well as other noise sources in the affected area.	The noise dispersion model will provide a parameter to allow the assessment of noise pollution impacts on species endangered by it.
Marine and seabed pollution	Impact of discharging mud into the sea	1 Use water-base drilling mud. If there is a need to use other types of mud (oil-base, synthetic-base), it is required to obtain prior approval of competent authorities.	Water-base drilling mud has a significantly lower toxicity than synthetic-base or oil-base drilling mud.
Fisheries	Seismic surveying noise impact Platform installation and exploration and production drilling impacts Pipeline and supporting infrastructure installation impacts Platform removal impact	1 No exploitation of hydrocarbons in the narrow area of the Jabuka depression (surface area 305.38 km^2), 2 In the wider area of the Jabuka depression, which includes areas important for spawning and recruitment of fish species, and in other areas important for fisheries, it is required to harmonize the FPP implementation with authorities and shareholders in the fisheries sector, 3 Harmonization of the time and place of seismic surveys and other exploration works with authorities competent for activities of fishing vessels, 4 Harmonization of the planned platform and pipeline locations with trawling areas.	The Jabuka depression is the main spawning grounds of economically significant fish species. Fishing activities take place in a part of exploration blocks, so it is required to harmonise the FPP implementation with competent authorities.
Tourism	Impact of platforms on "sun and sea" tourism	1 Production platforms and supporting infrastructure have to be located so that they do not disturb the view-points of interest for the "sun and sea" tourism. Platforms may not represent a dominant view from beaches, settlements and tourist zones.	The visibility of platforms from the mainland is perceived as disturbing the view and may significantly reduce an area's attractiveness for the "sun and sea" tourism. This branch of the tourism sector is one of the key economic branches and it is closely linked with landscape features.
	Impact of platforms on nautical tourism	2 Modification of blocks 14 and 17 in order to exclude highly attractive nautical tourism areas and, for block 11, in agreement with the Ministry of Tourism, adaptation and harmonization of hydrocarbon exploration and production operations with nautical tourism activities.	The installing of, primarily production, platforms may result in disturbance of landscape features of highly attractive nautical tourism areas. Islands of the Central and Southern Adriatic are areas particularly attractive for nautical tourism, which represents an important and prosperous economic branch.
Biodiversity – whales and sea turtles	The impact of noise, primarily generated by seismic surveys and well	Prior to implementing the FPP operations: 1 make detailed noise dispersion models based on actual data about the	As sea turtles and whales are especially sensitive to increased noise levels, special protection measures are proposed for them.

	drilling during the FPP operations		environment in which the operations will be conducted,	
		2	determine the range, number and potential seasonality of presence of individual vulnerable species, - determine the acceptable variation in resulting values,	
		3	determine a detailed operating procedure for monitoring and protection of the listed species during performance of each particular operation representing a source of noise,	
		4	apply the Guidelines to address the impact of anthropogenic noise on cetaceans in the ACCOBAMS area.	
Other biodiversity	Noise generated by FPP operations	1	Prior to implementing the FPP for the licensee's Programme of exploration activities, procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network need to be conducted in accordance with regulations.	In order to avoid cumulative effects of seismic surveys, they must be time-delayed in individual blocks.
	Occupying a part of the water area	2	Prior to exploratory drilling, which involves anchoring of drilling vessels, it is necessary to determine the composition of the habitat at the position for drilling in order to determine potential presence of the Coralligenous communities.	Marine habitats in Croatia are mostly unexplored, so locations of rare habitat types, such as the Coralligenous habitats, are unknown.
	Discharge of drilling mud and well cuttings	3	It is proposed to use a cuttings dryer which removes drilling mud from cuttings in order to prevent the forming of noticeable cuttings formations on the seabed in the area around the platform.	With the additional removal of drilling mud from well cuttings, they become cleaner and less toxic to the marine environment. The cumulative effect of cuttings and mud formations on the seabed is avoided by keeping the distance for mud and cuttings discharge (one platform discharges mud in a 500 m radius).
	Well testing (flaring of hydrocarbons)	4	Use of high-efficiency flares on platforms, with combustion efficiency of 99%.	In order to reduce incomplete combustion and potential falling of hydrocarbon drops into the sea, high efficiency flares (burners) are used.
	Discharge of formation and technological water (release of hydrocarbons)	5	Monitoring of the sea surface when testing hydrocarbon reservoir deliverability.	No visible glow on the sea surface ensured.
	Light pollution	6	For lighting platforms, lighting that is least attractive to birds should be used.	Change of type of lighting will attract bird in lesser extent, resulting in reduced number of bird deaths from collision with the platform.
	Increased traffic of vessels and helicopters	7	Regular helicopter routes should be defined so that sea-bird nesting areas are avoided, at least during a particular part of the year.	The helicopter noise may result in leaving the nest, therefore it is required that helicopters do not fly near sea-bird nesting areas.
	Production platform and pipeline removal	8	After the end of production stage, the platform and pipeline constructions should be decommissioned as in the Rigs-to-Reef programme. Pipelines should be subject to chemical neutralization and left in the sea.	Over several decades, a sea platform is overgrown with different organisms, transforming it into an artificial reef. The removal of the platform would also remove the newly created ecosystem. The removal of the pipeline disturbs the

			seabed again and increases the possibility of marine pollution.
Ecological network	Noise impact on bird nesting	1 The project zone should be moved 1 km from the relevant area of the ecological network Pučinski otoci (Pelagic Islands).	Precautionary measure for birds nesting on Pučinski otoci.
	- reduction in food sources for sea-birds - bird deaths caused by - collision with platforms and hydrocarbon flaring - removal of platforms	2 After implementing the appropriate assessment of the project impact on the ecological network, appropriate mitigation measures need to be prescribed.	As the locations of planned activities are unknown at this FPP stage, appropriate measures will be prescribed depending on the exact location and scope of the project.
Maritime shipping, maritime transport and waterways	Changes in usual shipping routes	1 Alignment of possible corrections in usual shipping routes with competent maritime traffic authorities.	Considering the increased maritime transport and possible construction of new platforms, it is required to harmonize all maritime-traffic activities of the FPP implementation.
Cultural and historical heritage	-	1 If the exploration phase of the FPP implementation results in finding new unrecorded cultural heritage sites, it is required to suspend all works and inform the competent authority thereof.	Cultural heritage in the Adriatic is a part of the rich cultural and historical heritage of the Republic of Croatia which should be preserved.
Cross-border impact	Impact on the ecological network area IT3330009 Trezze san Pietro e Bordelli	1 Reduction of the surface area of the northern part of block 1.	Precautionary measures for conservation objectives of Natura 2000 area

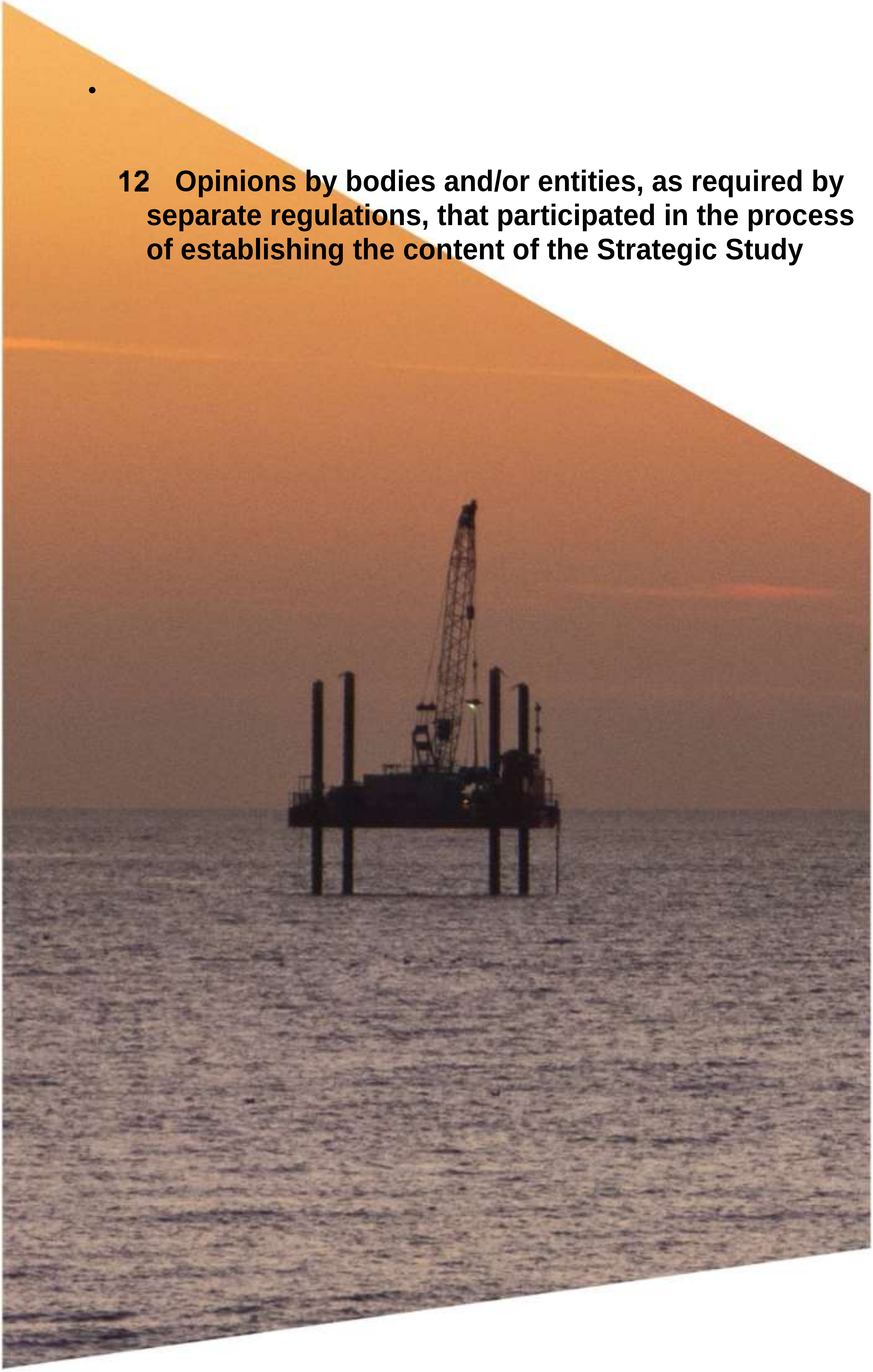
81 Environmental monitoring

Component	Indicator	Indicator monitoring tool	Person responsible for monitoring	Data source	Monitoring timeframe
Chemical properties	Sea water pH value in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP implementation	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Oxygen saturation level in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP implementation	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Nutrient concentration (dissolved inorganic nitrogen, orthophosphates, orthosilicates, etc.) in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP implementation	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Organic substance level (DOC, TOC, POC) in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP implementation	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Climate characteristics	Chemical composition of all gases discharged into the environment during hydrocarbon exploration and production	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Noise	Noise level in the sea in all areas covered by FPP operations	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Marine and seabed pollution	Pollutant concentration (ecotoxic metals, organotin compounds, persistent organic pollutants) in the sea and on the seabed in the immediate vicinity of exploratory and production wells	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Fisheries	Quantity of commercial sea species in the Adriatic	Regular monitoring	Fisheries authority	Regular reports	During exploration and production operations
	Distribution of commercial sea species by age	Regular monitoring	Fisheries authority	Regular reports	During exploration and production operations
Biodiversity	Number and distribution of loggerhead sea turtle (*Caretta caretta*) in the blocks	Regular monitoring	Licensee	Regular reports	Baseline, during exploration, during production and during decommissioning

Component	Indicator	Indicator monitoring tool	Person responsible for monitoring	Data source	Monitoring timeframe
	Number and distribution of common bottlenose dolphin (*Tursiops truncatus*) in the blocks	Regular monitoring	Licensee	Regular reports	Baseline, during exploration, during production and during decommissioning
	Number and distribution of European shag (*Phalacrocorax aristotelis desmarestii*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number and distribution of Cory's shearwater (*Calonectris diomedea*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number and distribution of yelkouan shearwater (*Puffinus yelkouan*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number and distribution of Audouin's gull (*Larus audouinif*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number of collisions of common crane (*Grus grus*) with mining facilities*	Regular monitoring	Licensee	Regular reports	During exploration and production operations
	Monitoring of marine pollution by surface hydrocarbons in the immediate vicinity of mining facilities	During well production capability testing	Licensee	Report upon activity completion	During exploration operations
	Monitoring of bird migration in the immediate vicinity of mining facilities during hydrocarbon flaring	During well production capability testing	Licensee	Report upon activity completion	During exploration operations

- This monitoring measure should by applied if the FPP operations are conducted in an area in which they can affect the above strictly protected species

12 Opinions by bodies and/or entities, as required by separate regulations, that participated in the process of establishing the content of the Strategic Study



Name	Opinion – Content and Scope of the Strategic Study	Dealt with in the Strategic Study
Ministry of Construction and Physical Planning, Directorate for Physical Planning CLASS: 350-01/14-02/516 FILE NO.: 531-06-1-14-2 Zagreb, 23 September 2014.	Particular attention needs to be paid to all the obstacles arising from the demarcation of the marine area, and in relation to the current and planned spatial interventions (infrastructure corridors – pipelines, electricity cables, etc., waterways, etc.). There also needs to be covered a section relating to other planned intentions in the area of the intervention (fishing areas, scientific research areas, areas for military exercises, protection areas, etc.).	The Opinion was taken into account. The interrelationship of the Strategic Study and the current and planned spatial interventions is dealt with under Chapters 2, 3, 8, and 10.
	It is necessary to cover all the relevant spatial planning documents (e.g. Spatial Development Strategy of the Republic of Croatia), and directives (e.g. Directive Establishing a Framework for Maritime Spatial Planning and Coastal Zone), to determine the effect of these documents on the exploration and production of hydrocarbons in the Adriatic.	The proposed documents are analysed in the Strategic Study, in Chapters 2 and 7.
	There need to be determined safe distances from the shore / islands for the intervention of the exploration and production of hydrocarbons. Also, a section on visual impact of the intervention needs to covered.	The proposal for exploration and production fields, which is analysed in the Strategic Study in relation to all the relevant environmental components, is given in the FPP, including also the proposed safe distances from the shore/islands. Visual impact of the intervention is dealt with under Chapters 8, 9, and 10.
	The justifiability of the exploration and production of hydrocarbons in the sea of the Republic of Croatia needs to be analysed within the study, having regard to the relevant legislation.	The Strategic Study, in its entire scope, analyses the justifiability for the exploration and production of hydrocarbons in the sea of the Republic of Croatia, having regard, amongst other things, to the relevant legislation.
	It is proposed to request opinion of the Croatian Institute for Spatial Development, which takes part, within its competencies, in drafting sectorial strategies, plans, studies and other documents.	Consistent with common practice, an opinion was not requested from particular subunits of the competent bodies, and the Croatian Institute for Spatial Development was not contacted individually. The Ministry of Construction and Physical Planning is, instead, considered as an umbrella body for this issue.
Ministry of Defence CLASS: 342-08/14-01/9 FILE NO.: 512-01-14-16 Zagreb, 29 September 2014	The Ministry of Defence has no objections as to the content and level of the scope of data to be covered by the Strategic Study.	The Opinion was received.
Ministry of Agriculture CLASS: 351-03/14-01/172 FILE NO.: 525-13/0340-14-2 Zagreb, 3 October 2014	The Strategic Study should, in addition to the impact of air shock waves on marine mammals, sea turtles, fish and plankton, also include the impact on other organisms in the ecosystem, like cephalopods, crustaceans and echinoderms.	The Opinion was taken into account and dealt with under Chapters 3, 4, 5, 6, 7, 8, 10. and 11.
	It is necessary to add a chapter describing a possible impact of the planned activities on the existing fish and shellfish farms, as well as the impact on the areas that are by spatial planning documentation envisaged for the fish- and shellfish-farming activities.	The Opinion was taken into account and dealt with under Chapters 3, 4, 5, 8, 9, 10. and 11.
Ministry of Maritime Affairs, Transport and Infrastructure CLASS: 310-01/14-01/05 FILE NO.: 530-03-1-14-18	It is necessary to cover the topic of the sea from an ecosystem point of view (water column, seabed, subsoil and ecological status). Also, it is necessary to cover a cross-border impact on sea pollution that leads to ecosystem pollution.	The Opinion was taken into account and dealt with under Chapters 3, 4, 5, 7, 8,10. and 11.

Zagreb, 7 October 2014	The Study needs to treat the available data about the type, volume and manner of the maritime traffic functioning, the existing sea routes, harbours, moorings, and anchorages, and their planned development. Furthermore, it is necessary to analyse the pressure, i.e. the impact of exploration and production of hydrocarbons on the planned development of the maritime traffic and infrastructure.	The Opinion was taken into and dealt with under Chapters 3, 4, 5, 7, 8, and 10.
	It is necessary to treat the cumulative impact of the maritime traffic, taking into consideration its future development, and production of hydrocarbons on marine environment, with particular emphasis on the protected areas.	The Opinion was taken into account and dealt with under Chapter 8.
	An integral approach to the maritime activities development needs to be treated in the Study.	The Opinion was taken into account integrated into the Study.
	The type and volume of the marine and coastal area pollution (existing and possible) needs to be analysed in the Study. There needs to be described how the expert exploration and production of hydrocarbons may have impact on the marine environment and ecosystems from the economic, sociologic, and environmental point of view. It is proposed that impacts be evaluated by describing if they are significant or not significant (secondary impacts), favourable or unfavourable, permanent or occasional, short-term, mid-term or long-term, and cumulative.	The Opinion was taken into account and dealt with under Chapter 8.
	It is necessary to treat the multidisciplinary approach to the production of hydrocarbons, respecting the sustainable development principles.	The Opinion was taken into account and integrated into the Study.
	It is necessary to treat spatial data (which are directly or indirectly linked to the geographic area where the exploration and production of hydrocarbons will be performed), and particularly with regard to hydrography.	The Opinion was taken into account and integrated into the Study, under Chapters 1, and 3.
	It is necessary to establish the causality chain between development, problems and consequences.	The Opinion was taken into account and the principle was applied in the Study.
	The drafting of regulatory and supervisory / control measures is proposed. Within such supervisory / control measures it is proposed to draft basic (or base measures), limited supplementary measures (for the planned defined period of time in future), and special measures: prevention measures (to avoid/prevent impact on other entities), and compensatory measures (in cases when impact is unavoidable/unpreventable). Also, it is proposed that the defined measures be particularly directed to process waters, drainage waters, water-based muds, drilled particles, non-ionic detergent (drilling by-products), industrial hazardous waste, industrial non-hazardous waste, packaging waste, oily waste.	The Opinion was taken into account and dealt with under Chapter 10.
	It is necessary to take into consideration the legislative framework relevant for the protection of the sea and for performing economic activities in the maritime domain (the Maritime Code, the Maritime Domain and Seaports Act, and other relevant subordinate legislation).	The Opinion was taken into account and integrated into the Study.
Ministry of Tourism CLASS: 011-02/14-02/26 FILE NO.: 529-04-14-10 Zagreb, 4 September 2014	It is necessary to define the impact of the exploration and production process on nautical tourism (the use of sea routes and cities' harbours and moorings).	The Opinion was taken into account and dealt with under 5, 8, 9, and 10.
	It is necessary to identify potential risks, assess the likelihood of risk, evaluate risks, determine the risk avoidance measures, determine operating methods and measures in the event of incidents.	Due to lack of information, and in consultation with a member of the Expert Advisory Committee, the risk assessment method was deleted from the Study. The impact on tourism was assessed following the methodology outlined under Chapter 8, instead.
	It is necessary to balance the time series/schedule of interventions in the Adriatic Sea, particularly in summer months in times of intensified vessel traffic.	The Opinion was taken into account and dealt with under Chapters 8, 9, and 10.

Ministry of the Interior No.: 511-01-152-79795/2-2014 Zagreb, 12 September 2014	The Ministry has no requests or proposals.	The Opinion was received.
Ministry of Foreign and European Affairs CLASS: 011-02/14-01/266 FILE NO.: 521-V-01-02-14-2 Zagreb, 17 September 2014	In conducting the subject procedure, it is necessary to apply the relevant provisions of the Environmental Protection Act (OG 80/13), the Decree on environmental impact assessment (OG 61/14), and the Regulation on information and participation of the public and interested public in environmental matters (OG 64/08).	The Opinion was taken into account.
	It is necessary to ensure implementation of all legislation in the area of environmental and nature protection, applicable to the Study.	The Opinion was taken into account.
Ministry of Environmental and Nature Protection CLASS: 351-03/14-04/452 FILE NO.: 517-06-2-1-2-14-4 Zagreb, 30 September 2014	The Strategic Study needs to include a chapter on the Main Appropriate Assessment of the FPP for the ecological network. This chapter needs to include the following: data on the ecological network, a cartographic representation of the ecological network in appropriate scale, a description of possible significant impacts of the FPP implementation on the ecological network, a survey of other solutions and their impact on the ecological network, a proposal of measures for mitigating negative impacts of the FPP implementation, a conclusion (a final appropriate assessment of the FPP).	The Opinion was taken into account and dealt with under Chapter 6.
	The Strategic Study needs to analyse and assess possible impacts on biodiversity and the protected areas, based on the Nature Protection Act. A particular attention needs to be paid to the strictly protected species, especially those that are sensitive to exploration activities (e.g. species of marine mammals, sea turtles, and cartilaginous fish), and to possible pollution that may occur during the exploration and production periods, and that may be caused by accidents. Furthermore, it is necessary to include measures for the reduction of negative impact on biodiversity and protected areas (if any).	The Opinion was taken into account and dealt with under Chapters 8, and 10.
	It is necessary, in the Study, to treat the impacts of industrial waste on the environment in the area of defined exploration and production zones in the Adriatic Sea.	The Opinion was taken into account and dealt with under Chapter 8.

	Due to strong impact of the interventions planned in the sea, it is necessary to start drafting additional expert background papers and studies, to ensure conditions for a comprehensive and objective environmental impact assessment of the intervention / Appropriate Assessment of the intervention on the ecological network. The Strategic Study needs to take into account also the Marine Strategy Framework Directive (2008/56/EC), and the related Commission Decision on Criteria and Methodological Standards on Good Environmental Status of Marine Waters (2010/477/EU) In terms of the marine protection, the Study needs to: - take into account the drafted documents of the Marine Strategy "Initial assessment of the state and load of the marine environment of the Croatian part of the Adriatic", and "A Set of Characteristics of Good Environmental Status (GES), and of Objectives in the Marine Environment Protection", which are in the adoption procedure, in the section relating to the status of fish resources and of other economically significant marine organisms, with concluding recommendations for a long-term and sustainable management and the protection of fish resources, including the establishment of fishing protected areas in the wider area of Jabuka Depression; - take into account the draft document of the Marine Strategy "Monitoring and Observation System for Ongoing Assessment of the Adriatic Sea", for which the public consultations procedure is completed, and it is currently in the procedure of adoption by the Government of the Republic of Croatia; - include an overview of the existing pressures to defined exploration sites, with aim to establish negative cumulative and synergistic impacts on eco-systems; - include the impact of expected activities on fishing areas identified as areas of national interest for long-term and sustainable management and the protection of plant resources; - establish physical loss, physical damage and other physical disturbance, and in accordance with the Marine Strategy Framework Directive; - possible pressure of contamination by hazardous substances needs to be established for the "exploratory drilling" and "development drilling and mining facilities and plants", in addition to the given possible impacts.	The Opinion was taken into account and dealt with under Chapters 3, 4, 5, 7, 8, 9, and 10.

Split-Dalmatia County, Administrative Department for Construction, Public Utilities Affairs, Infrastructure and Environment Protection CLASS: 351-01/14-01/0452 FILE NO.: 2181/1-10-14-2	The content of the Study needs to be aligned with Annex I of the Regulation on strategic impact assessment of the plan or programme (OG 64/08).	The Opinion was taken into account.
	It is necessary to lay down the protection measures for the marine and coastal areas, aimed at preventing, reducing, mitigating, and compensating for negative impacts on this environmental component.	The protection measures for the marine and coastal areas are stipulated within the measures for various environmental components under Chapter 10.
Zadar County, Administrative Department for the Economy CLASS: 310-01/14-01/02 FILE NO.: 2198/1-06-14-2 Zadar, 24 September 2014	There are no objections or proposals as to the content of the Strategic Study.	The Opinion was received.
Dubrovnik-Neretva County CLASS: 351-01/14-01/77 FILE NO.: 2117/1-01-14-02 Dubrovnik, 29 September 2014	The Strategic Study needs to take into account a wider buffer zone than 15 – 20 km from the shore and islands, where stricter protection measures will be considered and possible distancing of particular exploration blocks located in the zones of high vulnerability, i.e. of particular landscape value, proposed.	The Opinion was taken into account, and the protection measures were stipulated, as well as distancing of particular exploration areas from the zones of high vulnerability. A buffer zone of 15 – 20 km from the shore and islands is not applicable, since the Strategic Study is an analysis of the FPP, which already at earlier stage defined the area covered by exploration and production fields as the subject matter of analysis in the areas of the territorial sea and the continental shelf. However, the Study proposes that particular fields be distanced from the shore and islands, in accordance with various environmental components and vulnerability of the area.
	The Strategic Study needs to consider possible impacts on, and establish separate restrictions and possible exemption of ecological network habitats, and areas that are in the vicinity of or within the protected areas, like the Lastovo Islands Nature Park (including 44 islands, islets, rocks and reefs), and the Mljet National Park, from exploration zones.	The Opinion was taken into account and dealt with under Chapters 3, and 6.
	It is necessary to describe the marine chemistry, the existing pressure of contamination by hazardous substances in the marine ecosystem, and compare it with the pressures expected in exploration and production.	The Opinion was taken into account and dealt with under Chapters 3, and 8.
	It is necessary to assess the impact of emissions of hazardous substances from plants to air in the course of exploration and production.	The Opinion was taken into account and dealt with under Chapters 8.

	The Strategic Study has to cover, in a separate chapter, the environmental impact in case of accidents (oil spill, emissions of hydrogen sulphide), and other occasional or permanent pollution, and lay down the protection measures, taking into account the MARPOL Convention, the Barcelona Convention, and its Protocols, and the legislation of the Republic of Croatia.	The environmental impact in case of accident is dealt with under Chapter 8. The protection measures in case of accidents are not laid down, because, due to lack of information on particular interventions and their technical characteristics, it was not possible to establish the criteria for environmental impact assessment at the level of the Strategic Study, nor to assess in details the impact that would require mitigation measures to be established. It is expected that a detailed analysis of the environmental impact of accidents for particular interventions relating to exploration and production of hydrocarbons will be undertaken in the course of further procedures of environmental impact assessments / Appropriate Assessment of the intervention on the ecological network.
	It is necessary to consider the mitigation measures, e.g. restrictions of activities (recording seismic activities, drilling…) within the sea mammals protected areas.	The Opinion was taken into account and dealt with under Chapter 10.
	It is necessary to provide the missing or unavailable data to cover particular chapters of the Strategic Study.	The Opinion was taken into account.
	The study needs to take into account the Risk and Vulnerability Assessment of the Area of Activity for the Intervention Plan for Accidental Marine Pollution in the Dubrovnik-Neretva County.	Intervention plans for particular counties are not specified in the Study. They are, instead, taken into account in assessing impact and prescribing mitigation measures, and a direct reference in the Study is made to the national Intervention Plan for Accidental Marine Pollution (OG 92/08), the plans of particular counties are aligned with.
Istria County, Administrative Department for Sustainable Development CLASS: 351-01/14-01/111 FILE NO.: 2163/1-08/2-14-2	The content of the Strategic Study needs to be supplemented with the following item: the Description of the Applied Assessment Methodology.	The Opinion was taken into account and dealt with under Chapter 8.
	Under item 1 of the content of the Strategic Study, the objectives of the framework plan and programme need to be clearly detailed.	The Opinion was taken into account and dealt with under Chapter 1.
	Under item 2, the existing status needs to be covered, taking into consideration the 11 descriptors analysed in the Good Environmental Status, as a constituent part of the Marine Strategy. Particular attention needs to be paid to descriptors that are found to be lacking data required for evaluation (e.g. impact of noise – Descriptor no. 11).	The Opinion was taken into account. The descriptors were taken into account in drafting Chapters 3, 8, and 10.
	Item 3 needs to be amended including possible accidents with the worst possible scenario.	Accidents are dealt with under Chapters 1, 4, and 8.
	Under item 4, it is necessary to clearly define measures regarding the activities relating to exploration, to the time of erecting a drilling platform, to the measures for mitigating the consequences of accident situations, recognised in the chapter under point 2, of the content of the Strategic Study of Environmental Impacts (SSEI).	Measures for all the phases of exploration and production of hydrocarbons are defined under Chapter 10. The measures for mitigating consequences of accidents are not prescribed, because, due to lack of information on particular interventions and their technical characteristics, it was not possible to establish the criteria for environmental impact assessment at the level of the Strategic Study, nor to assess in details the impact that would require mitigation measures to be established. It is expected that a detailed analysis of the environmental impact of accidents for particular interventions relating to exploration and production of hydrocarbons will be undertaken in the course of further procedures of environmental impact assessments / Appropriate Assessment of the intervention on the ecological network.

	Item 5 of the SSEI content needs to be amended by recognising possible inter-impacts (of the existing activities – the existing production, tourism, transport, fisheries, infrastructure), as well as possible cumulative impacts (existing / planned activities) on environmental components.	The Opinion was taken into account and dealt with under Chapter 8.
	Item 7 of the SSEI content needs to be amended by the description of solution variants.	The Opinion was taken into account and dealt with under Chapter 9.
	The SSEI uses terminology of the current legislation and subordinate legislation, in particular the Environmental Protection Act, the Nature Protection Act, the Air Protection Act, the Act on Sustainable Waste Management, the Noise Protection Act, etc.	The Opinion was taken into account.

13 Conclusions and Recommendations

A Strategic Study of the Likely Significant Environmental Impact of the Framework Plan and Programme (FPP) of Exploration and Production of Hydrocarbons in the Adriatic has identified potentially significant impacts of implementation of the FPP on individual environmental components and accordingly proposes measures that need to mitigate the identified impacts. For all activities that will take place under the implementation of the FPP it will be necessary, in accordance with legislation, to carry out procedures for the Appropriate Assessment for the ecological network, i.e. the Environmental Impact Assessment.

13.1 Impact on tourism

The visibility of platforms from the mainland is perceived as disturbing the view and may significantly reduce an area's attractiveness for the "sun and sea" tourism. This branch of the tourism sector is one of the key economic branches and it is closely linked with the landscape features. The installing of platforms, primarily those for production, may result in disturbance of landscape features of highly attractive nautical tourism areas. Islands of the Central and Southern Adriatic are areas particularly attractive for nautical tourism, which represents an important and prosperous economic branch.

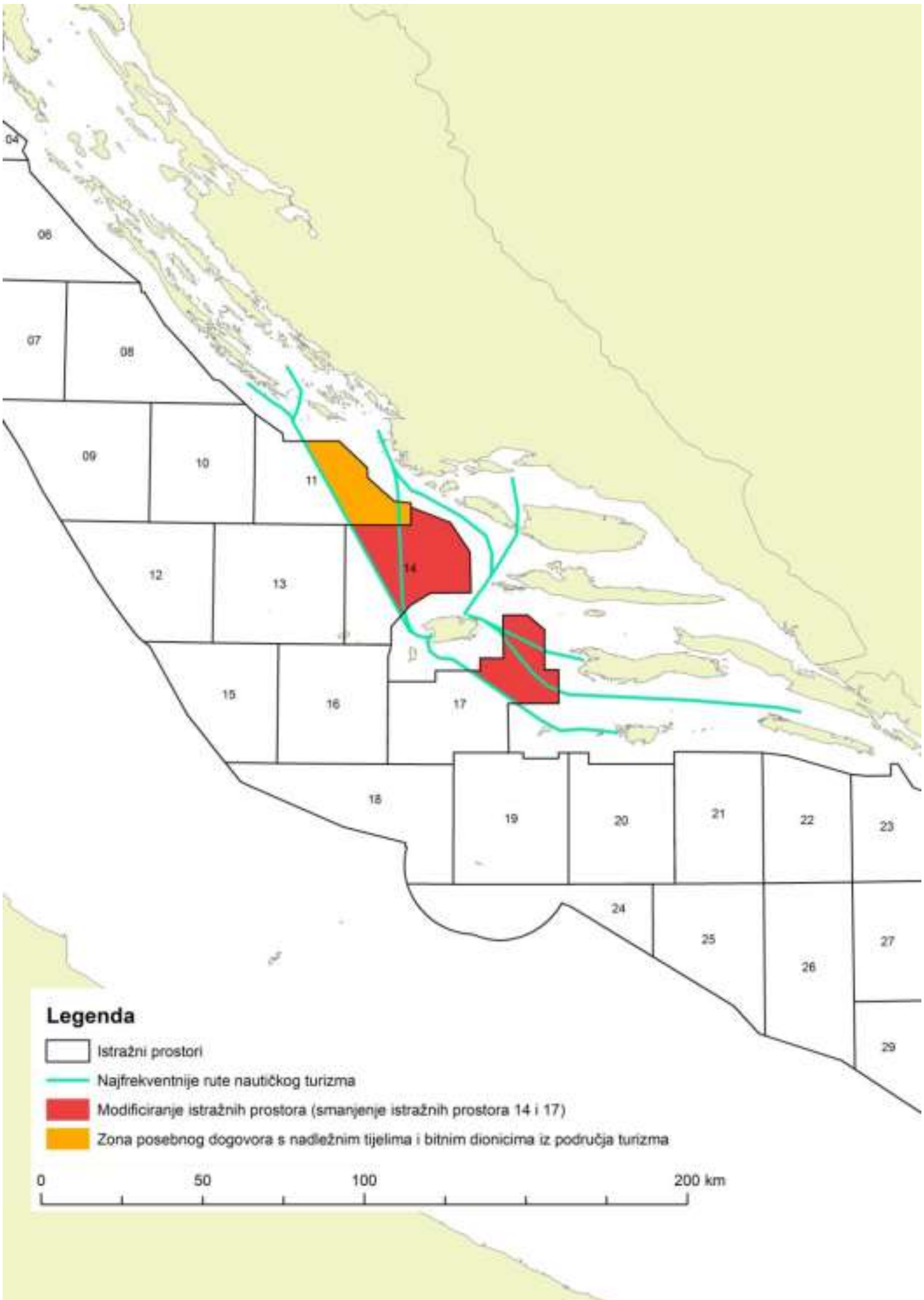


Figure 13.1 Proposal of modifications of blocks in order to prevent conflicts between the FPP and the nautical tourism

Legend: Istražni prostori – blocks, Najfrekventnije rute nautičkog turizma – The most frequent nautical tourism routes, Modificiranje istražnih prostora (smanjenje istražnih prostora 14 i 17 – Modification of blocks (shrinking of blocks 14 and 17), Zona posebnog dogovora s nadležnim tijelima i bitnim dionicima iz područja turizma – Area of a special agreement with the competent authorities and important stakeholders from the tourism sector

13.2 Impact on fisheries

Impacts on fisheries are possible in various stages of implementation of the FPP. On the basis of the analysis of the expert bases on the movement of fishing vessels, areas of particular importance for fisheries have been identified. Particularly sensitive is the narrow area of the Jabuka Pit, as well as the broader area around it, for which, in order to protect this important fishery resources area, the introduction of a complete trawlers fishing ban zone - no-take zone - is planned. The boundaries of this area are determined on the basis of scientific research in cooperation between Croatian and Italian scientists. The identified impacts on fisheries regard the impact of noise during the conduct of seismic surveys, the impact of the installation of platforms and of exploratory and exploitation drilling, the impact due to installation of pipelines and related infrastructure and the impact of platforms removal.

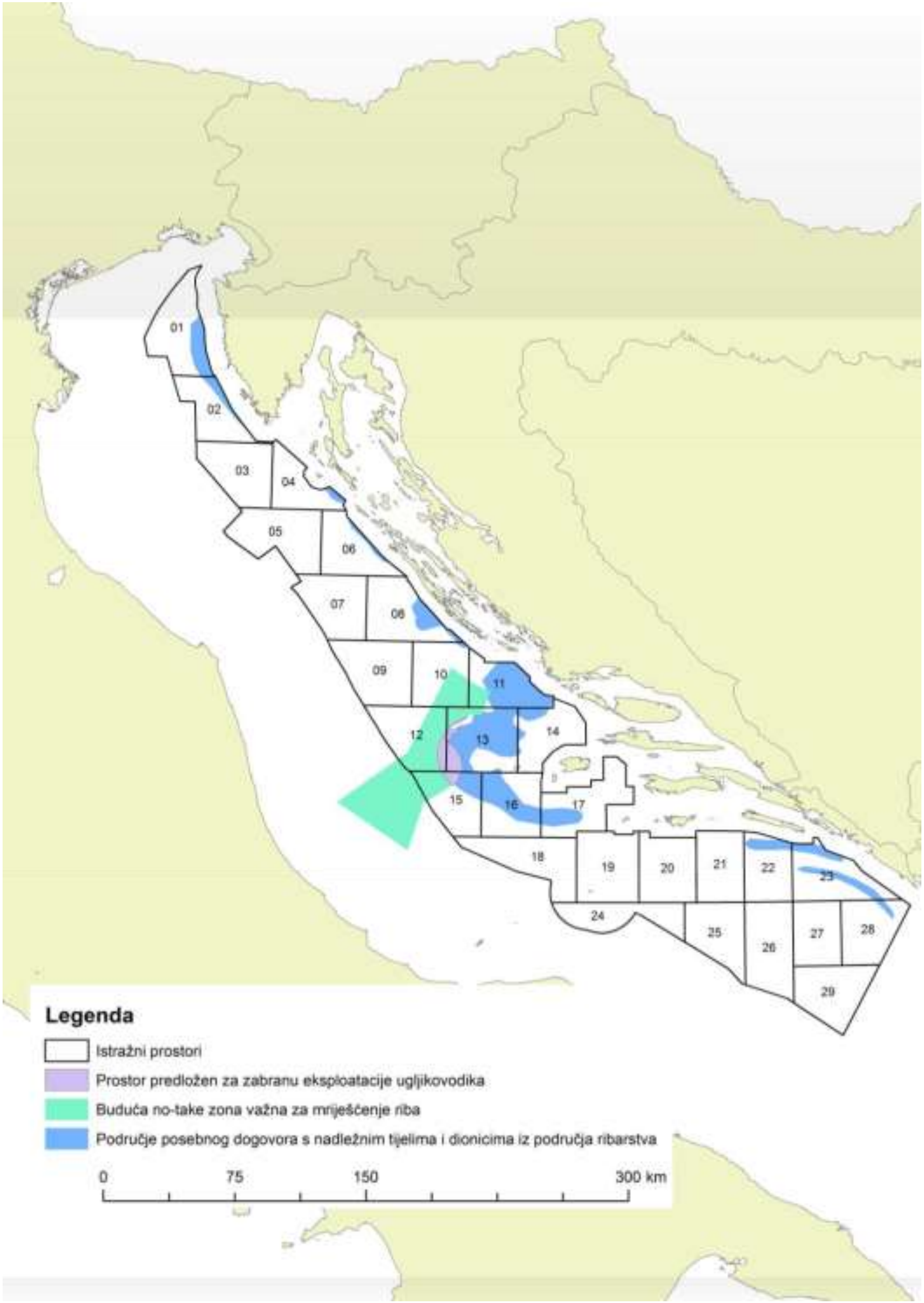


Figure 13.2 Areas of importance for fisheries in relation to blocks

Legend: Istražni prostori – blocks, Prostor predložen za zabranu eksploatacije ugljikovodika – Area proposed for the ban on production of hydrocarbons, Buduća no-take zona važna za mriješćenje riba – The future no-take zone important for spawning, Područje posebnog dogovora s nadležnim tijelima i bitnim dionicima iz područja turizma – Area of a special agreement with the competent authorities and important stakeholders from the tourism sector

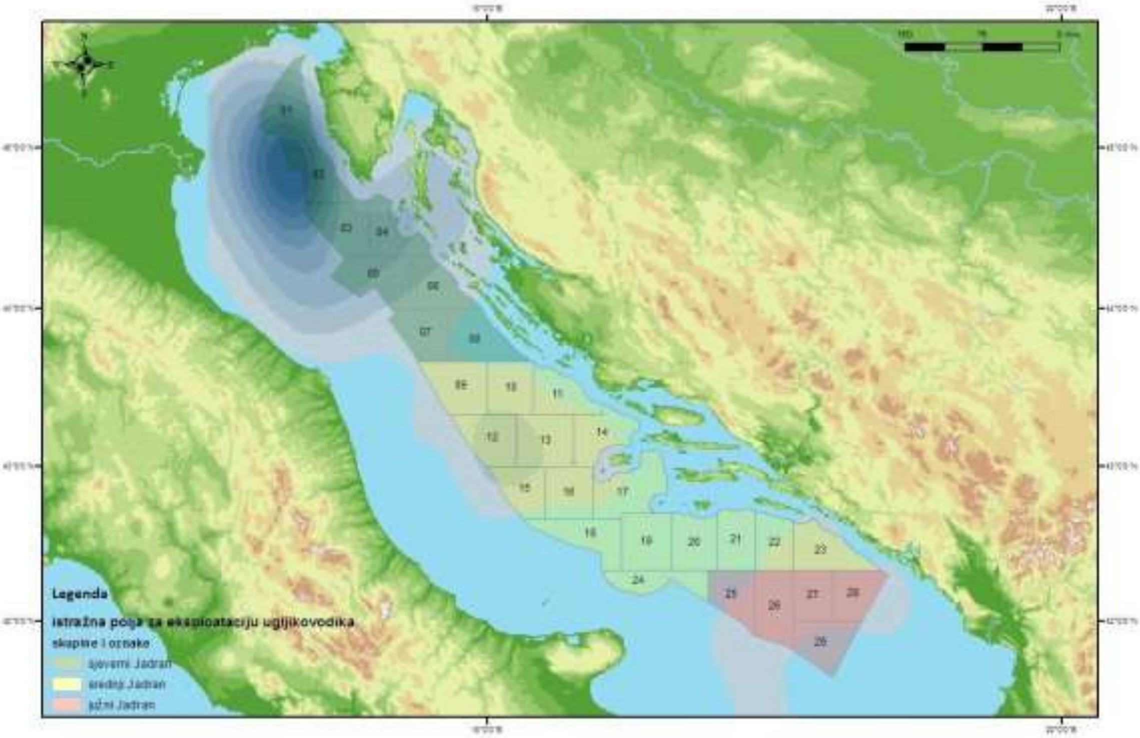
13.3 Impact on biodiversity

13.3.1 Cetaceans and sea turtles

The impact of noise, primarily generated by seismic surveys and well drilling during operations of the FPP, is the most significant impact on cetaceans and sea turtles. The impact of noise pollution on cetaceans is especially significant, as they are greatly dependent on sound which they use as the primary sense, which plays an important role in social interactions and sense biology. The impact of anthropogenic noise can cause simple problems with sound detection, but can also lead to unrest, changes in behaviour, hearing damage and serious injuries. The level of impact depends mostly on exposure duration, sound pressure and total soundwave energy, as well as their frequency. Numerous researchers proposed that criteria be made for the assessment of the impact of noise on cetaceans. Different criteria are used to determine influence zones and to enable risk assessment and the enactment of impact reduction measures. Simultaneously, there are almost no measures which have been truly tested in a natural environment, making their efficiency questionable.

Anthropogenic noise may have varied impact on sea turtles, which can be classified in the following categories: causing physical injuries, affecting hearing, affecting behaviour and affecting survival and the general population-level health.

Currently it is not possible to unambiguously define the impact of noise on them, as there is a significant lack of information on the distribution, abundance and the possible impact of noise. Research done in experimental / induced conditions, as well as monitoring side effects, indicate a possibly significant negative impact which has not been confirmed in natural habitat conditions of the species. Noise generated by seismic surveys and well drilling is time-limited, and there is also interaction with other permanent sources of noise in the marine environment.

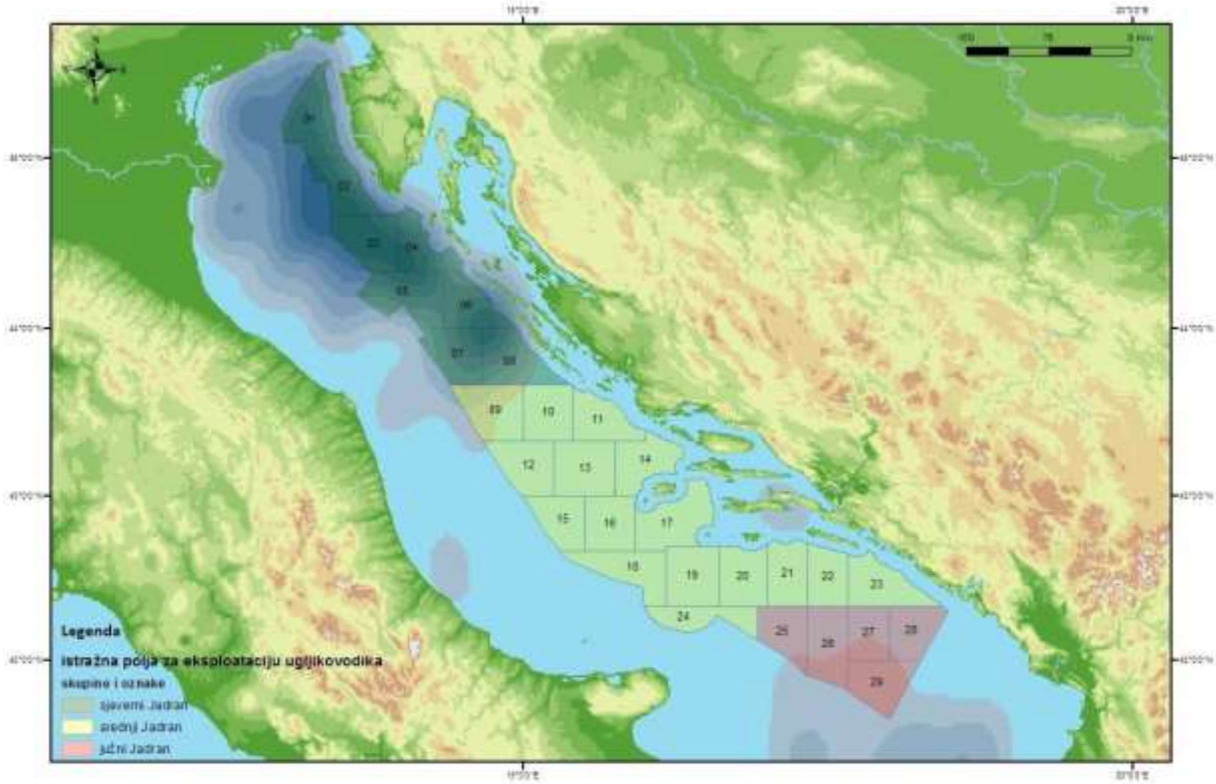


Dobri dupin (Tursiops truncatus) - područje velike brojnosti - Izvor: ISPRA i BWI

Common bottlenose dolphin (Tursiops truncatus) – area of great abundance - Source: ISPRV and BWI

Legend:
Hydrocarbon production blocks
groups and markings

northern Adriatic
central Adriatic
southern Adriatic



Glavata želva (Caretta caretta) - područje velike brojnosti - Izvor: ISPRA i BWI

Loggerhead sea turtle (Caretta caretta) – area of great abundance - Source: ISPRV and BWI

Legend:
Hydrocarbon production blocks
groups and markings

northern Adriatic
central Adriatic
southern Adriatic

13.3.2 Ecological network

Possible impacts of implementing the FPP on the species and habitats of the ecological network can be sorted by steps defined by the FPP in three groups: impacts during exploration, impacts during production and impacts during the removal of mining facilities and plants. Impacts defined in such a way indicate the time interval in which to expect them. Impacts during exploration can be expected during the first 2 to 7 years while exploration operations are conducted. This is followed by impacts of installing platforms and pipelines, producing hydrocarbons and additional exploration. These impacts are to be expected in the following 25 years at least, depending on the capacities of the discovered reservoirs. The final group of impacts is to be expected during the removal of mining facilities and plants. Impacts on targeted habitats within the POVS area HR3000099 Brusnik and Svetac, HR3000100 Island of Jabuka underground, HR3000121 Island of Palagruža underground, HR3000122 Islet of Galijula, HR3000423 Jabuka Pit are expected mainly during exploratory well drilling, installing platforms and removing them later. These operations are very space- and time-limited, they are not dependent on the type of marine habitat, but rather on the depth. For this reason, significant negative impacts are expected only if the platforms were to be installed on exceptionally rare and small habitats (e.g. coral reefs). The analysis of possible impacts indicates a potentially significant negative impact on nesting populations of seabirds. The only populations of the species *Puffinus yelkouan* (yelkouan shearwater) and Calonectris diomedea (Cory's shearwater) in Croatia nest on Pučinski otoci i otočići (Pelagic islands and inlets; Sv. Andrija, Svetac, Kamnik and Palagruža), as well as the major part of the Croatian population of *Falco eleonorae* (Eleonora's falcon). The impacts of implementing the FPP may threaten them to such an extent that they leave the nesting grounds permanently.

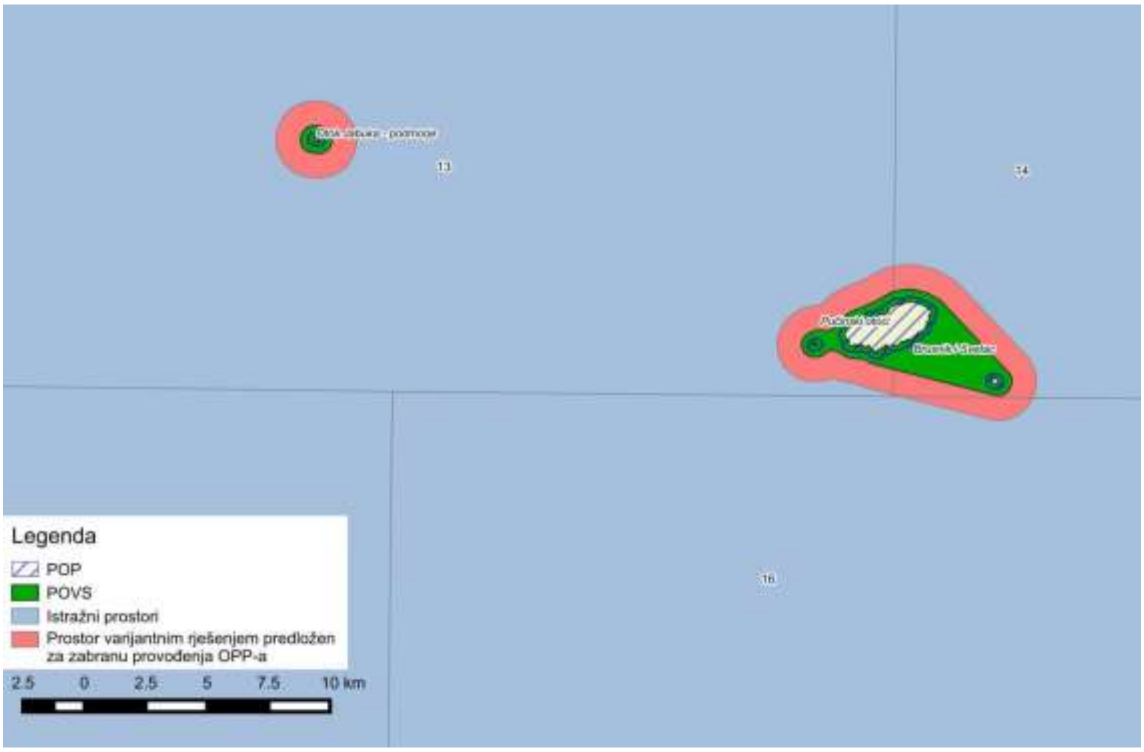


Image 13.3 Proposed modifications of blocks for the protection of conservation goals of the Ecological network NATURA 2000 in the areas: Island of Jabuka - underground, Pelagic Islands, and Brusnik and Svetac

Legend: POP; POVS; blocks; area proposed by variant decision for the ban of FPP implementation

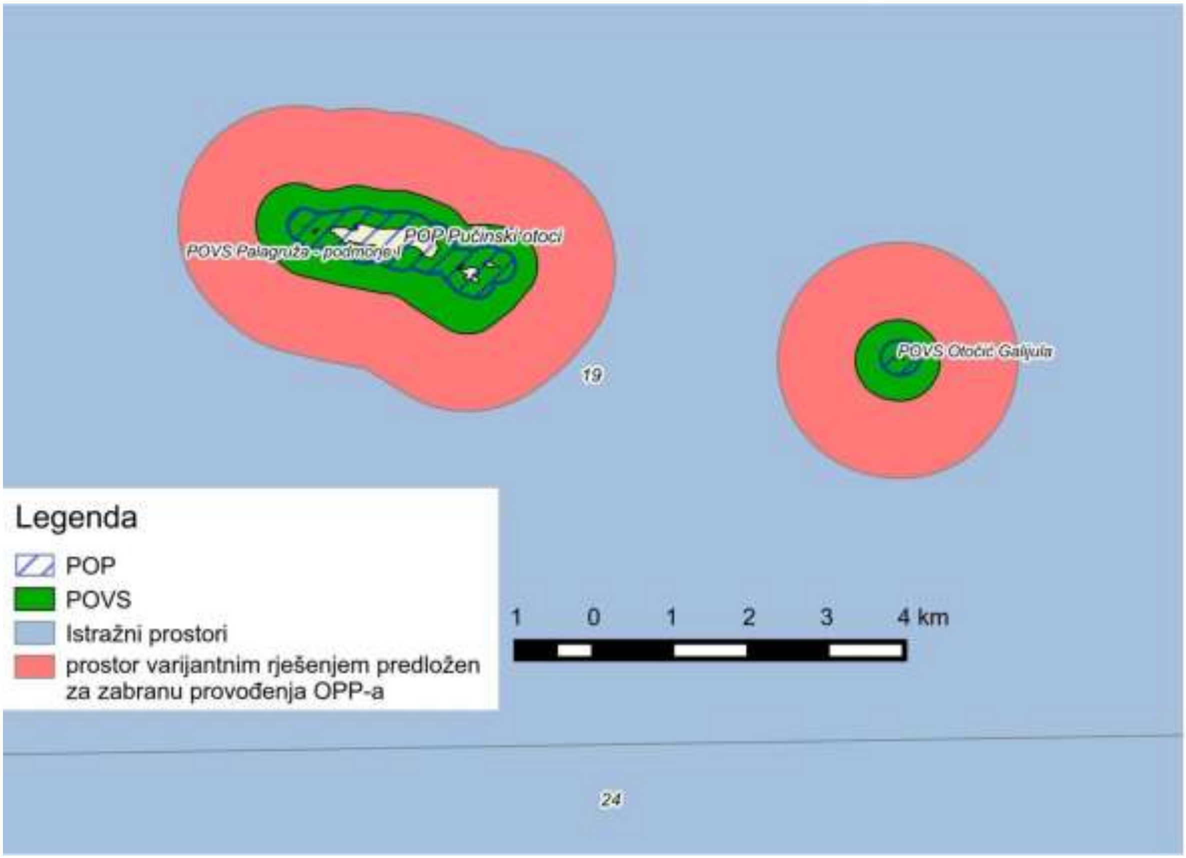


Image 13.4 Proposed modifications of blocks for the protection of conservation goals of the NATURA 2000 ecological network in the areas: Island of Palagruža - underground, Pelagic Islands, and Islet of Galijula

Legend: POP; POVS; blocks; area proposed by variant decision for the ban of FPP implementation

13.3.3 Coralligenous communities

A part of the water area will be occupied due to the implementation of the FPP operations. Marine habitats in Croatia are mostly unexplored, so locations of rare habitat types, such as the coralligenous communities, are unknown.

13.4 Cultural and historical heritage

To this day, numerous underwater sites which significantly contributed to the improved knowledge of maritime history have been discovered and explored and their value for both Croatian and world's culture and science is indisputable (such as remarkably preserved and artistically exquisite statue from the Antiquity known as the Croatian Apoxyomenos discovered near Lošinj or numerous shipwrecks from the antiquity period carrying amphorae or more recent shipwrecks such as the Baron Gautsch shipwreck. Exact locations of the sites will be forwarded to investors awarded licenses granting them the right to exploration of hydrocarbons and direct grant of a concession in the event of a commercial discovery. On each of the sites all protection measures provided for protected underwater archaeological sites need to be taken, in the 300m diameter area, which constitutes a site's safety zone.

13.5 Cross-border impact

The FPP analysis found a possible cross-border impact on the Natura 2000 IT3330009 Trezze san Pietro e Bordelli (SCI) Area, located on the edge of the northern part of Block 1.

Figure 13.5 Proposal for forming Block 1 (reduce peak area)

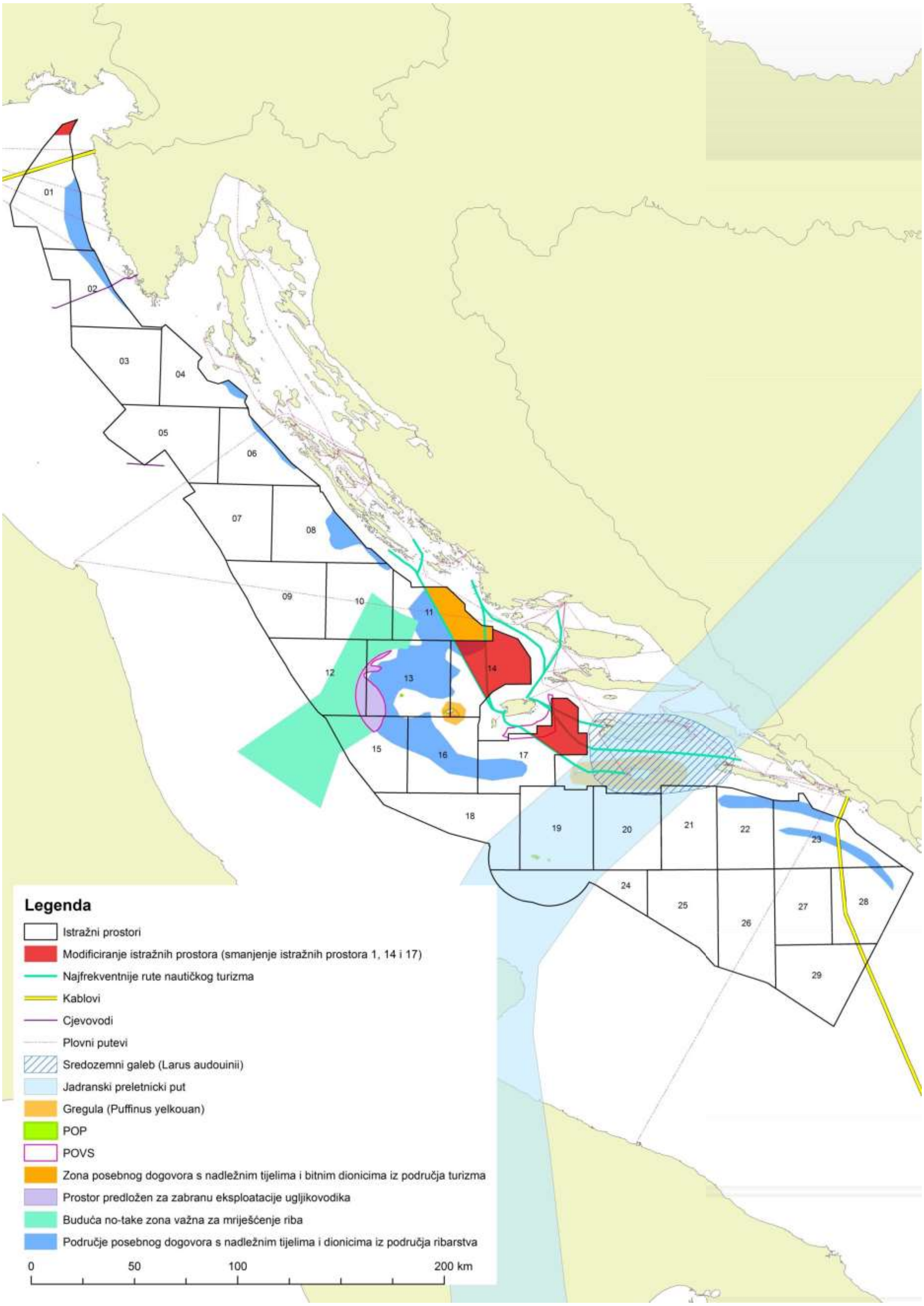


Figure 13.6 Overview of environmental components that may be impacted by FPP implementation

Legend: Istražni prostori – Blocks

Modificiranje istražnih prostora (smanjenje istražnih prosotra) – Block modification (block reduction)

Najfrekventnije rute nautičkog turizma – Nautical tourism most frequent routes

Kablovi - Cables

Cjevovodi - Pipelines

Plovni putovi – Waterways

Sredozemni galeb (Laurus audouinii) – Audouin's seagull (Laurus audouinii)

Jadranski preletnički put – Adriatic Flyway

Gregula (Puffinus yelkouan) - Mediterranean shearwater

POP –Areas of conservation important for birds

POVS - Areas of conservation important for species and habitat types

Zona posebnog dogovora s nadležnim tijelima i bitnim dionicima iz područja turizma – Zone of special agreement with competent authorities and significant stakeholders from the tourism sector.

Prostor predložen za zabranu eksploatacije ugljikovodika – Area proposed for the ban of hydrocarbon production

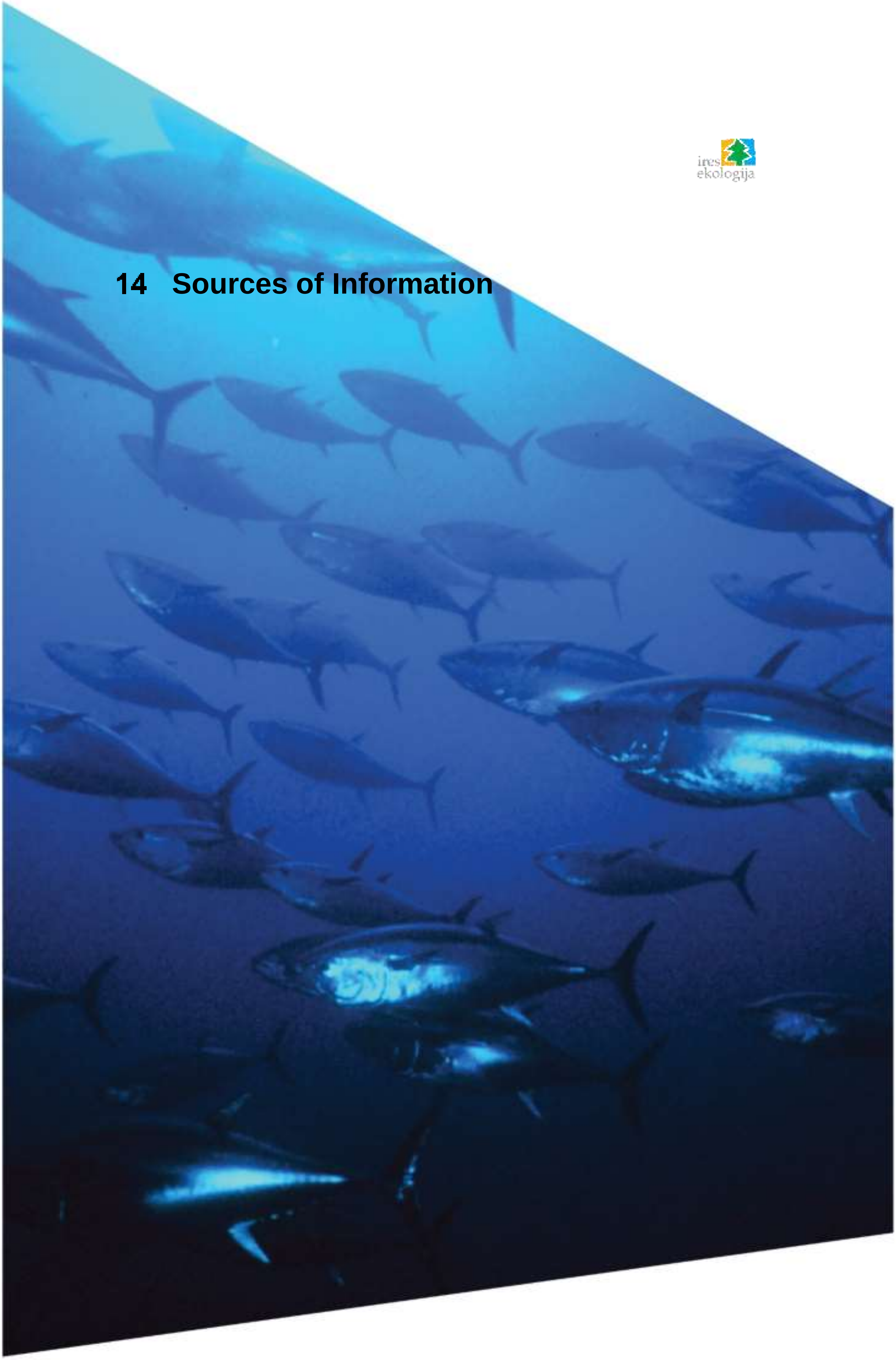
Buduća no-take zona važna za mriješćenje riba – Future no-take zone important for spawning of fish

Područje posebnog dogovora s nadležnim tijelima i bitnim dionicima iz područja ribarstva -Area of special agreement with competent authorities and significant stakeholders from the fisheries sector

Based on the environment components status and assessment of potential FPP implementation, protection measures and monitoring of the environment was proposed. Based on the above, changes in size and shape of blocks were defined: 1 (due to possible cross-border effect), and 14 and 17 (due to possible conflict with nautical tourism). The following recommendation refers to the ban on hydrocarbon production in the narrow area of the Jabuka Pit – covering the area of 305.38km2, as well as the ban on seismic exploration and exploration wells during spawning and recruitment of fish species (parts of blocks 12, 13 and 15). Due to the estimated impact on the Natura 2000 areas, it is recommended to move the exploration and production of hydrocarbons zone 1 km from the area of the ecological network in fields 13,14,16 and 19 where the Pelagic Islands (Pučinski otoci) are located. For block 11, in agreement with the Ministry of Tourism, adaptation and harmonization of hydrocarbon exploration and production operations with nautical tourism activities is needed. Due to possible effects on fishery on parts of blocks 1, 2, 4, 6, 8, 10, 11, 12,

13, 14, 15, 16, 17, 22, 23 and 28, petroleum operations should be performed in agreement with competent authorities and significant stakeholders from the fisheries sector. A possible impact on whales and sea turtles was assessed as well, which is why before implementing FPP, sound propagation models need to be created. These models will be based on actual data about the environment in which the activities will be performed, distribution, numbers and possible seasonality with regard to certain sensitive species determined, allowed variation of determined values established and detailed operational procedure for monitoring and protection of these species when carrying out each activity which acts as a source of noise determined,. The conclusion from the assessment of a possible cumulative impact was that the exploration should not be conducted on more than three blocks simultaneously.

14 Sources of Information



14.1 Scientific and professional papers

ACCOBAMS (2010): Guidelines to address the issue of the impact of anthropogenic noise on Cetaceans in the ACCOBAMS area. In: *Resolution 4.17*, p. 11.

ACCOBAMS SC (2011): Report of the seventh meeting of the Scientific Committee of ACCOBAMS. ACCOBAMS Scientific Committee, Monaco.

ACCOBAMS SC (2012a): Statement from the ACCOBAMS Scientific Committee concerning the ongoing seismic survey work in the area of the Hellenic Trench. In: *Eighth Meeting of the ACCOBAMS Scientific Committee*, Monaco.

ACCOBAMS SC (2012b): Statement of concern about atypical mass strandings of beaked whales in the Ionian Sea. ACCOBAMS Scientific Commitee, Monaco.

ACCOBAMS (2013): Methodological guide: “Guidance on underwater noise mitigation measures”. Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area

ACCOBAMS (2014): ACCOBAMS Proposal on common indicators related to EO11. In: *4th Meeting of the EcAp Coordination Group*. UNEP/MAP, Athens, Greece.

Affronte M., Stanzani L.A., Stanzani G. (2003) First record of humpback whale, *Megaptera novaeangliae* (Barowski, 1781) in the Adriatic Sea. *Annales Series Historia Naturalis* 13, 51-4.

Aguilar, A. (2000): Population biology, conservation threats and status of Mediterranean striped dolphins (*Stenella coeruleoalba*). *Journal of Cetacean Research and Management* 2, 17-26.

Aguilar,A., Gaspari, S. (2012): *Stenella coeruleoalba* (Mediterranean subpopulation). URL http://www.iucnredlist.org/.

Aguilar de Soto, N., Delorme, N., Atkins, J., Howard, S., Williams, J., Johnson, M. (2013): Antropogenic noise causes body malformations and delays development in marine larvae. Sci. Rep. 3, 2831; DOI:10.1038/srep02831.

Airoldi S., Bendinoni F., Azzellino A., Fadda V., Profice, A. (2005): Abundance estimates of Risso's dolphins (*Grampus griseus*) in the Western Ligurian Sea through photographic mark-recapture. *European Research on Cetaceans* 19, 109.

Almeda, R., Wambaugh, Z., Wang, Z., Hyatt, C., Liu, Z., Buskey, E. J. (2013): Interactions between Zooplankton and Crude Oil: Toxic Effects and Bioaccumulation of Polycyclic Aromatic Hydrocarbons.

Andre, M., Sole, M., Lenoir, M., Durfort M., Quero, C., Mas, A., Lombarte, A., Van der Schaar, M., Lopez-Bejar, M., Morell, M., Zaugg, S., Houegnigan, L. (2011): Low-frequency sounds induce acoustic trauma in cephalopods.*Frontiers in Ecology and the Environment* **9**: 489–493. http://dx.doi.org/10.1890/100124

Arbelo, M., De Quiros, Y.B., Sierra, E., Méndez, M., Godinho, A., Ramírez, G., Caballero, M.J., Fernández, A. (2008): Atypical beaked whale mass stranding in Almeria's coasts: pathological study. *Bioacoustics* 17, 294-7.

Au, W.W.L. (1993): *The Sonar of Dolphins*. Springer-Verlag, New York.

Azzellino, A., Gaspari, S., Airoldi, S., Nani, B. (2008): Habitat use and preferences of cetaceans along the continental slope and the adjacent pelagic waters in the western Ligurian Sea. *Deep-Sea Research Part I-Oceanographic Research Papers* 55, 296-323.

Bakke, T., Klungøyr, J., Sanni, S. (2012): Long-term effects of discharges to sea from petroleum-related activities: The results od ten years' research, research council of Norway, Oslo.

Bakran-Petricioli, T. (2007): Morska staništa–priručnik za inventarizaciju i praćenje stanja. *DZZP, Zagreb*.

Bakran-Petricioli, T., Krča, S., Smital, T., Petricioli, D., Čižmek, H. (2007): Pregled obraštaja na platformi Ivana A i njen utjecaj na okoliš, Prirodoslovno- matematički fakultet, Zagreb, siječanj 2007.

Barr, F.J., Sanders, J.I. (1989): Attenuation of water-column reverberations using pressure and velocity detectors in a water-bottom cable: 59th Annual Meeting SEG Expanded Abstracts, paper SA 2.6, 653.

Barić, G., Tari, V. (2001): Petroleum systems of the Adriatic Offshore, Croatia. 63rd EAGE Conference & Technical Exhibition. Amsterdam, Extended Abstracts, 2, P 504.

Barić, G., Velić, J. (2001): Organskogeokemijske značajke gornjopaleozojskih i mezozojskih plitkomorskih taložina na području Jadranske karbonatne platforme/Knjiga sažetaka = Abstracts / Dragičević, Ivan ; Velić, Ivo (ur.). Zagreb : Rudarsko-geološko-naftni fakultet, 2001. 23-26 (predavanje,domaća recenzija,sažetak,znanstveni).

Barlow, M. J., Kingston, P. F. (2001): Observations on the Effects of Barite on the Gill Tissues of the Suspension Feeder Cerastoderma edule (Linné) and the Deposit Feeder Macoma balthica (Linné). Marine Pollution Bulletin 42: 71-76.

Barlow, J.,Taylor, B.L. (2005): Estimates of sperm whale abundance in the northeastern temperate Pacific from a combined acoustic and visual survey.
Marine Mammal Science 21, 429-45.

Bartol, S., Bartol; I. (2011): Hearing capabilities of loggerhead sea turtles (Caretta caretta) throughout ontogeny: an integrative approach involving behavioral and electrophysiological techniques. *Final Report to Joint Industry Programme (JIP22 07–14)*.

Bartol, S.M., Ketten, D.R. (2006): Turtle and tuna hearing. *Sea turtle and pelagic fish sensory biology: developing techniques to reduce sea turtle bycatch in longline fisheries*.

Bartol, S.M., Musick, J.A., Lenhardt, M.L. (1999): Auditory evoked potentials of the loggerhead sea turtle (Caretta caretta). *Copeia*, 836-40.

Bearzi, G. (1989): Contributo alle conoscenze sulla biologia di *Tursiops truncatus* (Montagu, 1821) nel mare Adriatico settentrionale. p. 172. University of Padova, Padova.

Bearzi, G. (2000): First report of a common dolphin (*Delphinus delphis*) death following penetration of a biopsy dart. *Journal of Cetacean Research and Management* 2, 217-21.

Bearzi, G., Azzellino, A., Politi, E., Costa, M., Bastianini, M. (2008a): Influence of seasonal forcing on habitat use by bottlenose dolphins *Tursiops truncatus* in the northern Adriatic Sea. *Ocean Science Journal* 43, 175-82.

Bearzi, G., Costa, M., Politi, E., Agazzi, S., Pierantonio, N., Tonini, D., Bastianini, M. (2009): Cetacean records and encounter rates in the northern Adriatic Sea during the years 1988-2007. *Annales, Series Historia Naturalis* 19, 145-50.

Bearzi, G., Fortuna, C.M. (2012): *Tursiops truncatus* (Mediterranean subpopulation). URL http://www.iucnredlist.org/.

Bearzi, G., Fortuna, C.M., Reeves, R.R. (2008b): Ecology and conservation of common bottlenose dolphins *Tursiops truncatus* in the Mediterranean Sea. *Mammal Review* 39, 92-123.

Bearzi, G., Holcer, D., Di Sciara G.N. (2004): The role of historical dolphin takes and habitat degradation in shaping the present status of northern Adriatic cetaceans. *Aquatic Conservation-Marine and Freshwater Ecosystems* 14, 363-79.

Bearzi, G., Notarbartolo di Sciara, G. (1995): A comparison of the present occurrence of bottlenose dolphins, *Tursiops truncatus*, and common dolphins, *Delphinus delphis*, in the Kvarneric (northern Adriatic Sea). *Annales Series Historia Naturalis* 7, 61-8.

Bearzi, G., Notarbartolo di Sciara, G., Fortuna C.M. (1998): Unusual sighting of a striped dolphin (*Stenella coeruleoalba*) in the Kvarneric, Northern Adriatic Sea. *Natura Croatica* 7, 169-278.

Bearzi, G., Notarbartolo di Sciara, G., Politi E. (1997): Social ecology of bottlenose dolphins in the Kvarnerić (northern Adriatic Sea). *Marine Mammal Science* 13, 650-68.

Bearzi, G., Pierantonio, N., Affronte, M., Holcer, D., Maio, N., Notarbartolo Di Sciara, G. (2011a): Overview of sperm whale *Physeter macrocephalus* mortality events in the Adriatic Sea, 1555–2009. *Mammal Review* 41, 276-93.

Bearzi, G., Politi, E., di Sciara, G.N. (1999): Diurnal behavior of free-ranging bottlenose dolphins in the Kvarnerić (northern Adriatic Sea). *Marine Mammal Science* 15, 1065-97.

Bearzi, G., Politi, E., Fortuna, C.M., Mel L., Notarbartolo di Sciara G. (2000): An overview of cetacean sighting data from the northern Adriatic Sea: 1987– 1999. *European Research on Cetaceans* 14, 356-61.

Bearzi, G., Reeves, R.R., Notarbartolo-Di-Sciara, G., Politi, E., Canadas, A.N.A., Frantzis, A. Mussi, B. (2003): Ecology, status and conservation of short- beaked common dolphins *Delphinus delphis* in the Mediterranean Sea. *Mammal Review* 33, 224-52.

Bearzi, G., Reeves, R.R., Remonato, E., Pierantonio, N., Airoldi S. (2011b): Risso's dolphin *Grampus griseus* in the Mediterranean Sea. *Mammalian Biology - Zeitschrift für Säugetierkunde* 76, 385-400.

Becker, E.A., Pavlović, A., Nemet, S., Mackelworth C.P. (2013): Legal issues concerning the Cres-Lošinj marine habitat and protected area legislation in Croatia. *Environs Environmental Law And Policy Journal UC Davis* 37, 1-25.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty C. Krutzen, M. (2006): Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology* 20, 1791-8.

Belošić, Ž. (2001): osnovne aktivnosti ine d.d. u segmentu djelatnosti istraživanje i proizvodnja nafte i plina (Naftaplin) u zemlji i inozemstvu. Naftaplin, 1, 1- 5.

Bilandžić, N., Sedak, M., Đokić, M., Đuras, Gomerčić, M., Gomerčić, T., Zadravec, M., Benić, M., Prevendar Crnić, A. (2012): Toxic element concentrations in the bottlenose (*Tursiops truncatus*), striped (*Stenella coeruleoalba*) and Risso's (*Grampus griseus*) dolphins stranded in Eastern Adriatic Sea. *Bulletin of Environmental Contamination and Toxicology* 89, 467-73.

Bjørgesæter, A. (2008): Environmental effects of oil and gas exploration on the benthic fauna of the Norwegian Continental Shelf, An analysis using the OLF-database, Department of Biology, University of Oslo, Norway.

Bjorndal, K. (2003): Roles of loggerhead sea turtles in marine ecosystems. *Loggerhead sea turtles. Smithsonian Books, Washington, DC*.

Bjorndal, K.A., Bolten, A.B. (1988): Growth rates of immature green turtles, Chelonia mydas, on feeding grounds in the southern Bahamas. *Copeia*, 555-64.

Bjorndal, K.A., Lutz, P., Musick, J. (1997): Foraging ecology and nutrition of sea turtles. *The biology of sea turtles* 1, 199-231.

Blanco, C., Raduan, M.A., Raga, J.A. (2006): Diet of Risso's dolphin (*Grampus griseus*) in the western Mediterranean Sea. *Scientia Marina* 70, 407-11.

Blanco, C., Raga, J.A. (2000): Cephalopod prey of two *Ziphius cavirostris* (Cetacea) stranded on the western Mediterranean coast. *Journal of the Marine Biological Association of the United Kingdom* 80, 381-2.

Blaxter, J.H.S., Gray, J.A.B., Denton, E.J. (1981): Sound and startle responses in herring shoals. J Mar Biol Assoc UK 61:851–870.

Boisseau, O., Lacey, C., Lewis, T., Moscrop, A., Danbolt, M., Mclanaghan, R. (2010): Encounter rates of cetaceans in the Mediterranean Sea and contiguous Atlantic area. *Journal of the Marine Biological Association of the United Kingdom* 90, 1589-99.

Bolten, A. B. (2003a): Active swimmers-passive drifters: the oceanic juvenile stage of loggerheads in the Atlantic system. *Smithsonian Books, Washington D. C.*

Bolten, A.B. (2003b): Variation in sea turtle life history patterns: neritic vs. oceanic developmental stages. CRC Press, Boca Raton, FL.

Bowen, B., Avise, J.C., Richardson, J.I., Meylan, A.B., Margaritoulis, D., HOPKINS-MURPHY, S.R. (1993): Population structure of loggerhead turtles (Caretta caretta) in the northwestern Atlantic Ocean and Mediterranean Sea. *Conservation Biology* 7, 834-44.

Bowen, B.W., Meylan, A.B., Ross, J.P., Limpus, C.J., Balazs, G.H., Avise, J.C. (1992): Global population structure and natural history of the green turtle (Chelonia mydas) in terms of matriarchal phylogeny. *Evolution*, 865-81.

Boothe, P.N., Presley,B.J. (1989): Trends in sediment trace element concentrations around six petroleum drilling platforms in the northwestern Gulf of Mexico, pp. 3-21. In: F.R. Engelhardt, J.P. Ray and A.H. Gillam (eds.), Drilling Wastes. Elsevier Applied Science, New York. 867 pp.

Breitburg, D.L., Riedel, G.F. (2005): Multiple stressors in marine systems. *Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity (eds. by Norse E i Crowder LB), Island Press, Washington*, pp 167-82.

Broderick, A.C., Coyne, M.S., Fuller, W.J., Glen, F., Godley, B.J. (2007): Fidelity and over-wintering of sea turtles. *Proceedings of the Royal Society B: Biological Sciences* 274, 1533-9.

Broderick, A.C., Glen, F., Godley, B.J., Hays G.C. (2002): Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean.
Oryx 36, 227-35.

Brown, R.S., Carlson, T.J., Gingerich, A.J., Stephenson, J.R., Pflugrath, B.D., Welch, A.E., Langeslay, M.J., Ahmann, M.L., Johnson, R.L., Skalski J.R. (2012): Quantifying mortal injury of juvenile Chinook salmon exposed to simulated hydro-turbine passage. *Transactions of the American Fisheries Society* 141, 147-57.

Brusina, S. (1889): Sisavci Jadranskog mora. *Rad JAZU* 95, 79-177.

Buljan, M., Zore-Armanda, M. (1971): Osnovi oceanografije i pomorske meteorologije. Institut za oceanografiju i ribarstvo, Split.

Burger, J.(1994): Before and After an Oil Spill: The Arthur Kill. Rutgers university

press: New Brunswick. Caldwell, J., Dragoset, W. (2000): Abrief overview of

seismic air-gun arrays, Texas, 2000.

Cadée, G. C. (2002): Seabirds and floating plastic debris. *Marine Pollution Bulletin*, *44*(11), 1294-1295.

Cañadas, A. (2011): Estimate of abundance of beaked whales in the Alboran Sea. In: *63. meeting of the Scientific Committee of International Whaling Commission*, p. 16. International Whaling Commission, Tromsø, Norway.

Cañadas, A. (2012): *Ziphius cavirostris* (Mediterranean subpopulation). URL http://www.iucnredlist.org/details/full/16381144/0.

Cañadas, A., Fortuna, C., Pulcini, M., Lauriano, G., Bearzi, B., Cotte, C., Raga, J.A., Panigada, S., Politi, E., Rendell, L., B-Nagy, A., Pastor, X., Frantzis A., Mussi B. (2011): Accobams collaborative effort to map high-use areas by beaked whales in the Mediterranean. In: *63 Scientific Committee Meeting of the International Whaling Commission*. International Whaling Commission, Tromso, Norway.

Canadas, A., Hammond, P.S. (2008): Abundance and habitat preferences of the short-beaked common dolphin *Delphinus delphis* in the southwestern Mediterranean: implications for conservation. *Endangered Species Research* 4, 309-31.

Canadas, A., Sagarminaga, R., De Stephanis, R., Urquiola, E., Hammond P.S. (2005): Habitat preference modelling as a conservation took proposals for marine protected areas for cetaceans in southern Spanish waters. *Aquatic Conservation-Marine and Freshwater Ecosystems* 15, 495-521.

Candler, J., Leuterman, A. (2008): Drill Fluids and Offshore Environmental Protection, July 2008.

Canese, S., Cardinali, A., Fortuna, C.M., Giusti, M., Lauriano,, G., Salvati, E., Greco, S. (2006): The first identified winter feeding ground of fin whales (*Balaenoptera physalus*) in the Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom* 86, 903-7.

Caputo, V., Giovannotti, M. (2009): Haplotype characterization of a stranded *Balaenoptera physalus* (Linnaeus, 1758) from Ancona (Adriatic Sea, Central Italy). *Hystrix-Italian Journal of Mammalogy* 20, 83-5.

Carlini, R., M P., Wurtz, M. (1992): Cephalopods from the stomach of a Cuvier's beaked whale, *Ziphius cavirostris*, (Cuvier, 1823) stranded at Fiumicino, Central Tyrrhenian Sea. In: *European Research on Cetaceans* (ed. by Evans PGH), pp. 190–1. European Cetacean Society, San Remo, Italy.

Carlson, T., Johnson, G. (2010): Columbia River Channel improvement project rock removal blasting: monitoring plan. Final Plan Report. *Pacific Northwest National Laboratory (PNNL–19076), Richland, WA*.

Carlucci, R., Battista, D., Capezzuto, F., Serena, F., Sion L. (2014): Occurrence of the basking shark Cetorhinus maximus (Gunnerus, 1765)(Lamniformes: Cetorhinidae) in the central-eastern Mediterranean Sea. *Italian Journal of Zoology* 81, 280-6.

Carrion-Cortez, J.A., Zarate, P., Seminoff, J.A. (2010): Feeding ecology of the green sea turtle (Chelonia mydas) in the Galapagos Islands. *Journal of the Marine Biological Association of the United Kingdom* 90, 1005-13.

Casale, P. (2011): Sea turtle by-catch in the Mediterranean. *Fish and Fisheries* 12, 299-316.

Casale, P., Abbate, G., Freggi, D., Conte, N., Oliverio, M., Argano R. (2008): Foraging ecology of loggerhead sea turtles Caretta caretta in the central Mediterranean Sea: evidence for a relaxed life history model. *Mar Ecol Prog Ser* 372, 265-276 doi: 10.3354/meps07702.

Casale, P., Affronte, M., Insacco, G., Freggi, D., Vallini, C., Pino d'Astore, P., Basso, R., Paolillo, G., Abbate, G., Argano R. (2010): Sea turtle strandings reveal high anthropogenic mortality in Italian waters. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20, 611-20.

Casale, P., Affronte, M., Scaravelli, D., Lazar, B., Vallini, C., Luschi P. (2012): Foraging grounds, movement patterns and habitat connectivity of juvenile loggerhead turtles (Caretta caretta) tracked from the Adriatic Sea. *Marine biology* 159, 1527-35.

Casale, P., Freggi, D., Basso, R., Argano, R. (2005): Oceanic habitats for loggerhead turtles (Caretta caretta) in the Mediterranean Sea. *Marine Turtle Newsletter* 107, 10-1.

Casale, P., Freggi, D., Basso, R., Vallini, C., Argano R. (2007): A model of area fidelity, nomadism, and distribution patterns of loggerhead sea turtles (Caretta caretta) in the Mediterranean Sea. *Marine Biology* 152, 1039-49.

Casale, P., Laurent, L., De Metrio, G. (2004): Incidental capture of marine turtles by the Italian trawl fishery in the north Adriatic Sea. *Biological Conservation* 119, 287-95.

Casale, P., Margaritoulis, D. (2010): *Sea turtles in the Mediterranean: distribution, threats and conservation priorities*. IUCN.

Casale, P., Mariani, P. (2014): The first 'lost year'of Mediterranean sea turtles: dispersal patterns indicate subregional management units for conservation. *Marine Ecology-Progress Series* 498, 263-74.

Casale, P., Nicolosi, P., Freggi, D., Turchetto, M., Argano R. (2003): Leatherback turtles (Dermochelys coriacea) in Italy and in the Mediterranean basin. *Herpetological journal* 13, 135-40.

Casper, B., Mann, D. (2009): Field hearing measurements of the Atlantic sharpnose shark Rhizoprionodon terraenovae. *Journal of Fish Biology* 75, 2768- 76.

Casper, B.M., Halvorsen, M.B., Matthews, F., Carlson, T.J., Popper, A.N. (2013): Recovery of Barotrauma Injuries Resulting from Exposure to Pile Driving Sound in Two Sizes of Hybrid Striped Bass. *PLoS ONE* 8, e73844.

Casper, B.M., Halvorsen, M.B., Popper, A.N. (2012): Are sharks even bothered by a noisy environment? In: *The effects of noise on aquatic life* (pp. 93-7. Springer.

Castellote, M., Clark, C.W., Lammers, M.O. (2010): Potential negative effects in the reproduction and survival on fin whales (Balaenoptera physalus) by shipping and airgun noise. In: IWC SC, p 12. *International Whaling Commission.*

Centro Studi Cetacei (1987): Cetacei spiaggiati lungo le coste Italiane, I. Rendiconto 1986. *Atti della Societa Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano* 128, 305-13.

Centro Studi Cetacei (1995): Cetacei spiaggiati lungo le coste Italiane. VII. Rendiconto 1992. (Mammalia). *Atti della Societa Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano* 134, 285-98.

Chevalier, J., Girondot M., Abreu-Grobois, F., Briseño-Dueñas, R., Márquez, R., Sarti, L. (2000): Recent population trend for Dermochelys coriacea in French Guiana. In: *Proceedings of the 18th Annual Symposium on Sea Turtle Biology and Conservation*, pp. 56-7.

Chitwood, J.E., McClure, A.C. (1987): Semisubmersible Drilling Tender Unit, SPE Drilling Engineering, June 1987.

Christian, J.R., Mathieu, A., Thomson, D.H., White, D., Buchanan, R.A. (2003): Effect of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Studies Research Funds Report No. 144. Calgary, AB, Canada.

Christian, J.R., Mathieu, A., Buchanan, R.A. (2004): Chronic effects of seismic energy on snow crab (*Chionoecetes opilio*). Environmental Studies Research Funds Report No. 158, Calgary, AB, Canada.

Clark, C.W., Ellison, W.T., Southall, B.L., Hatch, L., Van Parijs, S.M., Frankel, A., Ponirakis D. (2009): Acoustic masking in marine ecosystems: intuitions, analysis, and implication. *Marine Ecology Progress Series* 395, 201-22.

Compton, R., Goodwin, L., Handy R., Abbott, V. (2008): A critical examination of worldwide guidelines for minimising the disturbance to marine mammals during seismic surveys. *Marine Policy* 32, 255-62.

Continental Shelf Associates, Inc. (1997): Gulf of Mexico produced water bioaccumulation study, definitive component. Prepared for the Offshore Operators Committee, New Orleans, LA.

Continental Shelf Associates, Inc. (2004): Geological and geophysical exploration for mineral resources on the Gulf of Mexico outer continental shelf. Final programmatic environmental assessment. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS EIS/EA 2004-054. July 2004.

Continental Shelf Associates, Inc. (2006): Effects of oil and gas exploration and development at selected continental slope sites in the Gulf of Mexico. Volume II: Technical Report. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-045. 636 pp.

Cook, M.L.H. (2006): Behavioral and auditory evoked potential (AEP) hearing measurements in odontocete cetaceans. University of South Florida.

Corwin, J.T. (1981): Postembryonic production and aging of inner ear hair cells in sharks. *Journal of Comparative Neurology* 201, 541-53.

Corwin, J.T. (1983): Postembryonic growth of the macula neglecta auditory detector in the ray, Raja clavata: continual increases in hair cell number, neural convergence, and physiological sensitivity. *Journal of Comparative Neurology* 217, 345-56.

Crum, L.A., Mao Y. (1996): Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety. *The Journal of the Acoustical Society of America* 99, 2898-907.

Cushman-Roisin, B., Gacic, M., Poulain, P.-M., Artegiani, A. (2001): *Physical oceanography of the Adriatic Sea*. Kluwer Academic Publishers.

Cramp, S., Simmons, K. E. L., (1983): Handbook of the birds of Europe, the Middle East and Africa. The birds of the western Palearctic vol. III: waders to gulls. Oxford University Press, Oxford.

Cranswick, D. (2001): Brief overview of Gulf of Mexico OCS oil and gas pipelines: Installation, potential impacts, and mitigation measures. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Report MMS 2001-067. August 2001.

D'Amico, A., Bergamasco, A., Zanasca, P., Carniel, S., Nacini, E., Portunato, N., Teloni, V., Mori, C., Barbanti R. (2003): Qualitative correlation of marine mammals with physical and biological parameters in the Ligurian Sea. *Ieee Journal of Oceanic Engineering* 28, 29-43.

Dalebout, M.L., Robertson, K.M., Frantzis, A., Engelhaupt, D.A.N., Mignucci-Giannoni, A.A., Rosario-Delestre, R.J., Baker, C.S. (2005): Worldwide structure of mtDNA diversity among Cuvier's beaked whales (*Ziphius cavirostris*): implications for threatened populations. *Molecular Ecology* 14, 3353-71.

Davis, J.M., Addy, J.M., Blackman, R.A. i dr. (1984): Environmental effects of the use of oil-based drilling muds in the North Sea, Elsevier, 1984.

Davis, R. A., Thomson, D. H. , Malme, C. I. (1998): Environmental Assessment of Seismic Exploration on the Scotian Shelf. 1998. Prepared for Mobil Oil Canada Properties Ltd., Shell Canada Ltd., and Imperial Oil Ltd. for submission to the Canada-Nova Scotia Offshore Petroleum Board.

De Maddalena, A. (2000): Historical and contemporary presence of the great white shark, Carcharodon carcharias (Linnaeus, 1758), in the Northern Adriatic sea. *Annales Ser. hist. nat.* 10, 3-18.

Dekeling, R., Tasker, M., Van der Graaf, A., Ainslie, M., Andersson, M., André, M., Borsani, J., Brensing, K., Castellote, M., Cronin, D., Dalen, J., Folegot,, T., Leaper, R., Pajala, J., Redman, P., Robinson, S.P., Sigray, P., Sutton, G., Thomsen, F., Werner, S., Wittekind, D., Young J.V. (2013): Monitoring guidance for underwater noise in European seas–monitoring guidance specifications. *Second Report of the Technical Subgroup on Underwater Noise (TSG Noise)* Part I, II and III.

Del Hoyo, J., Elliott, A., Sargatal, J. (1996): Handbook of the Birds of the World, vol. 3: Hoatzin to Auks. Lynx Edicions, Barcelona, Spain.

Dercourt, J., Gaetani, M., Vrielynck, B., Barrier, E., Biju-Duval, B., Brunet, M.F., Cadet, J.P., Crasquin, S., Sandulescu, M. (ur.) (2000): Atlas Peri-Tethys, Palaeogeographical maps.– CCGM/CGMW, Paris; 24 karte i tumač: I–XX; 1–269.

DNV (2013): Arild Rogne. Introduction to main type of mobile offshore units.

Dodge, R. E. (1982): Effects of drilling mud on the reef-building coral Montastrea annularis, Marine Biology November (I) 1982, Volume 71, Issue 2, str 141- 147

Dragoset B. (2000): Introduction to air guns and air-gun arrays. *The Leading Edge* 19, 892-7.

Dragoset, B. (2005): A historical reflection on reflections (in SEG; 75; Imaging the past, present, and future; Society of Exploration Geophysicists. Leading Edge (Tulsa, OK), 24, Suppl.:S46-S71.

Drouot, V., Berube, M., Gannier, A., Goold, J.C., Reid, R.J., Palsboll, P.J. (2004): A note on genetic isolation of Mediterranean sperm whales (*Physeter macrocephalus*) suggested by mitochondrial DNA. *Journal of Cetacean Research and Management* 6, 29-32.

Dutton, D., Dutton, P., Boulon, R. (2000): Recruitment and mortality estimates for female leatherbacks nesting in St. Croix, US Virgin Islands. In:
Proceedings of the 19th Annual Symposium on Sea Turtle Biology and Conservation, pp. 268-9.

Dutton, D.L., Dutton, P.H., Chaloupka, M., Boulon, R.H. (2005): Increase of a Caribbean leatherback turtle< i> Dermochelys coriacea</i> nesting population linked to long-term nest protection. *Biological Conservation* 126, 186-94.

Đurasek, N., Frank, G., Jenko, K., Kužina, A., Tončić-Gregl, R. (1981): prilog poznavanju naftno-geoloških odnosa u sjeverozapadnom dijelu Jadranskog podzemlja. Zbornik radova simp. „Kompleksna naftno-geološka problematika podzemlja i priobalnih dijelova Jadranskog mora“, Split (1981), 1, 19-21.

Eckert, S.A. (2002): Distribution of juvenile leatherback sea turtle Dermochelys coriacea sightings. *Marine Ecology Progress Series* 230, 289-93. ECOINA, d.o.o. (2008): Studija o utjecaju na okoliš eksploatacije plina na eksploatacijskom polju „Sjeverni Jadran“ – dopuna, Zagreb, kolovoz 2008.

ECOINA, d.o.o. (2013): Studija o utjecaju na okoliš izmjene tehnologije obrade slojne vode i prilagodbe uklanjanja H_2S iz plina na eksploatacijskim poljima "Sjeverni Jadran" i "Marica", Zagreb, lipanj 2013.

Ellis, J. I., Wilhelm, S. I., Hedd, A., Fraser, G. S., Robertson, G. J., Rail, J.-F., Fowler, M., Morgan, K. H. (2013): Mortality of migratory birds from marine commercial fisheries and offshore oil and gas production in Canada. Avian Conservation and Ecology 8(2): 4.

Ellison, W.T., Southall, B.L., Clark, C.W., Frankel, A.S. (2012): A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds. *Conservation Biology* 26, 21-8.

Engås, A., Løkkeborg, S., Ona, E., Soldal, A. V. (1996): Effects of seismic shooting on local abundance and catch rates of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus). Can. J. Fish. Aquat. Sci. Vol. 53, 2238-2249.

Faber, G.L. (1883): *The fisheries of the Adriatic and the fish thereof. A report of the Austro-Hungarian sea-fisheries, with detailed description of the Adriatic gulf.* Bernard Quaritch, London.

Fernández A., Edwards J.F., Rodríguez F., de los Monteros A.E., Herráez P., Castro P., Jaber J.R., Martín V. & Arbelo M. (2005) “Gas and Fat Embolic Syndrome” Involving a Mass Stranding of Beaked Whales (Family Ziphiidae) Exposed to Anthropogenic Sonar Signals. *Veterinary Pathology Online* 42, 446-57.

Ferretti, F., Osio, G.C., Jenkins, C.J., Rosenberg, A.A., Lotze, H.K. (2013): Long-term change in a meso-predator community in response to prolonged and heterogeneous human impact. *Scientific reports* 3.

Fewtrell, J.L., McCauley, R.D. (2012): Impact of air gun noise on the behaviour of marine fish and squid. *Marine Pollution Bulletin* 64, 984-93.

Finneran, J.J., Carder, D.A., Schlundt, C.E., Dear, R.L. (2010): Growth and recovery of temporary threshold shift at 3 kHz in bottlenose dolphins: Experimental data and mathematical models. *Journal of the Acoustical Society of America* 127, 3256-66.

Finneran, J.J., Carder, D.A., Schlundt, C.E., Ridgway, S.H. (2005): Temporary threshold shift in bottlenose dolphins (Tursiops truncatus) exposed to mid- frequency tones. *Journal of the Acoustical Society of America* 118, 2696-705.

Finneran, J.J., Schlundt, C.E., Dear, R., Carder, D.A., Ridgway S.H. (2002): Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. *Journal of the Acoustical Society of America* 111, 2929-40.

Finneran, J.J., Trickey, J.S., Branstetter, B.K., Schlundt, C.E., Jenkins, K. (2011): Auditory effects of multiple underwater impulses on bottlenose dolphins (Tursiops truncatus). *The Journal of the Acoustical Society of America* 130, 2561-.

Fortuna, C., Holcer, D., Mackelworth, P., Filidei, jr E., Donovan, G., Tunesi L., Lazar B. (2015): Summer distribution and abundance of sea turtles in the Adriatic Sea: Results from the first aerial survey in the region. In: *Proceedings of the 35th International Symposium on Sea Turtle Biology and Conservation*. Proceedings of the 35th International Symposium on Sea Turtle Biology and Conservation, Miami, Florida.

Fortuna, C.M. (2006): Ecology and conservation of bottlenose dolphins (*Tursiops truncatus)* in the North-Eastern Adriatic sea. p. 275. University of St. Andrews, St. Andrews, UK.

Fortuna, C. M., Marsili, L., Laurino, G. (2002): The effects of oil spils on Cetaceans. In: Oil Pollution and Conservation od Biodiversity (ed. by Walmsely JG), pp 49-54. NO Asinara, IFAW, MedMarAvis, Porto Torres (Sardinia).

Fortuna, C.M., Acquarone, M., Annunziatellis A., Arcangeli, A., Azzelino, A., Baccetti, N., Bellingeri, M., Bonizzoni, S., Borsani, F.J., Caliani, I., Canese, S., Canneri, R., Cerioli, N., De Lucia, A., Dimatteo, S., Fanizza, C., Filidei, Jr E., Fossi, C., Garibaldi, F., Gaspari, S., Giovanardi, O., Giusti, M., Gnone, G., Guidetti, P., Holcer, D., Lauriano, G., Marsili, L., Mazzola, A., Mo, G., Moulins, A., Mussi, B., Notarbartolo di Sciara, G., Orsi Relini, L., Pace, D.S., Panigada, S., Pavan, G., Podestà, M., Pulcini, M., Raicevich, S., Randi, E., Romeo, T., Rosso, M., Sala, A., Tepsich, P., Zimmer, W., Zizzo, N. (2013): MSFD Supporting document on the Initial Assessment on Cetaceans, including methodology, data used and results. p. 62. ISPRA, Rome.

Fortuna, C.M., Canese, S., Giusti, M., Revelli, E., Consoli, P., Florio, G., Greco, S., Romeo, T., Andaloro, F., Fossi, M.C., Lauriano G. (2007): An insight into the status of the striped dolphins, *Stenella coeruleoalba*, of the southern Tyrrhenian Sea. *Journal of the Marine Biological Association of the United Kingdom* 87, 1321-6.

Fortuna, C.M., Holcer, D., Filidei, E.j., Tunesi, L. (2011a): Relazione finale del progetto "Valutazione dell'impatto della mortalita causata da attivita di pesca su Cetacei e tartarughe marine in Adriatico: primo survey per la stima dell'abbondanza". In: *Prot. MIPAAF DG PEMAC n. 1690 del 10/02/2010 e al Prot. MATTM DPN n. 27623 del 23/12/2009*, p. 75. ISPRA, Rome.

Fortuna, C.M., Holcer, D., Filidei, Jr E., Donovan, G.P., Tunesi, L. (2011b): The first cetacean aerial survey in the Adriatic sea: summer 2010. In: *7th Meeting of the ACCOBAMS Scientific committee*, p. 16.

Fortuna, C.M., Kell, L., Holcer, D., Canese, S., Filidei, E., Mackelworth, P., Donovan, G. (2014a): Summer distribution and abundance of the giant devil ray (Mobula mobular) in the Adriatic Sea: Baseline data for an iterative management framework. *Scientia Marina* 78, 227-37.

Fortuna, C.M., Mackelworth, C.P., Holcer, D. (2014b): Toward the identification of EBSAs in the Adriatic sea: hotspots of megafauna. In: *Mediterranean Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas (EBSAs)*. Convention on Biological Diversity, Málaga, Spain.

Fortuna, C.M., Vallini, C., Filidei, Jr E., Ruffino, M., Consalvo, I., di Muccio, S., Gion, C., Scacco, U., Tarulli, E., Giovanardi ,O., Mazzola, A. (2010): By-catch of cetaceans and other species of conservation concern during pair trawl fishing operations in the Adriatic Sea (Italy). *Chemistry and Ecology* 26, 65-76.

Fortuna, C.M., Wilson, B., Wiemann, A., Riva, L., Gaspari, S., Matesic, M., Oehen, S., Pribanic, S. (2000): How many dolphins are we studying and is our study area big enough? In: *European Research on Cetaceans 14* (eds. by Evans PGH, Pitt-Aiken R & Rogen E), pp. 370-3, Cork, Ireland.

Francese, M., Picciulin, M., Tempesta, M., Zuppa, F., Merson, E., Intini, A., Mazzatenta, A., Genov, T. (2007): Occurrence of Striped dolphins (*Stenella coeruleoalba*) in the Gulf of Trieste. *Annales, Series Historia Naturalis* 17, 185-90.

Francese, M., Zucca, P., Picciulin, M., Zuppa, F., Spoto, M. (1999): Cetaceans living in the North Adriatic Sea (Gulf of Trieste–Grado lagoon): intervention protocol for healthy and distressed animals. *European Research on Cetaceans* 13, 410-5.

Frank, G., Križ, J., Vlašić, B. (1983): Results and directions in hydrocarbon exploration of the Adriatic

offshore. Nafta, 34, 7-8, 387-396. Frantzis, A. (1998): Does acoustic testing strand whales? *Nature* 392, 29.

Frantzis, A., Alexiadou, P., Paximadis, G., Politi, E., Gannier, A., Corsini-Foka, M. (2003): Current knowledge of the cetacean fauna of the Greek Seas.
Journal of Cetacean Research and Management 5, 219-32.

Freedman, A.H., Portier, K.M., Sunquist, M.E. (2003): Life history analysis for black bears (*Ursus americanus*) in a changing demographic landscape.
Ecological Modelling 167, 47-64.

Frost K.J. i Lowry L.F. (1994) Assessment of injury to harbor seals in Prince William Sound, Alaska, and adjacent areas following the Exxon Valdez oil spill. In: *Marine mammal study number 5.* . Alaska Department of Fish and Game, Wildlife Conservation Division.

Gamulin-Brida, H. (1974): *Biocoenoses benthiques de la mer Adriatique*. Institut za oceanografiju i ribarstvo.

Gannie,r A. (2011): Using existing data and focused surveys to highlight Cuvier's beaked whales favourable areas: A case study in the central Tyrrhenian Sea. *Marine Pollution Bulletin* 63, 10-7.

Gannier, A., Epinat J. (2008): Cuvier's beaked whale distribution in the Mediterranean Sea: Results from small boat surveys 1996-2007. *Journal of the Marine Biological Association of the United Kingdom* 88, 1245-51.

García-Párraga, D., Crespo-Picazo, J., de Quirós Y.B., Cervera, V., Martí-Bonmati, L., Díaz-Delgado, J., Arbelo, M., Moore, M., Jepson, P., Fernández, A. (2014): Decompression sickness ('the bends') in sea turtles. *Diseases of Aquatic Organisms* 111, 191-205.

Garland, E. (2005): Environmental Regulatory Framework in Europe: An Update, SPE 93796, the 2005 SPE/EPA/DOE Exploration and Production Environmental Conference, pp.1-10, Galveston, Texas, 2005.

Garofalo, L., Mastrogiacomo, A., Casale, P., Carlini, R., Eleni, C., Freggi, D., Gelli, D., Knittweis, L., Mifsud, C., Mingozzi, T., Novarini, N., Scaravelli, D., Scillitani, G., Oliverio, M., Novelletto, A. (2013): Genetic characterization of central Mediterranean stocks of the loggerhead turtle (Caretta caretta) using mitochondrial and nuclear markers, and conservation implications. *Aquatic Conservation: Marine and Freshwater Ecosystems* 23, 868-84.

Garza-Gil, M. D., Prada-Blanco, A., Vázquez-Rodríguez, M. X. (2006): Estimating the short-term economic damages from the Prestige oil spill in the Galician fisheries and tourism. *Ecological Economics*, *58*(4), 842-849.

Gaspari, S. (2004): Social and population structure of striped and Risso's dolphins in the Mediterranean Sea. In: *School of Biological and Biomedical Sciences*, p. 170. University of Durham, Durham.

Gaspari, S., Airoldi, S., Hoelzel, A.R. (2007): Risso's dolphins (*Grampus griseus*) in UK waters are differentiated from a population in the Mediterranean Sea and genetically less diverse. *Conservation Genetics* 8, 727-32.

Gaspari, S., Holcer, D., Mackelworth, P., Fortuna, C., Frantzis, A., Genov, T., Vighi, M., Natali, C., Rako, N., Banchi, E., Chelazzi, G., Ciofi C. (2013): Population genetic structure of common bottlenose dolphins (*Tursiops truncatus*) in the Adriatic Sea and contiguous regions: implications for international conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, n/a-n/a.

Gaspari, S., Natoli A. (2012): *Grampus griseus* (Mediterranean subpopulation).

Gaspari, S., Scheinin, A., Holcer, D., Fortuna, C., Natali, C., Genov, T., Frantzis, A., Chelazzi, G., Moura A. (in review) Drivers of population structure of the bottlenose dolphin (*Tursiops truncatus*) in the Eastern Mediterranean Sea. *Journal of Evolutionary Biology*.

Gaurina-Međimurec, N. (2014): The Underground Injection of Drilling Waste, Chapter 15 in Handbook of Research on Advancements in Environmental Engineering, IGI Global, 2014, pp.605. (Editor: Gaurina-Međimurec).

Gaurina-Međimurec, N. (2009): Predavanja „Bušotinski fluidi", RGNf, 2009.

Gaurina-Međimurec, N., Krištafor, Z. (2005): Offshore Drilling Wastes Management and EU Regulations (Postupanje s otpadom iz bušenja na moru i EU propisi), 6th International Symposium on Mine Haulage and Hoisting, Budva, Maj 23-25. 2005.

Gaurina-Međimurec, N., Rauker S., Bratuša Z., Veronek, B. (2001): Bušenje i zaštita okoliša. Međunarodni znanstveno-stručni skup o naftnom rudarstvu, Zadar, Hrvatska, 2.-5. listopad. 2001

Grandić, S., Kratković, I., Rusan, I. (2010): Procjena naftno-geološkog potencijala periplatformnih klastita duž JZ ruba Dinaridske karbonatne platforme. Nafta, 61, 7-8, 1-6.

Gaurina-Međimurec, N., Simon, K., Matanović, D., Pašić, B. (2006): Offshore Drilling and Environmental Protection, Energy and Environment 2006, Opatija, 2006, 309-318.

Getliff, J., Roach, A., Toyo, J., Carpenter, J. (1997): An overview of the environmental benefits of LAO based drilling fluids for offshore drilling. Report from Schlumberger Dowell. 10 pp.

Genov, T., Bearzi, G., Bonizzoni, S.,Tempesta M. (2012): Long-distance movement of a lone short-beaked common dolphin *Delphinus delphis* in the central Mediterranean Sea. *Marine Biodiversity Records* 5, null-null.

Genov, T., Kotnjek, P., Lesjak, J., Hace, A. (2008): Bottlenose dolphins (*Tursiops truncatus*) in Slovenian and adjacent waters (Northern Adriatic sea).
Annales, Series Historia Naturalis 18, 227-44.

Genov, T., Kotnjek, P., Lipej, L. (2009a): New record of the humpback whale (*Megaptera novaeangliae*) in the Adriatic Sea. *Annales, Series Historia Naturalis* 19, 25-30.

Genov, T., Wiemann, A., Fortuna, C.M. (2009b): Towards identification of the bottlenose dolphin (*Tursiops truncatus*) population structure in the north- eastern Adriatic sea: preliminary results. *Varstvo narave* 22, 73-80.

Giglioli, E.H. (1880): *Elenco dei Mamiferi: degli Uccelli e dei Rettili ittiofagi appartenento alla fauna italica e catalogo degli anfibi e dei Pesci italiani*. Stamperia Reale, Firenze.

Giovagnoli, L. (2013): Adriatic Shipping Company marine mammal sightings in the Adriatic Sea 1988-2000. URL

http://seamap.env.duke.edu/dataset/865. Gitschlag, G.R., Herczeg B.A. (1994): Sea turtle observations at explosive

removals of energy structures. *Marine Fisheries Review* 56, 1-8.

Gitschlag, G.R., Schrripa, J.S., Powers, J.E. (2000): Estimation of fisheries impacts due to underwater explosives used to sever and salvage oil and gas platforms in the U.S. Gulf of Mexico. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2000-087.

Godley, B., Richardson, S., Broderick, A., Coyne, M., Glen, F., Hays, G. (2002): Long-term satellite telemetry of the movements and habitat utilisation by green turtles in the Mediterranean. *Ecography* 25, 352-62.

Goldstein, D. B., Osofsky, H. J., Lichtveld, M. Y. (2011): The Gulf Oil Spill, The New England Journal of Medicine.
Gomerčić, H., Đuras Gomerčić, M., Gomerčić, T., Lucić, H., Dalebout, M., Galov, A., Škrtić, D., Ćurković, S., Vuković, S., Huber Đ. (2006a): Biological aspects of Cuvier's beaked whale (*Ziphius cavirostris*) recorded in the Croatian part of the Adriatic Sea. *European Journal of Wildlife Research* 52, 182-7.

Gomerčić, H., Đuras Gomerčić, M., Gomerčić, T., Lucić, H., Škrtić, D., Ćurković, S., Vuković, S., Huber, Đ., Gomerčić, V., Bubić Špoljar, J. (2006b): Abundance and mortality of Risso's dolphins (*Grampus griseus*) in the last 15 years in the Croatian part of the Adriatic sea. In: *9th Croatian Biological Congress* (eds. by Bessendorfer V & Klobučar GIV), pp. 297-8. Croatian Biological Society, Rovinj.

Gómez de Segura, A., Crespo, E., Pedraza, S., Hammond, P., Raga J. (2006): Abundance of small cetaceans in waters of the central Spanish Mediterranean. *Marine Biology* 150, 149-60.
Gómez de Segura, A., Hammond, P.S., Raga J.A. (2008): Influence of environmental factors on small cetacean distribution in the Spanish Mediterranean.
Journal of the Marine Biological Association of the United Kingdom 88, 1185-92.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R., Thompson D. (2003): A review of the effects of seismic surveys on marine mammals. *Marine Technology Society Journal* 37, 16-34.
Greene, C. R. (1987): Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. Journal of Acoustical Society of America 82(4):1315- 1324.

Greene, C.R.J., Moore, S.E. (1995): Man-made noise. In: *Marine mammals and noise* (pp. 101-58. Academic Press, San Diego, CA.

Guo, B., Song, S., Chacko, J., Ghalambor, A. (2005): Offshore Pipelines: Design, Installation andOperations. Elsevier Inc., Oxford, UK. ISBN 978-0-7506- 7847-6. 289 pp.

Gutiérrez, R., Guinart, E. (2008): The Ebro Delta Audouin's Gull colony and vagrancy potential to northwest Europe. British Birds 101(8): 443-447.

Halvorsen, M., Casper, B., Woodley, C., Carlson, T., Popper, A. (2011): Predicting and mitigating hydroacoustic impacts on fish from pile installations. NCHRP Report Research Results Digest 363, Project 25–28, National Cooperative Highway Research Program. *Transportation Research Board, National Academy of Sciences, Washington, DC http://apps. trb. org/cmsfeed/TRBNetProjectDisplay. asp*.

Halvorsen, M.B., Casper, B.M., Matthews, F., Carlson, T.J., Popper A.N. (2012a): Effects of exposure to pile-driving sounds on the lake sturgeon, Nile tilapia and hogchoker. *Proceedings of the Royal Society B: Biological Sciences*, rspb20121544.

Halvorsen, M.B., Casper, B.M., Woodley, C.M., Carlson, T.J., Popper A.N. (2012b): Threshold for onset of injury in Chinook salmon from exposure to impulsive pile driving sounds. *PLoS ONE* 7, e38968.

Hanski I. (2005): Landscape fragmentation, biodiversity loss and the societal response. *EMBO reports* 6, 388-92.

Hanski I., Gaggiotti O.E. (2004): Metapopulation biology: past, present, and future. In: *Ecology Genetics and Evolution of Metapopulations: Standard Methods for Inventory and Monitoring* (eds. by Hanski I & Gaggiotti OE), pp. 3-22. Academic Press.

Harland, E. J., Jones S. A. S., Clarke T. (2005): SEA 6 Technical report: Underwater ambient noise QINETIC/S&E/MAC/CR050575, Farnborough, Qinetiq

Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Løkkeborg, S., Misund, O. A., Østensen, Ø., Fonn, M., Haugland, E. K. (2004): Influence of seismic shooting on the lesser sandeel (Ammodytes marinus). ICES Journal of Marine Science, 61, 1165 – 1173.
Hanni, G., Hartley, J., Munro, R., Skullerd, A. (1998): Evolutionary Environmental Management of Drilling Discharges: Results without cost penalty. SPE 46617. SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, 7-10 June 1998, Caracas, Venezuela.

Herak M., Herak D., Markušić S. (1996): Revision of the earthquake catalogue and seismicity of Croatia, 1908-1992, Terra Nova 8, 86-94.

Haxhiu, I. (2010): Albania. In: *Sea turtles in the Mediterranean: distribution, threats and conservation priorities* (eds. by Casale P & Margritoulis D), pp. 15-

28. IUCN, Gland, Switzerland.

Haxhiu, I., Rumano M. (2005): CONSERVATION PROJECT OF SEA TURTLES IN PATOK (ALBANIA). In: *SECOND MEDITERRANEAN CONFERENCE ON MARINE TURTLES*, p. 87.

Hays, G.C., Fossette, S., Katselidis, K.A., Mariani, P., Schofield, G. (2010a): Ontogenetic development of migration: Lagrangian drift trajectories suggest a new paradigm for sea turtles. *Journal of the Royal Society Interface* 7, 1319-27.

Hays, G.C., Fossette, S., Katselidis K.A., Schofield, G., Gravenor, M.B. (2010b): Breeding periodicity for male sea turtles, operational sex ratios, and implications in the face of climate change. *Conservation Biology* 24, 1636-43.

Hays, G.C., Houghton, J.D., Myers, A.E. (2004): Endangered species: pan-Atlantic leatherback turtle movements. *Nature* 429, 522-.

Heyning, J. (1989): Cuvier's beaked whale *Ziphius cavirostris* G. Cuvier, 1823. In: *Handbook of marine mammals* (eds. by Ridgway SH & Harrison RJ), pp. 289-308. Academic Press, London.

Hildebrand, J.A. (2005): Impacts of Anthropogenic Sound. In: *Marine Mammal Research: Conservation beyond Crisis* (eds. by Reynolds JD, Perrin WF, Reeves Randall R, Montgomery S & Ragen TJ), p. 223. The Johns Hopkins University Press, Baltimore.

Hirth H. (1997) Synopsis of biological data on the green turtle *Chelonia mydas* (Linnaeus 1758). In: *Biological report 97*, p. 120. US Fish and wildlife service, Washington DC.

Hirtz, M. (1922): Kit debeloglavac, *Globicephalus melas* (Traill) u vodama Hrvatske. *Glasnik Hrvatskog Naravoslovnog Društva* 34, 84-

9. Hirtz, M. (1938): Rijetke vrste delfina u vodama Korčule. *Priroda* 27, 25-8.

Hochscheid, S., Bentivegna, F., Bradai, M.N., Hays G.C. (2007): Overwintering behaviour in sea turtles: dormancy is optional. *Marine Ecology Progress Series* 340, 287-98.

Holand, P. (1997): Offshore blowouts: Causes and control. Gulf Publishing Co.,

Houston, TX. 163 pp. Holcer, D. (1994): Prospective of cetology in Croatia.

European Research on Cetaceans 8, 120-1.

Holcer D. (2006): Kratkokljuni obični dupin (Short-beaked common dolphin), *Delphinus delphis* Linnaeus, 1758. In: *Crvena knjiga sisavaca Hrvatske (Red book of mammals of Croatia)* (ed. by Tvrtković N), p. 127. Ministarstvo kulture, Državni zavod za zaštitu prirode, Zagreb.

Holcer, D. (2012): Ecology of the common bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821) in the Central Adriatic sea. In: *Faculty of Sciences*, p. 208

+ LIV. University of Zagreb, Zagreb.

Holcer, D., Di Sciara, G.N., Fortuna, C.M., Laza, B., Onofri V. (2007): Occurrence of Cuvier's beaked whales in the southern Adriatic Sea: Evidence of an important Mediterranean habitat. *Journal of the Marine Biological Association of the United Kingdom* 87, 359-62.

Holcer, D., Fortuna, C., Filidei, E., Mackelworth, P., Tunesi L. (2010a): Distribution and abundance of megafauna in the Adriatic Sea: relevance for identification of important marine areas. In: *3rd International Workshop on Biodiversity in the Adriatic: Towards a representative network of MPAs in the Adriatic*.

Holcer, D., Fortuna, C., Mackelworth P. (2006): The Lošinj Dolphin Reserve: two decades of work for a conservation success story? *FINS* 3, 22-7.

Holcer, D., Fortuna C.M. (2011): The aerial survey of cetacean abundance in the areas of Kvarner/Kvarnerić and Central Adriatic: August 2010. A project report to State institute for nature protection, Zagreb. p. 26. Blue World Vis, Vis.

Holcer, D., Fortun,a C.M., Mackelworth C.P. (2014a): Status and Conservation of Cetaceans in the Adriatic Sea. Draft internal report. In: *Mediterranean Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas (EBSAs)*, p. 70. UNEP-MAP-RAC/SPA, Tunis, Málaga, Spain.

Holcer, D., Fortuna, C.M., Nimak, M., Mackelworth, C.P., Pleslić, G., Jovanović, J., Krstinić P. (2008a): Jadranski projekt dupin - Vis. Izvještaj o obavljenom preliminarnom istraživanju dobrih dupina (*Tursiops truncatus*) šireg područja otoka Visa tijekom 2008. godine. p. 27. Plavi svijet Institut za istraživanje i zaštitu mora, Veli Lošinj.

Holcer, D., Mackelworth C.P., Fortuna C.M. (2014b): Status and Conservation of Cetaceans in the Adriatic Sea - draft. In: *Mediterranean Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas*, p. 70. UNEP-MAP-RAC/SPA, Malaga, Spain.

Holcer, D., Mackelworth, P., Fortuna C.M. (2002): Present state of understanding of the Cetacean fauna of the Croatian Adriatic sea. *European Research on Cetaceans* 16.

Holcer, D., Nimak, M., Pleslić, G., Jovanović J. (2008b): Adriatic dolphin project research report: Lastovo 2008. p. 6. Blue World Institute of Marine Research and Conservation, Veli Lošinj.

Holcer D., Nimak M., Pleslić G., Jovanović J., Fortuna C.M. (2009): Survey of bottlenose dolphins (*Tursiops truncatus*) in the area of Lastovo island, Adriatic sea. In: *10th Croatian Biological Congress* (eds. by Besendorfer V, Kopjar N, Vidaković-Cifrek Ž, Tkalec M, Bauer N & Lukša Ž), pp. 300-1. Croatian Biological Society, Osijek.

Holcer, D., Nimak Wood, M., Fortuna, C.M., Mackelworth, P., Rako, N., Dobrić, V., Cukrov M. (2010b): Utvrđivanje brojnosti i distribucije dupina na području Viškog arhipelaga, te davanje preporuka za očuvanje i održivo korištenje utvrđenih posebno značajnih područja., p. 61. Plavi svijet, Veli Lošinj

Holcer, D., Notarbartolo di Sciara, G., Fortuna, C.M., Onofri, V., Lazar, B., Tvrtković N. (2003): The occurrence of Cuvier's beaked whale (*Ziphius cavirostris*) in Croatian Adriatic waters. In: *Proceeding of Abstracts of Eight Croatian Biological Congress* (eds. by Besendorfer V & Kopjar N), pp. 255-6. Croatian Biological Society, Zagreb, Croatia.

Holcer, D., Wiemann, A., Mackelworth, P., Fortuna, C.M. (2008c): Preliminary results on the distribution and abundance of Cetaceans in the Croatian southern Adriatic sea. In: *22nd conference of the European Cetacean Society*. European Cetacean Society, Egmond aan Zee, Netherlands.

Hoogendoorm, W. and Mackrill, E.J. 1987. Audouin's gull in southwestern Palearctic. Dutch Birding 9(4): 99-107.

Impetuoso, A., Wiemann, A., Antollovich, W., Holcer, D., Mackelworth, P.C., Fortuna C.M. (2003): A preliminary study of Cetacean presence and abundance in the archipelago of the Kornati National park (Croatia). In: *8th Croatian Biological Congress* (eds. by Besendorfer V & Kopjar N). Croatian Biological Society, Zagreb, Croatia, 27.09 - 2.10.2003.

James, M.C., Andrea, Ottensmeyer, C., Myers R.A. (2005): Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. *Ecology Letters* 8, 195-201.

Janik, V.M. (2000): Source levels and the estimated active space of bottlenose dolphin (Tursiops truncatus) whistles in the Moray Firth, Scotland. *Journal of Comparative Physiology a-Sensory Neural and Behavioral Physiology* 186, 673-80.

Janik, V.M. (2005): Underwater acoustic communication networks in marine mammals. In *Animal communication networks (ed. by McGregor PK)*, pp 390-

415. Cambrige University Press, Cambrige.

Jepson, P., Arbelo, M., Deaville, R., Patterson, I., Castro, P., Baker J., Degollada, E., Ross, H., Herráez, P., Pocknell, A., Rodríguez, F., Howie, F., Espinosa ,A., Reid, R., Jaber, J., Martin, V., Cunningham, A., Fernández, A. (2003): Gas-bubble lesions in stranded cetaceans. *Nature* 425, 575-6.

Jepson, P., Deaville, R., Patterson, I., Pocknell, A., Ross, H., Baker, J., Howie, F., Reid, R., Colloff, A., Cunningham A. (2005): Acute and chronic gas bubble lesions in cetaceans stranded in the United Kingdom. *Veterinary Pathology Online* 42, 291-305.
JNCC (2010): JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys. p.

16. Joint nature conservation committee, Aberdeen, UK.

Joint NWG (2014): Joint CMS/ASCOBANS/ACCOBAMS noise working group contribution to CBD notification no. 2014-001. In: *Expert Workshop on Underwater Noise and its Impacts on Marine and Coastal Biodiversity*, London, UK.

Jones, F.V., Leuterman, J.J., Still, I. (2000): Discharge Practices and Standards for Offshore Operations Around the World, Presented at 7th International Petroleum Environmental Conference Albuquerque, New Mexico, November 7-10, 2000.

Jüttner Preradović, Ivanka (2005): Uvod u naftno gospodarstvo. RGNF Zagreb, 2005

Kalac, K., Bajraktarević, Z., Marković, Z., Barbić, Z., Gušić, I. (1995): Stratigrafija pliocensko-pleistocenskih sedimenata u bušotinama podzemlja Jadrana. 1. Hrvatski geološki kongres. Opatija, 18-21. 10. 1995., Zbornik radova, 1, 281-284, Zagreb.

Kammigan, I.C., Bräger, S., Hennig, V., Wiemann, A., Impetuoso, A. (2008): Ecology of bottlenose dolphins (*Tursiops truncatus*) in the Kornati National Park, Croatia: Population estimation, group composition and distribution. In: *22nd Annual Conference of the European Cetacean Society* (eds. by Pierce GJ, Philips E & Lick R). European Cetacean Society, Egmond aan Zee, The Netherlands.

Ketten, D. (1997): Structure and function in whale ears. *Bioacoustics* 8, 103-35.

Ketten, D., Cramer, S., Arruda, J., Brooks, L., O'Malley, J., Reidenberg, J., McCall, S., Craig, J., Rye K. (2005): Experimental measures of blast trauma in sea turtles. In: *Symposium on Environmental Consequences of Underwater Sound, Office of Naval Research, Arlington, VA (paper available on ONR website).*

Ketten, D., Lien, J., Todd S. (1993): Blast injury in humpback whale ears: evidence and implications. *The Journal of the Acoustical Society of America* 94, 1849-50.

Kenneth, W. F., Sayed, Z. E. S. (1979): Effect of oil production and drilling operations on the ecology of phytoplankton in the OEI study area.The Rice University Studies, vol. 65, no. 4, pp. 352-354.

Klima, E.F., Gitschlag, G.R., Renaud M.L. (1988): Impacts of the explosive removal of offshore petroleum platforms on sea turtles and dolphins. *Marine Fisheries Review* 50, 33-42.

Kollmann, H., Stachowitsch M. (2001): Long-Term Changes in the Benthos of the Northern Adriatic Sea: A Phototransect Approach. *Marine Ecology* 22, 135-54.

Kolombatović, G. (1894): Godišnje izvješće C. K. velike realke u Splitu (Yearly report of the Royal High School in Split). p. 54. A.Zannoni, Split.

Kovačić, I., Gomerčić, M.Đ., Gomerčić, H., Lucić, H., Gomerčić T. (2010): Stomach contents of two Cuvier's beaked whales (*Ziphius cavirostris*) stranded in the Adriatic Sea. *Marine Biodiversity Records* 3.

Kranjec, V. (1981): Neke značajke naftoplinonosnosti naslaga i moguća daljnja nalazišta ugljikovodika u predjelima Vanjskih Dinarida i Jadranskog područja. Pomorski zbornik, 19/83, 385-412, Rijeka.

Kranjec, V., Aljinović, B., Šparica, M., Krulc, Z. (1987): On some new results and problems of geological and geophysical exploration for oil an gas in the Sava-Drava river area, the Outer Dinarides and in the Adria. Nafta, 38, 4-5, 189-204.

KRAIL, P. M.(1994): Vertical-cable as a subsalt imaging tool: The Leading Edge, 13(8): 885-887.

Krstulović Šifner, S., Peharda Uljević, M., Dadić, V., Isjalović, I., Ezgeta, D., Marušić, I., Vlahović, V., Bašković, D (2009): Opis ribolovnih resursa i preporuke za održiv pridneni ribolov u otvorenom Srednjem Jadranu. Institut za oceanigrafiju i ribarstvo.

Kruse, S., Caldwell, D., Caldwell, M. (1999): Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). In: *Handbook of marine mammals* (eds. by Ridgway SH & Harrison R), pp. 183-212. Academic Press, San Diego.

La Bella, G., Cannata, S., Froglia, C., Modica, A., Ratti, S. and Rivas, G. (1996) First assessment of effects of air-gun seismic shooting on marine resources in the central Adriatic Sea. Society of Petroleum Engineers. International Conference on Health, Safety and Environment, New Orleans, Louisiana, 9–12 June, pp. 227–238.

Lamani, F., Peja, N., Ruka, E. (1976): Balena me sqep e Kyvierit (*Ziphius cavirostris*) ne bregdetin shqiptar. *Buletini i Shkencave te Natyres* 1, 73-8.

Laran, S., Joiris, C., Gannier, A., Kenney, R.D. (2010): Seasonal estimates of densities and predation rates of cetaceans in the Ligurian Sea, northwestern Mediterranean Sea: an initial examination. *J Cetacean Res Manag* 11, 31-40.

Lauriano, G., Panigada, S., Fortuna, C.M., Holcer, D., Filidei Jr, E., Pierantonio N., Donovan G.P. (2011): Monitoring density and abundance of cetaceans in the seas around Italy through aerial surveys: a summary contribution to conservation and the future ACCOBAMS survey. In: *63. Meeting of the IWC Scientific committee*, p. 5.

Lavende,r A.L., Bartol, S.M., Bartol, I.K. (2012): Hearing capabilities of loggerhead sea turtles (Caretta caretta) throughout ontogeny. In: *The Effects of Noise on Aquatic Life* (pp. 89-92. Springer.

Law, R.J., Kelly, C. 2004. The impact of the "Sea Empress" oil spill, Aquat. Living Resour. 17, 389–394

Lazar, B. (2009): Ecology and Conservation of Loggerhead Sea Turtle Caretta caretta (Linnaeus 1758) in the Eastern Adriatic Sea. PhD thesis. University of Zagreb, Faculty of Science, Croatia: 178 pp.[in Croatian with abstract in English].

Lazar, B. (2010): Croatia. In: *Sea turtles in the Mediterranean: distribution, threats and conservation priorities* (ed. by Casale P), pp. 29-38. IUCN, Gland, Switzerland.

Lazar, B., Casale, P., Tvrtkovic, N., Kozul, V., Tutman, P., Glavic, N. (2004a): The presence of the green sea turtle, Chelonia mydas, in the Adriatic Sea.
Herpetological journal 14, 143-8.

Lazar, B., Formia, A., Kocijan, I., Ciofi, C., Lacković, G., Tvrtković, N. (2007): Population structure of loggerhead sea turtles, Caretta caretta, in the Adriatic Sea. In: *27th International Symposium on Sea Turtle Biology and Conservation (27; 2007).*

Lazar, B., Gargia-Borboroglu, P., Tvrtkovic, N., Ziza, V., Seminoff, J. (2003): Temporal and spatial distribution of the loggerhead sea turtle Caretta caretta in the eastern Adriatic Sea: a seasonal migration pathway. In: Proceedings ofthe22.Annualsymposiumon sea turtle biology and conservation (ed.bySeminoff JA), pp. 238 -284. NOAA/NMFS, Miami, Fl.

Lazar, B., Gracan, R., Zavodnik, D., Tvrtkovic, N. (2008a): Feeding ecology of ‘pelagic’loggerhead turtles, Caretta caretta, in the northern Adriatic Sea: proof of an early ontogenetic habitat shift. In: *Proc 25th Annu Symp on Sea Turtle Biology and Conservation*.

Lazar, B., Gračan, R. (2011): Ingestion of marine debris by loggerhead sea turtles,< i> Caretta caretta</i>, in the Adriatic Sea. *Marine Pollution Bulletin* 62, 43-7.

Lazar, B., Gračan, R., Katić, J., Zavodnik, D., Jaklin, A., Tvrtković, N. (2011a): Loggerhead sea turtles (Caretta caretta) as bioturbators in neritic habitats: an insight through the analysis of benthic molluscs in the diet. *Marine Ecology* 32, 65-74.

Lazar,, B., Gračan, R., Lacković, G., Tvrtković, N. (2011b): Bycatch of loggerhead sea turtles by bottom trawls in the northeastern Adriatic Sea. In: *4th Mediterranean Conference on Marine Turtles* (eds. by Bentivegna F, Maffuci F & Mauriello F), p. 106, Naples, Italy.

Lazar, B., Gračan, R., Zavodnik, D., Katić, J., Buršić, M., Tvrtković, N. (2006a): Diet composition of loggerhead sea turtle Caretta caretta in the Adriatic Sea. In: *International Symposium on Sea Turtle Biology and Conservation (26; 2006)*.

Lazar, B., Holcer, D., Mackelworth, P., Klinčić, D., Herceg Romanić, S. (2012): Organochlorine contaminant levels in tissues of a short-beaked common dolphin, *Delphinus delphis*, from northern Adriatic Sea. *Natura Croatica* 21, 391-401.

Lazar, B., Lipej, L., Holcer, D., Onofri, V., Ziza, V., Tutman, P., Marcelja, E., Tvrtkovic, N. (2008b): New data on the occurrence of leatherback turtles
Dermochelys coriacea in the Eastern Adriatic Sea. *Vie Et Milieu-Life and Environment* 58, 237-41.

Lazar, B., Margaritoulis, D., Tvrtkovic, N. (2004b): Tag recoveries of the loggerhead sea turtle Caretta caretta in the eastern Adriatic Sea: implications for conservation. *Journal of the Marine Biological Association of the United Kingdom* 84, 475-80.

Lazar, B., Maslov, L., Romanić, S.H., Gračan, R., Krauthacker, B., Holcer, D., Tvrtković, N. (2011c): Accumulation of organochlorine contaminants in loggerhead sea turtles, Caretta caretta, from the eastern Adriatic Sea. *Chemosphere* 82, 121-9.

Lazar, B., Tvrtkovic, N. (1995): Marine turtles in the eastern part of the Adriatic Sea: preliminary research. *Natura Croatica* 4, 59-74.

Lazar, B., Tvrtkovic, N. (2003): Corroboration of the critical habitat hypothesis for the loggerhead sea turtle Caretta caretta in the eastern Adriatic Sea. In:
Proceedings of the First Mediterranean Conference on Marine Turtles. Barcelona Convention–Bern Convention–Bonn Convention (CMS), pp. 165-9.

Laza,r B., Z˘uljevic, A., Holcer, D. (2010): Diet composition of a green turtle, Chelonia mydas, from the Adriatic Sea. *Natura Croatica* 19, 263-71.

Lazar, B., Ziza, V., Tvrtkovic, N. (2006b): Interactions of gillnet fishery with loggerhead sea turtles Caretta caretta in the northern Adriatic Sea. In: *Book of Abstracts*, p. 252.

Leatherwood, S., Perrin, W.F., Kirby, V.L., Hubbs, C.L., Dahlheim, M. (1980): Distribution and movements of Risso's dolphin, *Grampus griseus*, in the eastern North Pacific. *Fishery Bulletin* 77, 951-63.

Lefkaditou, E., Poulopoulos, Y. (1998): Cephalopod remains in the stomach-content of beaked whales, *Ziphius cavirostris* (Cuvier 1823) from the Ionian Sea. In: *Rapport du 35e Congres de la Commision Internationale pour l'Exploration Scientifique de la Mer Mediterranee*, pp. 460–1. CIESM, Dubrovnik, Croatia.

Lenhardt, M. (1994): Seismic and very low frequency sound induced behaviors in captive loggerhead marine turtles (Caretta caretta). In: *Proceedings of the fourteenth annual symposium on sea turtle biology and conservation (KA Bjorndal, AB Bolten, DA Johnson & PJ Eliazar, eds.) NOAA Technical Memorandum, NMFSSEFC-351, National Technical Information Service, Springfield, Virginia*, pp. 238-41.

Lenhardt, M.L., Klinger, R., Musick, J. (1985): Marine turtle middle-ear anatomy. *The Journal of*

auditory research 25, 66-72. Levorsen, A. I. (1956): Geology of Petroleum. W. H. Freeman and

Company. 1-703.

Lewison, R.L., Freeman, S.A., Crowder, L.B. (2004) Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. *Ecology Letters* 7, 221-31.

Liberman, M.C. (2015): Noise-induced hearing loss: permanent vs. temporary threshold shifts and the effects of hair-cell vs. neuronal degeneration. In: *The effects of noise on aquatic life, II.* (eds. by Popper A & Hawkins AD). Springer, New York.

Lim, E.F.H., Ronalds, B.F. (2000): Evolution of the Production Semisubmersible, SPE paper 63036 presented at the 2000 SPE Annual Technical Conference and Exhibition held in Dallas, Texas, 1–4 October 2000.

Limpus, C., Chaloupka, M. (1997): Nonparametric regression modelling of green sea turtle growth rates (southern Great Barrier Reef). *Marine Ecology- Progress Series* 149, 23-34.

Limpus, C., Couper, P., Read, M. (1994): The green turtle, Chelonia mydas, in Queensland: Population structure in a warm temperature feeding area.
Memoirs of the Queensland Museum. Brisbane 35, 139-54.

Limpus, C., Limpus, D. (2003): Biology of the loggerhead turtle in western South Pacific Ocean foraging areas. *Loggerhead Sea Turtles* 1, 63-78.

Limpus, C.J., Limpus, D.J. (2001): The loggerhead turtle, Caretta caretta, in Queensland: breeding migrations and fidelity to a warm temperate feeding area.
Chelonian Conservation and Biology 4, 142-53.

Lipej, L., Dulčić, J., Kryštufek, B. (2004): On the occurrence of the fin whale (*Balaenoptera physalus*) in the northern Adriatic. *Journal of the Marine Biological Association of the United Kingdom* 84, 861-2.

Løkkeborg, S., Ona, E., Vold, A., Salthaug A. (2012): Effects of Sounds From Seismic Air Guns on Fish Behavior and Catch Rates. In: *The Effects of Noise on Aquatic Life* (eds. by Popper A & Hawkins A), pp. 415-9. Springer New York.

Lombarte, A., Popper, A.N. (1994): Quantitative analyses of postembryonic hair cell addition in the otolithic endorgans of the inner ear of the European hake, Merluccius merluccius (Gadiformes, Teleostei). *Journal of Comparative Neurology* 345, 419-28.

Lombarte, A., Yan, H.Y., Popper, A.N., Chang, J.S., Platt, C. (1993): Damage and regeneration of hair cell ciliary bundles in a fish ear following treatment with gentamicin. *Hearing Research* 64, 166-74.

Long, S. M., Holdway, D. A. (2002): Acute toxicity of crude and disperdes oil to Octopus pallidus (Hoyle, 1885) hatchlings. RMIT- University Water Research 36 (2002) 2769-2776, Victoria, Australia.

López-Mendilaharsu, M., Gardner, S.C., Seminoff, J.A. Riosmena-Rodriguez, R. (2005): Identifying critical foraging habitats of the green turtle (Chelonia mydas) along the Pacific coast of the Baja California peninsula, Mexico. *Aquatic Conservation: Marine and Freshwater Ecosystems* 15, 259-69.

Lovell, J.M., Findley, M.M., Moate, R.M., Yan, H.Y. (2005): The hearing abilities of the prawn *Palaemon serratus*. Comp. Biochem. Physiol. Part A 140:89- 100.

Loya, Y., Rinkevich, B. (1980): Effects of Oil Pollution on Coral Reef Communities. Department of Zoology, The George S. Wise Centre for Life Sciences, Tel-Aviv University. Tel-Aviv. Vol. 3: 167-180, 1980. Israel (http://ambergriscaye.com/art/pdfs/Effects_of_Oil_Pollution_on_Coral_Reef_Communities.pdf).

Lucke, K., Siebert, U., Lepper, P.A., Blanchet, M.A. (2009): Temporary shift in masked hearing thresholds in a harbor porpoise (Phocoena phocoena) after exposure to seismic airgun stimuli. *Journal of the Acoustical Society of America* 125, 4060-70.

Luschi, P., Mencacci, R., Vallini, C., Ligas, A., Lambardi, P., Benvenuti, S. (2013): Long-Term Tracking of Adult Loggerhead Turtles (Caretta caretta) in the Mediterranean Sea. *Journal of Herpetology* 47, 227-31.

Lusseau, D., Williams, R., Wilson, B., Grellier, K., Barton, T.R., Hammond, P.S., Thompson, P.M. (2004): Parallel influence of climate on the behaviour of Pacific killer whales and Atlantic bottlenose dolphins. *Ecology Letters* 7, 1068-76.

Luyeye, N. (2005): A review of the impacts of seismic surveying and toxicity of oil products on the early life history stages of pelagic fish, the benthos and the pelagic ecosystem with potential application to the sardinella fishery (Sardinella aurita) in the Angolan Waters. Project: LMR/CF/03/12: Benguela Current Large Marine Ecosystem Programme – INIP, Luanda, Angola.

Mackelworth, P., Fortuna, C.M., Holcer, D., Weimann, A., Giannoni, L., Lazar, B. (2003): The identification of critical habitats and the analysis of the management procedures for the future Lošinj-Cres marine protected area. p. 45. Blue World Institute, Veli Lošinj.

Mackelworth, P., Holcer, D. (2011): The Cres-Lošinj Special Marine Reserve – governance analysis. In: *Governing Marine Protected Areas: getting the balance right – Volume 2* (eds. by Jones PJS, Qiu W & De Santo EM), pp. 206- 22. Technical Report to Marine & Coastal Ecosystems Branch, UNEP, Nairobi.

Mackelworth, P., Holcer, D., Fortuna, C. (2013): Unbalanced governance: the Cres-Lošinj Special Marine Reserve, a missed conservation opportunity.
Marine Policy 41, 126-33.

Mackelworth, P., Holcer, D., Fortuna, C.M. (2002): The Cres-Lošinj Dolphin Reserve Kvarnerić, Northern Adriatic. Proposal for creation of Special Zoological Reserve. p. 8. Blue World Institute, Veli Lošinj.

MacLeod, C.D. (2005): Niche partitioning, distribution and competition in North Atlantic beaked whales. In: *School of Biological Sciences*, p. 238. University of Aberdeen, Aberdeen,UK.

MacLeod, C.D. (2006): How big is a beaked whale? A review of body length and sexual size dimorphism in the family Ziphiidae. *Journal of Cetacean Research and Management* 7, 301-8.

Malins, D. C. (1977): Effects of Petroleum on Arctic Environments and Organisms. Academic Press, Inc, New York.

Malvić, T., Đureković, M., Šikonja, Ž., Čogelja, Z., Ilijaš, T., Kruljac, I. (2011): Istraživačke i proizvodne aktivnosti u Sjevernom Jadranu (Hrvatska) kao primjer uspješnog zajedničkog ulaganja Ine (Hrvatska) i ENI-ja (Italija), Nafta 62 (9-10), 293-296 (2011).

Mañosa, S., Oro, D., Ruiz, X. (2004): Activity patterns and foraging behaviour of Audouin's gulls at the Ebro Delta, NW Mediterranean. Scientia Marina 68: 605-614.

Marasović, I., Peharda, M., Vrgoč, N., Ezgeta, D. (2007): Stanje prirodnih populacija školjkaša istočne obale Jadrana, Institut za oceanografiju i ribarstvo, Split. (http://www.provincia.ferrara.it/download/4-Daria_HR%20.pdf?server=sd2.provincia.fe.it&db=/intranet/internet.nsf&uid=68BC81A6F6E3E89AC12574DA004CA996)

Marić Đureković, Ž. (2011): Litofacijesne i stratigrafske značajke pleistocenskih naslaga sjevernoga Jadrana na temelju visokorazlučivih karotažnih mjerenja. Disertacija. Sveučilište u Zagrebu. Rudarsko-geološko-naftni fakultet. 1-143.

Mattavelli, L., Pieri, M., Groppi, G. (1993): Petroleum exploaration in Italy: a review. Marine and Petroleum Geology, 10, 410-425.

Margaritoulis, D., Argano, R., Baran, I., Bentivegna, F., Bradai, M., Camiñas, J.A., Casale, P., De Metrio, G., Demetropoulos, A., Gerosa, G. (2003): Loggerhead turtles in the Mediterranean Sea: present knowledge and conservation perspectives. In: *Loggerhead Sea Turtles (editors: AB Bolten, BE Witherington). Smithsonian Institution Press, Washington DC* (eds. by Bolten A & Witherington B).

Margaritoulis, D., Teneketzis, K. (2001): Identification of a developmental habitat of the green turtle in Lakonikos Bay, Greece. In: *First Mediterranean conference on marine turtles*, p. 170.

Maritime Communication Services, Inc. (2008): Strategic Environmental Assessment (SEA) Concerning Hydrocarbon Activities within the Exclusive Economic Zone of the Republic of Cyprus, 15 November 2008.

Matanović, D., Moslavac, B. (2011): Opremanje i održavanje bušotina. Sveučilišni udžbenik. Sveučilište u Zagrebu. Rudarsko-geološko-naftni fakultet. Zagreb.

Mazzariol, S., Di Guardo, G., Petrella, A., Marsili, L., Fossi, C.M., Leonzio, C., Zizzo, N., Vizzini, S., Gaspari, S., Pavan, G., Podestà, M., Garibaldi, F., Ferrante, M., Copat, C., Traversa, D., Marcer, F., Airoldi, S., Frantzis, A., De Bernaldo, Quirós, Y., Cozzi, B., Fernández, A. (2011) Sometimes sperm whales (*Physeter macrocephalus*) cannot find their way back to the high seas: a multidisciplinary study on a mass stranding. *PLoS ONE* 6, e19417.

McCauley, R.D., Cato D. H., Jeffrey A. F. (1996): A study of the impacts of vessel noise on humpback whales in Hervey Bay. Prepared for the Queensland Department of Environment and Heritage, Maryborough Branch.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M-N., Penrose1, J.D., Prince R.I.T., Adhitya, A., Murdoch, J., McCabe, K. (2000): Marine seismic surveys - a study of environmental implications. Appea Journal, 692-708.

McCauley, R.D., Production, A.P., Association, E. (2000): *Marine seismic surveys: a study of environmental implications*. Australian Petroleum Production and Exploration Association.

McKinstry, C.A., Carlson, T.J., Brown, R.S. (2007): *Derivation of a mortal injury metric for studies of rapid decompression of depth-acclimated physostomous fish*. Pacific Northwest National Laboratory Richland, Washington.

Melton, H.R., Smith, J.P., Mairs, H.L., Bernier, R.F., Garland, E., Glickman, A.H., Jones, F.V., Ray, J.P., Thomas, D., Campbell, J.A. (2004): Environmental Aspects of the Use and Disposal of Non-aqueous Drilling fluids Associated with Offshore Oil&Gas Operations, SPE 86696, The Seventh SPE International Conference on Health, safety, and Environment in Oil and Gas Exploration and production, pp. 1-10, Calgary, Alberta, Canada, 2004.

Menichetti, M., Mencucci, D., Colantoni, P., Nesci, O. (2006): The Northern Apennines and Dinarides and Adria concept. In: MENICHETTI, M.
&MENCUCCI, D. (Eds.): Adria 2006, International Geological Congress on the Adriatic area. Field trip Guide, University of Urbino „Carlo Bo", 10-14.

MGRH (2014): Odluka o provođenju postupka strateške procjene utjecaja na okoliš Okvirnog plana i programa istraživanja i eksploatacije ugljikovodika na Jadranu. (ed. by RH Mg), Zagreb.

Miller P.J. (2006): Diversity in sound pressure levels and estimated active space of resident killer whale vocalizations. *Journal of Comparative Physiology A*

192, 449-59.
Milić, S., Kadija, S., Runjić, Š., Dmitrović, G. (1981): Otkrivanje komercijalnih zaliha plina u mezozojskim kolektorima Jadranskog podzemlja. Zbornik radova simp. „Kompleksna naftno-geološka problematika podzemlja i priobalnih dijelova Jadranskog mora", Split (1981), 1, 239-246.

Miller, I., Cripps, E. (2013): Three dimensional marine seismic survey has no measurable effect on species richness or abundance of a coral reef associated fish community. Marine Pollution Bulletin, 77, 63–70.

Milišić, N. (2000): Glavonošći- divna i čudesna morska bića,

Marjan knjiga. Split. Milišić, N. (2008.): Enciklopedija jadranskih

koralja. Marjan tisak, Split.

Minerals Management Service (MMS) (2000): Gulf of Mexico Deepwater Operations and Activities: Environmental Assessment. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS EIS/EA MMS 2000-001.

Minerals Management Service (MMS) (2005a): Structure removal operations on the Gulf of Mexico outer continental shelf: Programmatic environmental assessment. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS EIS/EA MMS 2005-013.

Minerals Management Service (MMS) (2007b): Gulf of Mexico OCS Oil and Gas Lease Sales: 2007- 2012. Western Planning Area Sales 204, 207, 210, 215, and 218; Central Planning Area Sales 205, 206, 208, 213, 216, and 222. Final Environmental Impact Statement. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. OCS EIS/EA MMS 2007-018. April 2007.

Minerals Management Service (MMS) (2008): Mobile Offshore Drilling Unit. U.S. Department of the Interior, Minerals Management Service, Herndon, VA.

Mingozzi, T., Masciari, G., Paolillo, G., Pisani, B., Russo, M., Massolo, A. (2008): Discovery of a regular nesting area of loggerhead turtle Caretta caretta in southern Italy: a new perspective for national conservation. In: *Biodiversity and Conservation in Europe* (pp. 277-99. Springer.
Ministarstvo kulture RH (2006): Rješenje o preventivnoj zaštiti dijela mora uz istočne obale otoka Cresa i Lošinja u kategoriji posebnog rezervata - rezervata u moru.

Moein, S., Musick, J., Keinath, J., Barnard, D., Lenhardt, M., George, R. (1994): Evaluation of seismic sources for repelling sea turtles from hopper dredges.
Report for US Army Corps of Engineers, from Virginia Institute of Marine Science, VA USA.

Mohl, B., Wahlberg, M., Madsen, P.T., Heerfordt, A., Lund, A. (2003): The monopulsed nature of sperm whale clicks. *Journal of the Acoustical Society of America* 114, 1143-54.

Mooney, T.A., Hanlon, R., Madsen, P.T., Christensen-Dalsgaard, J., Ketten, D.R., Nachtigall, P.E. (2012): Potential for sound sensitivity in cephalopods. In:
The Effects of Noise on Aquatic Life (pp. 125-8. Springer.

Mooney, T.A., Nachtigall, P.E., Breese, M., Vlachos, S., Au, W.W. (2009): Predicting temporary threshold shifts in a bottlenose dolphin (Tursiops truncatus): The effects of noise level and duration. *The Journal of the Acoustical Society of America* 125, 1816-26.

Mortimer, J. (1982): Feeding ecology of sea turtles. *Biology and Conservation of Sea Turtles. Smithsonian Institute Press, Washington, DC*.

Moulins, A., Rosso, M., Nani, B., Wurtz, M. (2007): Aspects of the distribution of Cuvier's beaked whale (*Ziphius cavirostris*) in relation to topographic features in the Pelagos Sanctuary (north-western Mediterranean Sea). *Journal of the Marine Biological Association of the United Kingdom* 87, 177-86.

Mora, R., Penco, S., Guastini, L. (2011): The Effect of Sonar on Human Hearing, Sonar Systems, Prof. Nikolai Kolev (Ed.), ISBN: 978-953-307-345-3, InTech, Available from: http://www.intechopen.com/books/sonar-systems/the-effect-of-sonar-on-human-hearing

Martin, K.J., Alessi, S.C., GaspardJ.C.,Tucker A.D., Bauer G.B., Mann D.A. (2012): Under water hearing in the logger head turtle(Caretta caretta):acomparisonofbehavioralandauditory evokedpotential audiograms.J Exp Biol215, 3001-3009.

Murray, A. S., Tracey, R. M. (2001): Best practice in gravitiy surveying. Geoscience Australia.

Musick, J.A., Limpus, C.J., Lutz, P., Musick, J. (1997): Habitat utilization and migration in juvenile sea turtles. *The biology of sea turtles* 1, 137-63.

Myrberg Jr A.A. (2001): The acoustical biology of elasmobranchs. *Environmental Biology of Fishes* 60, 31-46.

MZOS (2014): Zastupničko pitanje dr.sc. Mirele Holy, u vezi sa seizmičkim istraživanjima Jadrana od strane tvrtke Spectrum - odgovor. (ed. by Ministarstvo znanosti oisR), Zagreb.

Nachtigall, P.E., Pawloski, J.L., Au, W.W. (2003): Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (Tursiops truncatus). *The Journal of the Acoustical Society of America* 113, 3425-9.

Nachtigall, P.E., Supin, A.Y., Pawloski, J., Au, W.W.L. (2004): Temporary threshold shifts after noise exposure in the bottlenose dolphin (Tursiops truncatus) measured using evoked auditory potentials. *Marine Mammal Science* 20, 673-87.

Natoli, A., Birkun, A., Aguilar, A., Lopez, A., Hoelzel, A.R. (2005): Habitat structure and the dispersal of male and female bottlenose dolphins (*Tursiops truncatus*). *Proceedings of the Royal Society B-Biological Sciences* 272, 1217-26.

Neff, J.M., McKelvie, S., Ayers, R.C. Jr. (2000): Environmental impacts of synthetic based drilling fluids. Report prepared by Robert Ayers & Associates, Inc.
U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2000-064. 118 pp.

Neff, J.M. (1986) Histopathologic and Biochemical Responses in Arctic Marine Bivalve Molluscs Exposed to Experimentally Spilled Oil, Artic 40 , SUPP. 1 (1987)P.220-229.

Neff, J.M. (2002): Bioaccumulation in marine organisms. Effects of contaminants from oil well produced water. Elsevier, London.

Neff. J.M. (2005): Composition, Environmental Fates, and Biological Effect of water Based Drilling Muds And Cuttings Discharged to the Marine Environment: A Synthesis and Annotated Bibliography, prepared for petroleum Environmental Research Forum (PERF) and American Petroleum Institute, Battelle, The Business of Innovation, Duxbury, MA, January 2005.

Nieukirk, S.L., Mellinger, D.K., Moore, S.E., Klinck, K., Dziak, R.P., Goslin, J. (2012): Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999–2009. *The Journal of the Acoustical Society of America* 131, 1102-12.

Nieukirk, S.L., Stafford, K.M., Mellinger, D.K., Dziak, R.P., Fox, C.G. (2004): Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. *The Journal of the Acoustical Society of America* 115, 1832-43.

Nimak-Wood, M., Pleslić, G., Rako, N., Mackelworth, P., Holcer, D., Fortuna, C.M. (2011): Presence of a solitary striped dolphin (*Stenella coeruleoalba*) in Mali Lošinj harbour, northern Adriatic sea, Croatia. *Vie et Milieu* 61, 87-93.

Normandeau Associates Inc (2012): Effects of noise on fish, fisheries, and invertebrates in the U.S. Atlantic and Arctic from energy industry sound- generating activities. Workshop Report. p. 361. U.S. Dept. of the Interior, Bureau of Ocean Energy Management.

Notarbartolo di Sciara G. (2002): Cetacean species occurring in the Mediterranean and Black Seas. In: Cetaceans of the Mediterranean and Black Seas: state ofknowledge andconservation strategies.Section 3.A report to the ACCOBAMS InterimSecretariat.

Notarbartolo-Di-Sciara, G., Zanardelli, M., Jahoda, M., Panigada, S., Airoldi, S. (2003): The fin whale *Balaenoptera physalus* (L. 1758) in the Mediterranean Sea. *Mammal Review* 33, 105-50.

Notarbartolo di Sciara, G., Bearzi, G. (1992): Cetaceans in the northern Adriatic Sea: past, present, and future. *Rapport Commisione Internationale Mer Méditerranée* 33, 303.

Notarbartolo di Sciara, G., Birkun, A. (2010): *Conserving whales, dolphins and porpoises in the Mediterranean and Black Seas: an ACCOBAMS status report*. ACCOBAMS, Monaco.

Notarbartolo di Sciara, G., Holcer, D., Bearzi, G. (1994): Past and present status of cetaceans in the northern and central Adriatic Sea. In: *Proceeding of Abstracts of the 5th Congress of biologists of Croatia* (ed. by Gomerčić H), pp. 401-2. Croatian Biological Society, Pula, Croatia.

Notarbartolo Di Sciara, G.N., Venturino, M.C., Zanardelli, M., Bearzi, G., Borsani, F.J., Cavalloni, B. (1993): Cetaceans in the Central Mediterranean Sea - distribution and sighting frequencies. *Bollettino di zoologia* 60, 131-8.

Nowacek, D.P., Bröker, K., Donovan, G.P., Gailey, G., Racca, R., Reeves, R.R. (2013): Responsible Practices for Minimizing and Monitoring Environmental Impacts of Marine Seismic Surveys with an Emphasis on Marine Mammals. *Acquatic Mammals* 39, 356-77.

Nowacek, D.P., Thorne, L.H., Johnston, D.W., Tyack, P.L. (2007): Responses of cetaceans to anthropogenic noise. *Mammal Review* 37, 81-115.

Nowacek, S. M., Wells, R. S., Solow, A. R. (2001): Short-term effects of boat traffic on bottlenose dolphins, tursiops truncatus, in sarasota bay, Florida.
Marine Mammal Science,*17*(4), 673-688.

NRC (2003): Ocean noise and marine mammals. (ed. by Council NR). NRC, Washington DC.

NRC (2005): Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant

Effects. National Academies Press. O'Hara, J. Wilcox, J. (1990): Responses of loggerhead sea turtles, Caretta caretta, to

low frequency sound. *Copeia* 199, 564–7.

OIKON Institut za primijenjenu ekologiju (2011): Elaborat o utjecaju zahvata na okoliš za izgradnju novih platformi na postojećem polju za eksploataciju ugljikovodika „Sjeverni Jadran", Zagreb, studeni 2011.

OIKON Institut za primjenjenu ekologiju (2012): Studija korištenja i zaštite mora i podzemlja na području Splitsko-dalmatinske županije, s naglaskom na djelatnost MARIKULTURE, u multisektorskom kontekstu Integralnog upravljanja obalnim područjem (IUOP), Zagreb, travanj 2012.

O'Brien, P. Y., Dixon, P. S. (2007): The effects of oils and oil components on algae: A review, Department of Ecology and Evolutionary Biology, and Water Resources Laboratory, School of Engineering , University of California , Irvine, Ca., 92717, U.S.A.

Olsen, K. M., Larsson, H. (2004): Gulls of Europe, Asia and North America. Christopher Helm, London.

Olsgard, F., Gray, J.S. (1995): A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf, Section of Marine Zoology and Marine Chemistry, Department of Biology, University of Oslo, PO Box 1064, N-0316 Oslo, Norway.

Palsboll, P.J., Berube, M., Aguilar, A., Notarbartolo-Di-Sciara, G., Nielsen, R. (2004): Discerning between recurrent gene flow and recent divergence under a finite-site mutation model applied to North Atlantic and Mediterranean Sea fin whale (*Balaenoptera physalus*) populations. *Evolution* 58, 670-5.

Panigada, S., Lauriano, G., Burt, L., Pierantonio, N., Donovan, G. (2011): Monitoring winter and summer abundance of cetaceans in the Pelagos Sanctuary (northwestern Mediterranean Sea) through aerial surveys. *PLoS ONE* 6, e22878.

Panigada, S., Notarbartolo di Sciara, G. (2012): *Balaenoptera physalus* (Mediterranean subpopulation). URL http://www.iucnredlist.org/.

Parks, S.E., Johnson, M., Nowacek, D., Tyack, P.L. (2011): Individual right whales call louder in increased environmental noise. *Biology Letters* 7, 33-5.

Parrish, J.K. (2004): Behavioral approaches to marine conservation. In: *Marine Conservation Biology* (eds. by E.A. N & B.L. C), pp. 80-104. Island press, Washington.

Parsons, E., Dolman, S.J., Jasny, M., Rose, N.A., Simmonds, M.P., Wright, A.J. (2009): A critique of the UK's JNCC seismic survey guidelines for minimising acoustic disturbance to marine mammals: Best practise? *Marine Pollution Bulletin* 58, 643-51.

Pastorelli, A., Rositani, L., Vlora, A., Zizzo, N. (1999): Segnalazioni di tartarughe lungo le coste Pugliesi nel periodo 1978-1998: caratteristiche morfometriche. *Rivista di idrobiologia* 38, 129-39.

Patin, S. (1999): Environmental Impact of the Offshore Oil and Gas Industry. Ecomonitor Pub; 1 edition (December 1, 1999)

Paulsen, J.E., Omland, TH., Igeltjorn, H., Aas, N., Solvang, S.A. (2003): Drill Cuttings Disposal, Balancing Zero Discharge and Use of Best Available Technique, SPE/IADC 85296, SPE/IADC Middle East Drilling Technology Conference&Exhibition, pp.1-11, Abu Dhabi, UAE, 2003.

Payne, J.F., C.A. Andrews, L.L. Fancey, A.L. Cook, i J.R. Christian. 2007. Pilot study on the effects of seismic air gun noise on lobster (*Homarus americanus*). Fisheries and Oceans Canada, Can. Tech. Rep. Fish. Aquat. Sci. No. 2712.

Pegarda Uljević, M., Krstulović Šifner, S., Dadić, V., Isajlović, I., Ezgeta, D., Marušić, I., Vlahović, V., Bašković, D. (2008.): Evaluacija raspodjele i trenutnog stanja prirodnih zajednica školjkaša u demonstracijskom području u Zadarskoj županiji i prijedlozi za njihovu održivu eksploataciju- finalno izvješće, Institut za oceanografiju i ribarstvo, UNDP- Coast projekt (http://www.undp.hr/upload/file/228/114196/FILENAME/46_07D_2.PDF)

Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O., Dorémus, G., Huon, M., Ridoux, V. (2012): The significance of stranding data as indicators of cetacean populations at sea: Modelling the drift of cetacean carcasses. *Ecological Indicators* 18, 278-90.

Peljar, I. (1999): Jadransko more – istočna obala, IV izdanje. Hrvatski hidrografski institut, Split, 1-496.

Pigorini, B. (1967): Aspetti sedimentologici del mare Adriatico. Istituto di Mineralogiae Petrografia

dell' Uviversita di Pavia. Pilleri, G., Gihr, M. (1977): Some records of cetaceans in the Northern

Adriatic Sea. *Investigations on Cetacea* 8, 85-8.

Piniak, W.E.D., Mann, D.A., Eckert, S.A., Harms, C.A. (2012): Amphibious hearing in sea turtles. In: *The effects of noise on aquatic life* (pp. 83-7. Springer.

Pino d'Astore, P., Bearzi, B., Bonizzoni, S. (2008): Cetacean strandings in the province of Brindisi (Italy, southern Adriatic sea). *Annales, Series Historia Naturalis* 18, 29-38.

Pleslić, G., Rako-Gospić, N., Mackelworth, C.P., Wiemann, A., Holcer, D., & Fortuna, C.M. (2014): How many bottlenose dolphins (*Tursiops truncatus*) inhabit the former Cres-Lošinj Special Marine Reserve, Croatia? *European Research on Cetaceans* 28.

Pleslić, G., Rako, N., Mackelworth, C.P., Wiemann, A., Holcer, D., Fortuna, C.M. (2013): The abundance of common bottlenose dolphins (*Tursiops truncatus*) in the former marine protected area of the Cres-Lošinj archipelago, Croatia. *Aquatic Conservation: Marine and Freshwater Ecosystems.*

Podestà, M., D'amico, A., Pavan, G., Drougas, A., Komnenou, A., Portunato, N. (2006): A review of Cuvier's beaked whale strandings in the Mediterranean Sea. *Journal of Cetacean Research and Management* 7, 251-61.

Podestà, M., Meotti, C. (1991): The stomach contents of a Cuvier's beaked whale *Ziphius cavirostris*, and a Risso's dolphin *Grampus griseus*, stranded in Italy. In: *Fifth Annual Conference of the European Cetacean Society* (ed. by Evans PGH), pp. 58–61. European Cetacean Society, Sandefjord, Norway.

Popper, A.N., Fewtrell, J., Smith, M.E., McCauley, R.D. (2003): Anthropogenic sound: Effects on the behavior and physiology of fishes. *Marine Technology Society Journal* 37, 35-40.

Popper, A.N., Hawkins, A. (2011): *The effects of noise on aquatic life*. Springer.

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., & Halvorsen, M.B. (2014a): Sound Exposure Guidelines for Fishes and Sea Turtles. In: *ASA S3/SC1. 4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI* (pp. 33-51. Springer.

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., Halvorsen, M.B., Lokkeborg, S., Rogers, P.H., Southall, B.L., Zeddies, D.G., & Tavolga, W.N. (2014b): *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. Springer.

Popper, A.N., &Hoxter, B. (1984): Growth of a fish ear: 1. Quantitative analysis of hair cell and ganglion cell proliferation. *Hearing Research* 15, 133-42. Popper, A.N., Plachta, D.T.T., Mann, D.A., Higgs, D. (2004): Response of clupeid fish to ultrasound: a review. *ICES Journal of Marine Science* 61, 1057-61. Praca, E., Gannier, A. (2008): Ecological niches of three teuthophageous odontocetes in the northwestern Mediterranean Sea. *Ocean Science* 4, 49-59.

Prelogović, E., Kranjec, V. (1983): Geološki razvitak Jadranskog mora. Pomorski zbornik, 21/83, 387-405, Rijeka.

Pugh, R.S., Becker, P.R. (2001): *Sea turtle contaminants: A review with annotated bibliography*. US Department of Commerce, National Institute of Standards and Technology.

Rabke, S.P., K. Satterlee, C. Johnston, L. Henry, S. Wilson, T. Sharpe, and J. Ray. (2003): Achieving regulatory compliance with synthetic-based drilling fluids. SPE 80588. Society of Petroleum Engineers, Inc. Richardson, TX. 10 pp.

Rako, N., Fortuna, C.M., Holcer, D., Mackelworth, P., Nimak-Wood, M., Pleslić, G., Sebastianutto, L., Vilibić, I., Wiemann, A., & Picciulin, M. (2013): Leisure boating noise as a trigger for the displacement of the bottlenose dolphins of the Cres–Lošinj archipelago (northern Adriatic Sea, Croatia). *Marine Pollution Bulletin* 68, 77-84.

Rako, N., Fortuna, C.M., Mackelworth, P., Picciulin, M., Wiemann, A., Holcer, D. (2007): Anthropogenic noise and its impact on bottlenose dolphin (Tursiops truncatus) distribution in the Lošinj dolphin reserve (Croatia). In: *21st Conference of the European Cetacean Society*, p. 152, San Sebastian, Spain.

Rako, N., Holcer, D., Fortuna, C.M. (2009): Long-term inshore observation of a solitary striped dolphin, *Stenella coeruleoalba,* in the Vinodol Channel, northern Adriatic Sea (Croatia). *Natura Croatica* 18, 427-36.

Rako, N., Picciulin, M., Mackelworth, C.P., Holcer, D., & Fortuna, C.M. (2012): Long-term monitoring of anthropogenic noise and its relationship to bottlenose dolphin (*Tursiops truncatus*) distribution in the Cres–Lošinj archipelago, northern Adriatic, Croatia. In: *The Effects of Noise on Aquatic Life* (eds. by Popper AN & Hawkins A), pp. 323-5. Springer, Dordrecht.

Rees, A.F., Saad, A., Jony, M. (2008): Discovery of a regionally important green turtle Chelonia mydas rookery in Syria. *Oryx* 42, 456-9.

Regg, J.B., Atkins, S.,Hauser, B., Hennessey, J., Kruse, B.J.,Lowenhaupt, J. , Smith, B., White, A. (2000): Deepwater development: A reference document for the deepwater environmental assessment Gulf of Mexico OCS (1998 through 2007). OCS Report MMS 2000-015. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.

Revelli, E., Pusser, T., Bocconcelli, A., Ballardini, M., Sturlese, A., Johnson, M.P. (2008): Photoidentification catalog of Cuvier's beaked whale (*Ziphius cavirostris*) in the Ligurian Sea. URL http://hdl.handle.net/1912/2165.

Reynolds, J.E. (2005): *Marine mammal research: conservation beyond crisis*. JHU Press.

Rico-Martínez, R. i dr. (2013.) Synergistic toxicity of Macondo crude oil and dispersant Corexit 9500A® to the Brachionus plicatilis species complex (Rotifera), Environmental Pollution,Volume 173, February 2013, str 5–10.

Richardson, W., Greene, C.J., Malme, C., Thomson, D. (1995): *Marine Mammals and Noise*. Academic Press, San Diego.

Ridgway, S.H., Carter, D.A., Smith, R.R., Kamolnick, T., & Schlundt, C.E. (1997): Behavioral Responses and Temporary Shift in Masked Hearing Threshold of Bottlenose Dolphins, Tursiops truncatus, to 1- second Tones of 141 to 201 dB re 1 Micron Pa. DTIC Document.

Ridgway, S.H., Weve,r E.G., McCormick, J.G., Palin, J., & Anderson, J.H. (1969): Hearing in the giant sea turtle, Chelonia mydas. *Proceedings of the National Academy of Sciences* 64, 884-90.

Rodríguez-Trigoa, G., Zockb, J. P., Montes, I. I. (2007): Health Effects of Exposure to Oil Spills. *Journal of Epidemiol Community Health*

1999;53:306-310 doi:10.1136/jech.53.5.306.

Rosso, A., Moulins, A., Ballardini, M., Gelsomino, F., & Wurtz, M. (2007): Preliminary estimation of the population size of Cuvier's beaked whale (*Ziphius cavirostris*) in the northern Ligurian sea. *Rapp. Comm. int. Mer Médit* 38, 582.

Rosso, M., Ballardini, M., Moulins, A., Würtz, M. (2011): Natural markings of Cuvier's beaked whale *Ziphius cavirostris* in the Mediterranean Sea. *African Journal of Marine Science* 33, 45-57.

Roussel, E. (2002): *Disturbance to Mediterranean cetaceans caused by noise*. ACCOBAMS. https://www.gomr.mms.gov/PDFs/2000/2000-015.pdf

Russell, R.W. (2005): Interactions between migrating birds and offshore oil and gas platforms in the northern Gulf of Mexico: Final Report. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2005-009. 348 pp.

Sabatino, N., Vlahović, I., Jenkyns, H. C., Scopelliti, G., Neri, R., Prtoljan, B., Velić, I. (2013): Carbon-isotope record and palaeoenvironmental changes during the early Toarcian oceanic anoxic event in shallow-marine carbonates of the Adriatic Carbonate Platform in Croatia.– Geological magazine, 150/6; 1085-1102.

Satterlee, K., Smith, D.L., Barringer, J.J., Blythe, B.J., Brzuzy, L.P. i dr. (2011): Subsea Drilling, Well Operations and Completions, Paper #2-11, Working Document of the NPC North American Resource Development Study Made Available September 15, 2011.

Sanpera, C.; Ruiz, X.; Moreno, R.; Jover, L.; Waldron, S. 2007. Mercury and stable isotopes in feathers of Audouin's Gulls as indicators of feeding habits and migratory connectivity. Condor 109(2): 268-275.

Santulli, A., Messina, C., Ceffa, L., Curatolo, A., Rivas, G., Fabi, G., Amelio, V. (1999): Biochemical responses of European sea bass (*Dicentrachus labrax*) to the stress induced by offshore experimental seismic prospecting. Marine Pollution Bulletin 38:1105-1114.

Scandpower Risk Management Inc. (2004): An Assessment of Safety, Risks and CostsAssociated withSubsea Pipeline Disposals. Report for the U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. Report No. 32.701.001/R1. September 2004.

Schlumberger (2008a): Oilfield glossary.

Schlumberger (2008b): EverGreen burner.

Schofield, G., Dimadi, A., Fossette, S., Katselidis, K.A., Koutsoubas, D., Lilley, M.K., Luckman, A., Pantis, J.D., Karagouni, A.D., Hays, G.C. (2013): Satellite tracking large numbers of individuals to infer population level dispersal and core areas for the protection of an endangered species. *Diversity and Distributions* 19, 834-44.

Schofield, G., Hobson, V.J., Fossette, S., Lilley, M.K., Katselidis, K.A., Hays, G.C. (2010): Biodiversity Research: fidelity to foraging sites, consistency of migration routes and habitat modulation of home range by sea turtles. *Diversity and Distributions* 16, 840-53.

Schofield, G., Lilley, M.K., Bishop, C.M., Brown, P., Katselidis, K.A., Dimopoulos, P., Pantis, J.D., Hays, G.C. (2009): Conservation hotspots: implications of intense spatial area use by breeding male and female loggerheads at the Mediterranean's largest rookery. *Endangered Species Research* 10, 191-202.

Schuck, J.B., Smith, M.E. (2009): Cell proliferation follows acoustically-induced hair cell bundle loss in the zebrafish saccule. *Hearing Research* 253, 67-76.

Segawa, J., Joseph J. E., Nakayama, E., Kumar, V. K., Kusumoto, S., Ito, T., Sekizaki, S., Ishihara, T., Komazawa, M. (2005): Application of Gravimetry by Helicopter to Identify Marine Active Faults and Improve Accuracy of Geoid at Coastal Zones. International Association of Geodesy Symposia Volume 128, 229-235.

Sella, I. (1995): Sea turtles in the Eastern Mediterranean and northern Red Sea. In: *Biology and conservation of sea turtles* (ed. by Bjorndal KA), pp. 417-23. Smithsonian Institution Press, Washington D.C.

Serena, F., Barone, M. (2009): Report on the Cartilagenous Fishes in Slovenia, Croatia, Bosnia & Herzegovina and Montenegro: Proposal of a Sub- Regional Working Programme to Support the Implementation of the Regional Action Plan. p. 68. UNEP RAC/SPA, Tunis.

Shinn, E.A., Lidz, B.H., Reich, C.D., (1993): Habitat impacts of offshore drilling: Eastern Gulf of Mexico. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 93-0021. 73 pp.

Shumway, S., Parsons., J. (2006): Scallops: Biology, Ecology and Aquaculture. Elsevier. 2nd Edition. Elsevier Science Publisher. 1500 pp

Sil, A., Wakadikar, K., Kumar, S., Babu, S. S., Sivagami, S. P. M., Tandon, S., Kumar, R., Hettiaratchi, P. (2012): Toxicity Characteristics of Drilling Mud and Its Effect on Aquatic Fish Populations, Journal of Hazardous, Toxic and Radioactive Waste 16:51-57.

Sinovčić, G., Zorica, B., Čikeš Keč, V., Mustać, B. (2009): Innter-annual fluctuations of the population structure, condition, length-weight relationship and abundance of sardine, *Sardina Pilchardus* (Walb., 1792), in the nursery and spawning ground (coastal and open sea waters) of the eastern Adriatic Sea (Croatia). Acta Adriatica, 50 (1): 11-22, 2009.

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C., Popper, A.N. (2010): A noisy spring: the impact of globally rising underwater sound levels on fish. *Trends in Ecology & Evolution* 25, 419-27.

Smith, M.E. (2012): Predicting hearing loss in fishes. In: *The Effects of Noise on Aquatic Life* (pp. 259-62. Springer.

Smith, M.E. (2015): The relationship between hair cell loss and hearing in fishes. In: *The effects of noise on aquatic life, II.* (eds. by Popper A & Hawkins AD). Springer, New York.

Smith, M.E., Coffin, A.B., Miller, D.L., Popper, A.N. (2006): Anatomical and functional recovery of the goldfish (Carassius auratus) ear following noise exposure. *Journal of Experimental Biology* 209, 4193-202.

Smith, M.E., Schuck, J.B., Gilley, R.R., Rogers, B.D. (2011): Structural and functional effects of acoustic exposure in goldfish: evidence for tonotopy in the teleost saccule. *BMC Neuroscience* 12, 19.

Smodlaka, N., Batel, R., Bihari, N., Degobbis, D., Đakovac, T., Janeković, I., Travizi, A. (2009): The study of impact of drilling material on the sea (final report), Ruđer Bošković Institute, Center for Marine Research, Rovinj, January 2009.

Soldo, A., Dulcic, J. (2005): New record of a great white shark, Carcharodon carcharias (Lamnidae) from the eastern Adriatic

Sea. *Cybium* 29, 89-90.

Soldo, A., Jardas, I. (2002): Occurrence of great white shark, Carcharodon carcharias (Linnaeus, 1758) and basking shark, Cetorhinus maximus (Gunnerus, 1758) in the Eastern Adriatic and their protection. *Periodicum biologorum* 104, 195-201.

Soldo, A., Lucic, D., Jardas, I. (2008): Basking shark (Cetorhinus maximus) occurrence in relation to zooplankton abundance in the eastern Adriatic Sea.
Cybium 32, 103-9.

Sorensen, P.W., Medved, R.J., Hyman, M.A. Winn, H.E. (1984): Distribution and abundance of cetaceans in the vicinity of human activities along the continental shelf of the northwestern Atlantic. *Marine Environmental Research* 12, 69-81.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene, Jr C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., Tyack, P.L. (2007): Marine mammal noise-exposure criteria: initial scientific recommendations. *Aquatic Mammals* 33, 1-121.

Stanley, D.R., Wilson., C.A. (2000): Seasonal and spatial variation in the biomass and size frequency distribution of fish associated with oil and gas platforms in the northern Gulf of Mexico. Final report for the U.S. Department of the Interior, Minerals Management Service Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2000-005.

Stanzani, L., Piermarocchi, C. (1992): Cattura di alcuni individui di *Pseudorca crassidens* (Owen, 1846) in Adriatico. *Atti della Societa Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano* 133, 85-95.

Stephenson, J.R., Gingerich, A.J., Brown, R.S., Pflugrath, B.D., Deng, Z., Carlson, T.J., Langeslay, M.J., Ahmann, M.L., Johnson, R.L., Seaburg, A.G. (2010): Assessing barotrauma in neutrally and negatively buoyant juvenile salmonids exposed to simulated hydro-turbine passage using a mobile aquatic barotrauma laboratory. *Fisheries Research* 106, 271-8.

Stewart (2006): Introduction to physical oceanography, Department of Oceanography , Texas A & M University

Stipčević, M, Lukač, G. (2001): Status of tubenose seabirds Procellariiformes breeding in the eastern Adriatic. Acrocephalus 22(104–105): 9–21.

Storelli, M.M., Zizzo, N., Marcotrigiano ,G.O. (1999): Heavy metals and methylmercury in tissues of Risso's dolphin (*Grampus griseus*) and Cuvier's beaked whale (*Ziphius cavirostris*) stranded in Italy (South Adriatic Sea). *Bulletin of Environmental Contamination and Toxicology* 63, 703-10.

Strachan, M.F. (2010.) Studies on the Impact of a Water-based Drilling Mud Weighting Agent (Barite) on some Benthic Invertebrates, doktorska disertacija, Heriot-Watt University, School of Life Sciences

Stumberger, B., Schneider-Jacoby, M. (2010): Importance of the Adriatic Flyway for Common Crane (Grus grus). In Proc. 7th European Crane Conference, October (pp. 14-17).

Suarez, R. C. (2001): Advanced marine seismic methods: Ocean-bottom and vertical-cable analyses. ProQuest Dissertations And Theses; Thesis (Ph.D.)-- University of Calgary (Canada), 2000.; Publication Number: AAINQ49533; ISBN: 9780612495333; Source: Dissertation Abstracts International, Volume: 61- 05, Section: B, page: 2439.; 206.

Sultana, J., Borg, J. J. (2006): Population ecology and conservation of the Cory's Shearwater Calonectris diomedea. *ON THE MEDITERRANEAN ACTION PLAN FOR THE CONSERVATION OF MARINE AND COASTAL BIRDS*, 37.

Supic, N., Orlic, M. (1992): Annual cycle of sea surface temperature along the east Adriatic coast.

Geofizika 9, 79-97. Šumanovac, F. (2012): Osnove geofizičkih istraživanja. Udžbenici Sveučilišta u

Zagrebu, 1-358.

Talley (2006) Hydrography of the eastern tropical Pacific: A review, Progress in Oceanography, Volume 69, Issues 2–4, May–June 2006, Pages 143–180

Thorpe, J. (2003, May). Fatalities and destroyed civil aircraft due to bird strikes, 1912-2002. In *International Bird Strike Committee, 26th Meeting. Warsaw, Poland*.

Tišljar, J. (2004): Sedimentologija klastičnih i silicijskih taložina. Institut za geološka istraživanja. 1-426.
Todd, S., Lien, J., Marques, F., Stevick, P., Ketten, D. (1996): Behavioural effects of exposure to underwater explosions in humpback whales (Megaptera novaeangliae). *Canadian Journal of Zoology* 74, 1661-72.

Tomas, J., Guitart, R., Mateo, R., Raga, J. A. (2002): Marine debris ingestion in loggerhead sea turtles, *Caretta caretta*, from the western Mediterranean. Mar Pollut Bull 44: 211–216. doi: 10.1016/s0025-326x(01)00236-3.

Tricas, T.C. (1980): Courtship and mating-related behaviors in myliobatid rays. *Copeia*, 553-6.

Triossi, F., Willis, T.J., Pace, D.S. (2013): Occurrence of bottlenose dolphins *Tursiops truncatus* in natural gas fields of the northwestern Adriatic Sea.
Marine Ecology 34, 373-9.

Trois, E. (1894): Elenco dei cetacei dell'Adriatico. *Atti Regio Istituto Veneto di Scienze Lettere e Arti* 7, 1315-20.

Tutiš, V., Kralj, J., Radović, D., Ćiković, D., Barišić, S. (ur.), (2013): Crvena knjiga ptica Hrvatske. Ministarstvo zaštite okoliša i prirode, Državni zavod za zaštitu prirode, Zagreb, 258 pp.

Turkozan, O., Durmus, H. (2000): A feeding ground for juvenile green turtles, Chelonia mydas, on the western coast of Turkey. *British Herpetological Society Bulletin* 71, 1-5.

Tyack, P.L. (2008): Implications for Marine Mammals of Large-Scale Changes in the Marine Acoustic Environment. *Journal of Mammalogy*, 549-58.

Tyack, P.L., Miller, E.H. (2002): Vocal anatomy, acoustic communication and echolocation. *Marine Mammal Biology: an evolutionary approach*, 142-
84.

UNEP (2011): Sub-regional report on the "Identification of important ecosystem properties and assessment of ecological status and pressures to the Mediterranean marine and coastal biodiversity in the Adriatic Sea. In: *10th Meeting of Focal Points for SPAs* (ed. by WG.359/Inf.10 UDM), p. 63. UNEP, Marseille, France.

U.S. Environmental Protection Agency (USEPA) (1993): Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Offshore Subcategory of the Oil and Gas Extraction Point Source Category. EPA 821-R-93-003.Office of Water, Washington, DC.

U.S. Environmental Protection Agency (USEPA) (1999): The Behavior and Effects of Oil Spills In Aquatic Environments. EPA 540-K-99-007. Office of Emergency and Remedial Response.

U.S. Fish & Wildlife Service (2010): Effects of Oil on Wildlife and Habitat, June 2010. (http://www.fws.gov/home/dhoilspill/pdfs/dhjicfwsoilimpactswildlifefactsheet.pdf)

University of Maryland (2000): Conservation and Development Problem Solving Team Graduate Program in Sustainable Development and Conservation Biology: Anthropogenic Noise in the Marine Environment: Potential Impacts on the Marine Resources of Stellwagen Bank and Channel Islands National Marine Sanctuaries, December 2000.

Valle, A. (1900): Sulla comparsa di un *Grampus griseus* nelle acque istriane. *Bollettino Società Adriatica Scienze*, 81-7.

Vaniček, V. (2013): Pleistocenske taložine u hrvatskom dijelu podzemlja Jadrana. Disertacija. Sveučilište u Zagrebu. Prirodoslovno-matematički fakultet. 1- 219.

Vasiljević R. (2009) Doprinos spoznaji areala koraljnih vrsta *Alcyonium acaule* i *Eunicella singularis*. Naše more 56(3-4)/2009. (http://hrcak.srce.hr/file/66005)

Veil, J.A., Kimmell, T.A., Rechner,A.C. (2005): Characteristics of produced water discharged tothe Gulf of Mexico hypoxic zone. Report prepared by the Environmental Assessment Division, Argonne National Laboratory, Argonne, for the U.S. Department of Energy, National Energy Technology Laboratory. August 2005. ANL/EAD/05-3. 76 pp.

Velando, A.; Munilla, I.; Leyenda, P. M. (2005): Short-term indirect effects of the 'Prestige' oil spill on European shags: changes in availability of prey. Marine Ecology Progress Series 302: 263-274.

Velić, I., Vlahović, I., Matičec, D. (2002): Depositional sequences and palaeogeography of the Adriatic carbonate platform.– Mem. Soc. Geol. It., 57, 141- 151.

Velić, J., Malvić, T. (2011): Depositional conditions during Pliocene and Pleistocene in Northern Adriatic and possible lithostratigraphic division of these rocks. Nafta, 62 (1-2), 25-32.

Velić, J., Malvić, T., Cvetković, M. (2014): Geologija i istraživanje ležišta ugljikovodika. Udžbenici Sveučilišta u Zagrebu. u tisku.

Veseli, V. (1999): Facijesi karbonatnih sedimenata mlađeg mezozoika i paleogena u pučinskim bušotinama sjevernog Jadrana Disertacija (Carbonate facies of theYounger Mesozoic and Palaeogene of the off-shore wells from NW Adriatic region. Ph, D. thesis).– Sveučilište u Zagrebu, Rudarsko-geološko-naftni fakultet (University of Zagreb), 1-306.

Vlahović, I, Tišljar, J., Velić, I., Matičec, D. (2005): Evolution of the Adriatic Carbonate Platform: Palaeogeography, main events and depositional dynamics.– Palaeogeography, Palaeoclymatology and Palaeoecology, 220, 333–360.

Vlašić, B., Bauk, A. (1994): Possibilities of oil and gas exploration in the Republic of Croatia. Nafta, 45, 5-6, 263-272.

Wanless, S., Harris, M.P. and Morris, J.A. (1991): Foraging range and feeding locations of shags Phalacrocorax aristotelis during chick rearing. Ibis 133: 30- 36.

Wardlea, C. S., Carterb, T. J., Urquharta, G. G., Johnstonea, A. D. F., Ziolkowskic, A. M., Hampsond, G., Mackie, D. (2001): Effects of seismic air guns on marine fish. Continental Shelf Research, 21, 1005–1027.

Wartzok, D., Ketten, D.R. (1999): Marine mammal sensory systems. In: *Biology of marine*

mammals (pp. 117-75. Webster, J.S., (2014): Challenges in waste management facing

the offshore oil and gas sector.

Weilgart, L.S. (2007): The impacts of anthropogenic ocean noise on cetaceans and implications for management. *Canadian Journal of Zoology-Revue Canadienne De Zoologie* 85, 1091-116.

Weir, C.R. (2007): Observations of marine turtles in relation to seismic airgun sound off Angola. *Marine Turtle Newsletter* 116, 17-20.

Weir, C.R., Dolman, S.J. (2007): Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys, and guidance towards a worldwide standard. *Journal of International Wildlife Law and Policy* 10, 1-27.

Wever, E.G. (1978): The reptile ear: its structure and function.

Wever, E.G., Vernon, J.A. (1956): Sound transmission in the turtle's ear. *Proceedings of the National Academy of Sciences of the United States of America*

42, 292.

Wilson, B. (1995): The ecology of bottlenose dolphins in the Moray Firth, Scotland: a population at the northern extreme of the species' range. In: *Faculty of Biological Science*, p. 170. University of Arberdeen, Aberdeen, Scotland.

Woma, T.Y., Fagbenro, A.W. (2013): Application of Time Lapse (4D) Seismic for Petroleum Reservoir Monitoring and Management-A review. *Advances in Physics Theories and Applications* 23, 5-10.

Wrigley, R., Marszalek, A., Rodriguez, K., Hodgson, N. (2014): Offshore Croatia – Hunting „Big Oil" in the Centre of Europe, EAGE, vol. 32, May 2014, 61- 68.

Wrigley, R., Marszalek, A., Rodriguez, K., Hodgson, N. (2014): Offshore Croatia – Hunting 'Big Oil' in the centre of Europe. First Break, 32, 75-82.

Wurtz, M., Poggi, R., Clarke, M.R. (1992): Cephalopods from the stomachs of a Risso's dolphin (*Grampus griseus*) from the Mediterranean. *Journal of the Marine Biological Association of the United Kingdom* 72, 861-7.

Yalçin-Özdilek, S., Aureggi, M. (2006): Strandings of juvenile green turtles at Samandağ, Turkey. *Chelonian Conservation and Biology* 5, 152-4.

Yano, K., Sato, F., Takahashi, T. (1999): Observations of mating behavior of the manta ray, Manta birostris, at the Ogasawara Islands, Japan. *Ichthyological Research* 46, 289-96.

Zachariadis, R.G., Thomason, H.B., Teague, H.E. (1983): Ocean Bottom Seismometers in Seismic Exploration Surveys: Planning and Operations: 53rd Annual Meeting SEG Expanded Abstracts, paper S15.6, 468-470.

Zbinden, J.A., Aebischer, A., Margaritoulis, D., Arlettaz, R. (2008): Important areas at sea for adult loggerhead sea turtles in the Mediterranean Sea: satellite tracking corroborates findings from potentially biased sources. *Marine Biology* 153, 899-906.

Zbinden, J.A., Bearhop, S., Bradshaw, P., Gill, B., Margaritoulis, D., Newton, J., Godley, B.J. (2011): Migratory dichotomy and associated phenotypic variation in marine turtles revealed by satellite tracking and stable isotope analysis. *Marine Ecology Progress Series* 421, 291-302.

Zucca, P., Di Guardo, G., Francese, M., Scaravelli, D., Genov, T., Mazzatenta, A. (2005): Causes of stranding in four Risso's dolphins (*Grampus griseus*) found beached along the North Adriatic sea coast. *Veterinary Research Communications* 29, 261-4.

14.2 Internet Databases

Environmental Protection Agency (www.azu.hr)

American psychological association

(http://www.apa.org/monitor/2014/07-08/spill.aspx) Blue voice.org

(http://www.bluevoice.org/news_facts.php)

Bureau od Ocean Energy Managment, Regulation and Enforcement (Accessed: 25 June 2008): (http://www.mms.gov/ooc/Assets/KatrinaAndRita/BackgrounderMODU.pdf)

Conversations for Responsible Economic Development (http://credbc.ca/tourism-industry-impacts-the-deepwater-horizon-spill/) Discovery od Sound in the sea:

(http://www.dosits.org/science/soundsinthesea/commonsounds/)

GEOExPro (2010): Marine Seismic Sources Part IV (http://www.geoexpro.com/articles/2010/05/marine-seismic-sources-part-iv)

IMO - International Maritime Organization (12 November 2014): „Dumping of Wastes and Other Matter" (http://www.imo.org/OurWork/Environment/PollutionPrevention/Pages/Dumping-of-Wastes-and-Other-Matter.aspx)

Split Port Authority: (http://portsplit.com/cruising/statistika)

Mearsk Viking: Ultra deepwater drilling and development. Deepwater Advanced. (http://www.maerskdrilling.com/Documents/PDF/Drillingrigs/Specific- Rigs/Deepwater-Advanced-1.pd f)

Nacional.hr (14 May 2009): „Samo je sjeverni Jadran zaštićen od razornih tsunamija (Only North Adriatic is protected against devastating tsunamis)" http://www.nacional.hr/clanak/14059/samo-je-sjeverni-jadran-zasticen- od-razornih-tsunamija

NOAA (2010): NOAA Ocean Explorer: Expedition to the Deep Slope. National Oceanic and Atmospheric Administration, US Department of Commerce, August 26, 2010 (http://oceanexplorer.noaa.gov/explorations/06mexico/background/oil/media/types_600.html)

Offshore (2007): Fixed platforms remain important production facilities after more than 60 years. Offshore, September 01, 2007. Volume 67, Issue 9. (http://www.offshoremag.com/articles/article_display.cfm?ARTICLE_ID=307368&p=9)

SCOTESE (2002):

(http://www.scotese.com/) Spectrum

(http://www.spectrumasa.com)

Tportal.hr (17 March 2011): „I na Jadranu moguć desetometarski cunami (A ten metre high tsunami is also possible in the Adriatic)" (http://www.tportal.hr/vijesti/hrvatska/117173/I-na-Jadranu-moguc-desetometarski- cunami.html)

Večernji.hr (11 March 2011): „U slučaju tsunamija, na Jadranu ne bi bilo vremena za evakuaciju (No time for evacuation in the event of a tsunami in the Adriatic)" (http://www.vecernji.hr/hrvatska/u-slucaju-tsunamija-na- jadranu-ne-bi-bilo-vremena-za-evakuaciju-263734)

Wikipedia (2010): Rigs to Reefs (http://en.wikipedia.org/wiki/Rigs-to-Reefs)

14.3 Directives, Ordinances, Regulations, Legislation

Directive 2013/30/EC on safety of offshore oil and gas

operations Directive 2001/42/EC on the assessment of the

effects of certain plans and programmes on the environment

Directive o the European Parliament and of the Council of 12 December 2006 laying down technical requirements for inland waterway vessels and repealing Council Directive 82/714/EEC, (2006/87/EC)

Habitats Directive

(92/43/EEC) Birds Directive

(2009/147/EC) Council

Directive 92/43/EEC

Council Directive

79/409/EEC

Marine Strategy Framework Directive

(2008/56/EC) Water Framework Directive

(2000/60/EC)

Ordinance on main technical requirements on safety and security of offshore exploration and production of hydrocarbons

in the Republic of Croatia (Official Gazette 52/10) Decree on activities requiring implementation of noise protection

measures (Official Gazette 91/07)

Ordinance on measures for the protection from outdoor noise sources (Official Gazette 156/08)

Ordinance on manner and conditions for determination of zone of electronic communications infrastructure and associated facilities, of protected zone and radio corridor, and of obligation of construction work or building investor (Official Gazette 075/2013)

Ordinance on the maximum permitted noise level in an environment in which

people work and live (Official GAzette 145/04), Ordinance on the ecological

network impact assessment (Official Gazette 146/14)

Ordinance on the committee for strategic assessment (Official Gazette 70/08)
Ordinance on the conditions and methods of maintaining order in ports and on other parts of internal waters and territorial sea of the Republic of Croatia (Official Gazette 90/05, 155/08, 80/12)

Ordinance on catch, farming and trade of bluefin tuna (*Thunnus thynnus*), swordfish (*Xiphias gladius*) and Mediterranean spearfish *(Tetrapturus belone)* (Official Gazette 11/14, 20/14, 61/14, 66/14 and 94/14)

Ordinance on granting authorisations for laying and maintenance of submarine cables and pipelines in the continental shelf of the Republic of Croatia (Official Gazette 126/07)

Ordinance on navigational safety in internal waters and territorial sea of the Republic of Croatia and on methods and conditions on conducting inspections and navigating sea transport (Official Gazette 79/13)

Ordinance on strictly protected species (Official

Gazette 144/13), Maritime Code (Official

Gazette 112/04, 76/07, 146/08, 61/11, 56/13),

Regulation on ecological network (Official

Gazette 124/13)

Regulation on informing and participation of the public and public concerned in

environmental matters (Official Gazette 64/08), Regulation on the drawing up and

implementation of documents of the Strategy of managing maritime environment and

coastal area (Official Gazette 112/14), Regulation on environmental impact assessment

(Official Gazette 61/14)

Regulation on strategic environmental assessment of plans and

programmes (Official Gazette 64/08) Regulation on development

and protection of the protected coastal area (Official Gazette

128/04)

Maritime Domain and Seaports Act (Official Gazette 158/03, 100/04, 123/11, 141/06, 38/09)
Act on the ratification of the Agreement on the sub-regional contingency plan for prevention of, preparedness for and

response to major marine pollution incidents in the Adriatic Sea (Portorož, 2005) Official Gazette - International Agreements no. 7/08

Mining Act (Official Gazette 56/13, 14/14)

Act on Exploration and Production of Hydrocarbons

(Official Gazette 94/13, 14/14) Act on Sustainable Waste

Management (Official Gazette 94/13)

Physical Planning and Building Act (Official Gazette 76/07, 38/09, 55/11, 90/11, 50/12, 55/12, 80/13)

Act on the Protection and Preservation of Cultural Objects (Official Gazette 69/99, 151/03, 157/03, 100/04,

87/09, 88/10,61/11, 25/12, 136/12, 157/13, 152/14) Nature Protection Act (Official Gazette 80/13).

Environmental Protection Act (Official Gazette 80/13)

Noise Protection Act (Official Gazette

30/09, 50/13, 153/13) Air Protection Act

(Official Gazette 130/11, 47/14)

14.4 Conventions, Protocols, Agreements

Vienna Convention for the Protection of the Ozone Layer (1985)

Amendments to the Convention for the protection of the Mediterranean Sea against pollution (Barcelona, 1995). Published in Official Gazette - International Agreements no. 17/98, and entered into force in the Republic of Croatia on 9 July 2004, when it was published in Official Gazette - International Agreements no. 11/04

Amendments to the Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal (Barcelona, 1995). Published in Official Gazette - International Agreements no. 17/98

United Nations Convention on the Law of the Sea and the Final Act of the Third United Nations Conference on the Law of the Sea with Annexes I-VII and Appendix. December 10, 1982. (Official Gazette - International Agreements no. 9/2000)

Convention on Biological Diversity (1992)

Convention on International Trade in Endangered Species of Wild Fauna and

Flora (CITES) 1975 Convention on the High Seas (Official Gazette - International

Agreements no. XX/94)

Convention on the Transboundary Effects of Industrial Accidents

(Helsinki, 1992) Convention on Environmental Impact Assessment in

a Transboundary Context (Espoo, 1991.) Convention on the

conservation of European wildlife and natural habitats (Bern

Convention) Convention on the Conservation of Migratory Species of

Wild Animals (CMS) (1979.)

Convention on the Protection of the Underwater Cultural Heritage (PariS, 2001)

Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona, 1976) Pursuant to the notification of succession the Republic of Croatia is a party to the Convention since 8 October 1991. Official Gazette - International Agreements no. 12/93. (Barcelona Convention - *Convention for the Protection of the Mediterranean Sea against Pollution,* 1976.)

Kyoto Protocol (1997)

International Convention on Tonnage Measurement of Ships, 1969 (TONNAGE 1969)

International Convention for the Safety of Life at Sea, 1974 (SOLAS 74)

International Convention for the Safety of Life at Sea (SOLAS)

1974 International Convention for the Prevention of Pollution

from Ships (MARPOL 73/78) International Convention on Load

Lines 1966. (LOADLINE 1966) Montreal Protocol on Substances

that Deplete the Ozone Layer (1987) United Nations Framework

Convention on Climate Change (UNFCCC) (1992)

Protocol for the Prevention of Pollution in the Mediterranean Sea by Dumping from Ships and Aircraft (Barcelona, 1976). Pursuant to the notification of succession the Republic of Croatia is a party to the Convention since 8 October 1991. Official

Gazette - International Agreements no. 12/93

Protocol Concerning Cooperation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea (Malta 2002) Published in Official Gazette - International Agreements no. 12/03, and entered into force in the Republic of Croatia on 17 March 2004, when it was published in Official Gazette - International Agreements no. 4/04

Protocol for the Protection of the Mediterranean Sea Against Pollution Resulting from Exploitation of the Continental Shelf and the Seabed and its Subsoil (Madrid, 1994) The Republic of Croatia signed the Protocol. *(Protocol for the Protection of the Mediterranean Sea Against Pollution Resulting from Exploitation of the Continental Shelf and the Seabed and its Subsoil, 14 October, 1994.)*

Protocol on the Prevention of Pollution of the Mediterranean Sea by Transboundary Movements of Hazardous Wastes and their Disposal (Izmir, 1996) The Republic of Croatia has not signed the Protocol.

Protocol on Integrated Coastal Zone Management in the Mediterranean (Barcelona, 2008) Published in Official Gazette - International Agreements no. 8/12, and entered into force in the Republic of Croatia on 28 February 2013, when it was published in Official Gazette - International Agreements no. 2/13

Stockholm Convention on Persistent Organic Pollutants (2001)

14.5 Spatial plans

Istra County Spatial Plan (Official Bulletin of Istra County no. 02/02, 01/05, 04/05, 10/8, 7/10, 13/12)

Šibenik-Knin County Spatial Plan (Official Bulletin no. 11/02, 10/05, 03/06, 05/08, 06/12, 09/12, 04/13, 02/14, 08/14) Primorje-Gorski Kotar County Spatial Plan (Official Bulletin no. 14/00, 10/05)

Lika-Senj County Spatial Plan (County Bulletin no. 22/10, 19/11)

Zadar County Spatial Plan (Official Bulletin no. 2/01, 6/04, 2/05, 17/06, 3/10, 15/14)

Split-Dalmatia County Spatial Plan (Official Bulletin no. 1/03, 8/04, 5/05, 5/06, 13/07 and 9/13)

Dubrovnik-Neretva County Spatial Plan (Official Bulletin no. 06/03, 03/05, 03/06, 07/10, 04/12, 05/12, 10/12 i 9/13) National Park Kornati Spatial Plan (Official Gazette 118/03)

National Park Mljet Spatial Plan (Official Gazette 23/01) National Park Brijuni Spatial Plan (Official Gazette 45/01) Nature Park Telašćica Spatial Plan (Official Gazette 022/2014)

14.6 Plans, Strategies

National Strategic Plan for Development of Agriculture in the 2014-2020 period, Programme starting points and objectives (summary) Agenda 21 of the UN Conference on Environment and Development (1992)

Intervention Plan in Case of Sudden Sea Pollution (Official Gazette 98/08)

Institute of Oceanography and Fisheries (2012): Initial assessment of the state and load of the marine environment of the Croatian part of the Adriatic - draft, 2012.

Institute of Oceanography and Fisheries (2014): Set of characteristics for good environmental status of marine waters under Croatian sovereignty and set of objectives for the protection of marine environment and related indicators - draft.

Strategy and Action Plan for the Conservation of Biological and Landscape Diversity of the Republic of Croatia (Official Gazette 143/08)

Strategy of Maritime Development and Integrated Maritime Policy of the Republic of Croatia 2014-2020 (Official Gazette 93/14) Physical Planning Strategy of the Republic of Croatia (Official Gazette 93/14)

Nautical Tourism Development Strategy of the Republic of Croatia 2009 – 2019, Croatian Ministry of Maritime Affairs, Transport and Infrastructure and Croatian Ministry of Tourism (2008)

Croatian Tourism Development Strategy until 2020, Government of the Republic of Croatia (2013) Water Management Strategy (Official Gazette 91/08)

14.7 Publications, Posters

Assessing the Effects of the Gulf of Mexico Oil Spill on Human Health: A Summary of the June 2010 Workshop (Institute of Medicine (US), 2010.).

European Topic Centre on Biological Diversity (2014): Detailed conclusions of the representativity of habitats in the sci's of croatia. Biogeografski seminar 29. – 30. 2014., Zagreb.

SHAPE (2014): NATURA 2000 – STANIŠTE 1170, Grebeni. Morska staništa Istarske županije (http://shape.istra-istria.hr/uploads/media/Poster_6_Staniste_1170 5.pdf)

The international tanker owners pollution federation limited (ITOPF): Effects of oil pollution on fisheries and mariculture.

Tehnical information paper. Gulf of Mexico, four years of progress; (http://www.bp.com/content/dam/bp/pdf/gulf-of-mexico/4-years-of-progress-fact-sheet-final-10-14-14.pdf)

14.8 Photographs Used in the Study

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6Jmzu-3bBN5w-3KrXjg- ozRRWm-47DM22-3gtSar-6JmyY-3bBNK5-3bBNi1-3bBMX3-3bBMSy-eDoDP-h4Q23d-9UPu2A-8Cn787-aWV8R6-8Cj1Gk-8Cj5fX-bXcxwa-oyAwfp-8bkzov- p22PzX-7Vd8Kh-iwkGaE-8c5EJM-b19bex-adopm8-pNuBFz-8Cnerj-a37VcG-6bL1gX-asGu5j-bXcuwn-cez1B3-ceyYc1-bXcw1t-bXcvbg-pwk7uw-cE76Ss- 7QSUe4-7QXiDY-6bQjjC-jH3Umc)

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14.9 Reports

Environmental Protection Agency, The State of the Environment Report of the Republic of Croatia, 2005 – 2008. (http://www.azo.hr/Izvjesca30) Environmental Protection Agency, The State of the Environment Report of the Republic of Croatia, 2007.

Gomez, C., Green D. R. (2013): The impact of oil and gas drilling accidents on EU fisheries. University of Aberdeen, Scotland (http://www.europarl.europa.eu/RegData/etudes/note/join/2014/513996/IPOL-PECH_NT(2014)513996_EN.pdf)

Draft Final Report of the Adriatic Sea Monitoring Programme - Phase II, Zagreb 2014. (http://www.mzoip.hr/doc/Propisi/Nacrt_Konacnog_izvjesca_13_06_2014.pdf)

15 Summary

15.1 Introduction

15.1.1 Description of the Framework Plan and Programme

This Strategic Study analyses the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic (hereinafter: the FPP), adopted by the Government of the Republic of Croatia in accordance with the Decision on the Development of the Framework Plan and Programme for Works on Hydrocarbon Exploration and Production in the Adriatic (CLASS: 022-03/14-04/98; FILE NO.: 50301-05/18-14/-4) of

27 March 2014, on the Implementation of the Procedure for Issuing Licences and Publication of Public Tendering for Issuing Licences for Exploration and Production of Hydrocarbons in the Adriatic and the Decision of the Government of the Republic of Croatia (CLASS: 022-03/14-04/98; FILE NO.: 50301-05/18-14-2) of 27 March 2014 on Content, Terms and Conditions and Selection Criteria in the Tender for Exploration and Production of Hydrocarbons in the Adriatic.
In the event of the SEA procedure for the Plan and Programme, the Ministry of Economy of the Republic of Croatia (hereinafter: the Ministry) is competent for its implementation pursuant to the Environmental Protection Act. The Ministry carried out the procedure of the analytical review and on 25 August 2014 the Minister rendered the Decision on the Implementation of the SEA Procedure for the Plan and Programme (CLASS: 310-01/14-03/280, FILE NO.: 526-04-02-01/1-14-02). The Decision is enclosed in Annex 1 to this Strategic Study.
The provisions of the Act on Exploration and Production of Hydrocarbons (OG 94/13 and 14/14) apply to the exploration and production of hydrocarbons contained in the subsea of the internal sea waters or territorial sea of the Republic of Croatia, that is in the subsoil of the continental shelf of the Adriatic Sea to the line of delimitation with the neighbouring countries over which the Republic of Croatia, in compliance with international law, exercises jurisdiction and sovereign rights.
The Plan and Programme includes a portion of the Croatian continental shelf and the territorial sea, 35 833 km2 in area, in which 29 blocks are situated, the sizes of specific blocks amounting to from 1000 to 1600 km2. The eastern border of the tendering area is determined by the line 10 km away from the coast, and 6 km away from the external island line. The remaining borders of the project area are determined in compliance with the international agreements concluded with the neighbouring countries.
In accordance with the Plan and Programme, the flow and the scope of the activities are divided into the exploration and the production period. The exploration period shall include exploration operations which include primarily 2D and 3D seismic acquisition and exploratory drilling, as well as many other analytical studies the joint purpose of which is to collect geological and geophysical data with the aim of obtaining accurate hydrocarbon potential assessment and recognition of geological structures (gravity, geochemical, magnetic, magneto-telluric, transient electro magnetic, and bathymetric surveys, seabed sampling, satellite gravity survey), environmental baseline survey and the environmental impact assessment of works. Pursuant to Article 19, paragraph 3 of the Act on Exploration and Production of Hydrocarbons the exploration period shall last for maximum five years.
Following the expiry of the exploration period and provided the assumptions under the Act on Exploration and Production of Hydrocarbons for direct grant of a concession have been fulfilled, the production period shall commence and last until expiry of the period established under the licence. The licence grants the right to exploration of hydrocarbons and direct grant of a concession in the event of a commercial discovery and provided the Investor has duly fulfilled all contractual obligations. The licence shall be issued for a maximum period of 30 years (from the effective date of the Agreement) and shall include the exploration period and the production period which commences upon direct grant of a concession in the event of fulfilment of the conditions for granting of such concession.
During the production period the operations shall be carried out which include: development of the reservoir development studies, development drilling and well completion, construction of production plants and finally production of hydrocarbons.

15.1.2 Main objectives of the Framework Plan and Programme

The Framework Plan and Programme are developed with the aim of accurate monitoring of the operations concerning exploration and production of hydrocarbons in the Adriatic, issuance of licences, conclusion of agreements, determination of fees, infringement provisions and quality inspection, monitoring and foreseeing of the status of hydrocarbon reserves in the Adriatic, as determined under the Act on Exploration and Production of Hydrocarbons. The implementation of the Framework Plan and Programme is also essential for better efficiency and management of hydrocarbons, as also guaranteed under the Constitution of the Republic of Croatia.

15.2 Environmental characteristics of the areas that may be affected by the implementation of the Framework Plan and Programme

This chapter provides an overview of the environmental characteristics that may be affected by the implementation of the Framework Plan and Programme (FPP). Environmental characteristics considered from the perspective of potential impact are the following: chemical properties, climate characteristics, noise, biodiversity, ecological network, marine and seabed pollution, cultural and historical heritage, fisheries, tourism, maritime shipping, maritime transport and waterways, waste management, infrastructure, socioeconomic characteristics, landscape features as well as human health and quality of life.

Potential impacts on environmental characteristics are listed for each activity conducted in the course of hydrocarbon exploration and production. Each impact on the respective environmental characteristic is elaborated in Chapter 8.

Environmental characteristic that may be affected by an activity	Operations	Impacts resulting from operations	Documents, permits and authorizations to be conducted/obtained
OPERATIONS FORESEEN DURING THE EXPLORATION PERIOD			
Noise Biodiversity Ecological Network Fisheries Maritime shipping, maritime transport and waterways	2D and 3D seismic survey	Accompanying activities causing increased marine traffic and noise	Appropriate assessment of the project impact on the ecological network. Appropriate assessment for the ecological network area consists of the following: screening assessment, main appropriate assessment, determination of the overriding public interest and approval of the project with compensatory measures. Appropriate assessment of the project impact is conducted as part of the preparation of the planned project, prior to obtaining a location permit or other authorization required for the project implementation. Where no appropriate assessment, that is assessment of the need for an EIA is required, the project developer shall submit an application for screening to the competent authority
/	Other operations carried out during exploration (gravity, geochemical, magnetic, magneto-telluric, transient electro magnetic, and bathymetric surveys, seabed sampling, satellite gravity survey, environmental baseline survey)	No significant impact established. Prior to implementing the FPP for the Licensee's Activity and Exploration Programme, appropriate assessment of the impact on the ecological network /environment shall be carried out as provided for in the regulations; potential impacts will be assessed subsequently once activity details for respective blocks are known.	
Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Waste management Fisheries Maritime shipping, maritime transport and waterways	Installation of an exploratory drilling platform	Increase in maritime transport Pollutant emissions into the air Seabed disturbances Noise pollution. Partial use of habitats Landscape disturbance	Environmental impact assessment (Assessment of the need for an EIA, optional Study of the project impact on the environment) Assessment of the project impact on the environment is conducted as part of the preparation of the planned project, prior to obtaining a location permit or other authorization required for the project. Where the assessment of the project impact on the environment also includes the appropriate assessment for the ecological network in accordance with *leges speciales*, the appropriate assessment of the project impact on the ecological network shall be conducted
Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Landscape features Waste management Fisheries	Exploratory drilling	Discharge of mud and well cuttings Wastewater discharge Hydrocarbon spill Waste materials – ship generated waste Air pollutant emissions Noise pollution Well testing (hydrocarbon flaring) Formation water discharge Light pollution	

Maritime shipping, maritime transport and waterways		Partial use of habitats	(all operations conducted for the purpose of exploration and production of minerals, as well as rehabilitation of the area) require mining projects. Based on the proposed scope and type of mining works, the mining authority shall establish the need for a mining project as well as the type of the appropriate mining project: a preliminary mining project or a simplified mining project. *Development of the Mining project regarding the drilling rig on a drilling platform* *Floating installation safety certificate (Croatian register of shipping)* *Entry into the Register of floating installations and fixed offshore facilities (competent port authority)* *Minimum safe manning certificate (competent port authority; confirmed by the Committee)* *Certificate of class*
Climate characteristics Chemical properties Noise Biodiversity Ecological network Marine and seabed pollution Fisheries Maritime shipping, maritime	Accompanying activities – logistics	Increased traffic of vessels and helicopters Air pollutant emissions Hydrocarbon spill	
Chemical Characteristics Climate characteristics Biodiversity Ecological Network Marine and seabed pollution Cultural-historical heritage Landscape features Human health and quality of life Socio-economic characteristics Waste management Fisheries Tourism Maritime shipping, maritime transport and waterways Infrastructure	Accidents	Mud spill Formation water spill Oil spill Shipwreck Release of hydrogen sulfide from wells	
OPERATIONS FORESEEN DURING THE PRODUCTION PERIOD			
Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Cultural and historical heritage Waste management Fisheries Tourism Maritime shipping, maritime transport and waterways Landscape features	Installation of a production platform and pipelines	Increase in maritime transport Seabed disturbance Air pollutant emissions Noise pollution Partial use of habitats Landscape disturbance	A Study of the project impact on the environment is developed as part of the Environmental impact assessment. The Study addresses the production and decommissioning stages. Before developing a study of the project impact on the environment and considering the planned project, the project developer may request an instruction on the study content from the Ministry of Environmental and Nature Protection in writing. For the execution of mining activities and construction of mining facilities and plants a *main mining project*, an *additional mining project* and a *simplified mining project* shall be drawn up. The execution of the main mining project requires an executive *location permit* and a valid *decision certifying the quantity and quality of mineral raw materials.*
Chemical properties Climate characteristics Noise Biodiversity Ecological network Marine and seabed pollution Cultural-historical heritage Landscape features Waste management Socio-economic characteristics Tourism Fisheries Maritime shipping, maritime transport and waterways	Production drilling (presence of a production drilling platform)	Discharge of mud and well cuttings Wastewater discharge Hydrocarbon spill Waste material – ship-generated waste Emission of pollutants into the air Well Testing (hydrocarbon flaring) Formation water discharge	
Climate Characteristics Noise Biodiversity Ecological network	Accompanying activities – logistics	Increased traffic of vessels (including ballast water) and helicopters Air pollutant emissions Hydrocarbon spill	

pollution Fisheries Maritime shipping, maritime transport and waterways			*Floating installation safety certificate (Croatian register of shipping)* *Entry into the Register of floating installations and fixed offshore facilities (competent port authority)* *Minimum safe manning certificate (competent port authority; confirmed by the Committee)* *Certificate of class*
Noise Biodiversity Ecological Network Fisheries Maritime shipping, maritime transport and waterways	2D and 3D seismic survey	Increase in maritime transport Emission of pollutants into the air Airgun noise	
Chemical Characteristics Climate characteristics Biodiversity Ecological Network Marine and seabed pollution Cultural-historical heritage Landscape features Human health and quality of life Socio-economic characteristics Waste management Infrastructure Tourism Fisheries Maritime shipping, maritime transport and waterways	Accidents	Mud spill Formation water spill Oil spill Shipwreck Release of hydrogen sulfide from wells	
OPERATIONS FORESEEN DURING THE REMOVAL OF MINING FACILITIES AND PLANTS			
Climate Characteristics Noise Biodiversity Ecological Network Waste management Marine and seabed pollution Fisheries Maritime shipping, maritime transport and waterways	Removal of (exploration and production) mining facilities and plants	Use of explosives Noise pollution Removal of "artificial reefs"	
Chemical Characteristics Climate characteristics Biodiversity Ecological Network Marine and seabed pollution Cultural-historical heritage Landscape features Human health and quality of life Socio-economic characteristics Waste management Fisheries Tourism Maritime shipping, maritime transport and waterways	Accidents	Oil spill Shipwreck Release of hydrogen sulfide from wells Other accidents	

15.3 Main appropriate assessment of the Framework Plan and Programme regarding the ecological network

Since the plan and programme foresees activities in the area of the Croatian territorial sea and continental shelf, the Main Assessment, elaborates target species and habitats within the blocks foreseen by the FPP. These are the bird species which are the conservation objective of the ecological network area HR1000039 Pučinski otoci (Pelagic islands), as well as the Audouin's gull (*Larus audouinii*) and the common bottlenose dolphin (*Tursiops truncatus*) as a constantly present species in the water area covered by the FPP Even though it is not on the list of the Craotian target species, the loggerhead sea turtle (*Caretta caretta*) is included in the Annex II and IV of the Habitats Directive (EEC 92/43/EEC) and it was elaborated as such. Besides the loggerhead sea turtles, there are two more turtles which can be found in the Adriatic and which are listed in the Annex of the Habitats Directive (Table 6.1), but they are rare and the information about them is very scarce, and therefore, they were not elaborated in this document (see chapter Biodiversity). The Main Assessment recognized the potential impacts of the implementation of the plan and programme on passage migrants (Russel 2005). However, there are not enough data on passage migrants, and species that might be affected shall be analysed in the course of the assessment of the project impact on the ecological network when the exact species and the volume of planned operations in a respective block shall be identified. The common crane (*Grus grus*) was elaborated as a passage migrant which can be affected by the FPP implementation, and the potential impacts on the Main Assessment level can be applied to all other passage migrants which are conservation objectives.

Table 15.1. The list of turtles species which could be negatively affected by the FPP implementation, and which are listed in the Habitats Directive

Latin name	Croatian name	Countries where the species is protected	Habitats Directive (Council
Caretta caretta	Loggerhead sea turtle	Cyprus, Spain, France, Italy, Portugal, Great Britain	Annex II* and IV
Chelonia mydas	Green sea turtle	Cyprus, Spain, Italy	Annex IV
Dermochelys coriacea	Leatherback sea turtle	Spain, France, Italy, Great Britain	Annex IV

* Priority species

15.3.1 Characteristics of impacts arising from implementation of the Framework Plan and Programme on the ecological network

Potential impacts arising from the implementation of the plan and programme to the ecological network species and habitats can be classified in accordance with the steps defined by the FPP into three categories:

- impacts during the exploration period;
- impacts during the production period;
- impacts during the removal of mining facilities and plants.

The impacts defined in this way tell us about the time interval when they can be expected. Impacts during exploration can be expected during the first 2 to 7 years while exploration operations are conducted. Then, there are impacts of platforms and pipelines installation, hydrocarbon production and additional exploration. These impacts are expected during the next 25 years, at least, depending on the capacity of the discovered reservoirs. The last category of impacts is expected during the removal of mining facilities and plants. The shortest phase which may, but does not have to be implemented depending on the environmental impact assessment study results, and which follows after the exhaustion of deposits.

Considering the nature of impacts, it has been assessed whether these are positive or negative, direct or indirect, short-term, medium-term or permanent, and cumulative or synergistic. Based on the ecological network biodiversity, the impacts are classified into three categories:

- impacts on the target bird species;
- impacts on the target species within SAC areas;
- impacts on the target habitats within SAC areas.

15.3.1.1 Impacts on the bird species which are the conservation objective of the ecological network area

The impacts on the bird species which are the conservation objective of the ecological network are possible in two FPP stages (exploration and production). The impacts have been differentiated according to the previously described categories, and umbrella species described in the previous chapter have been chosen for the assessment of impact intensity, and the assessed impact is also applied to other species. Since the umbrella species act as indicators for the assessment of status of the categories, the impacts are afterwards assessed in relation to the categories and not to indicators of species. Potentially significant negative impact of the FPP implementation is possible in case of disturbance of breeding colonies, which would negatively affect the number of breeding pairs. Table 15.2 describes potential impacts, whereas Table 15.3 classifies impacts into groups.

Table 15.2 Potential impacts of the FPP on the target bird species (+2 likely significant positive impact, +1 likely moderate positive impact, 0 likely no impact, -1 likely moderate negative impact, -2 likely significant negative impact (in accordance with the Guidelines for the Appropriate Assessment of the Project on the Ecological Network); I - indirect impact; D - direct impact; S - short-term impact, M - medium-term impact

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Change of breeding colonies conditions due to noise level increase during the implementation of FPP operations	The noise impact can result in altered or unfavourable breeding conditions. During 2D and 3D surveys and in case of traffic increase, especially of increase of helicopter flights, a more significant negative impact is possible (Sultana, J i Borg, J. J. 2006).	-2	N		L			E,P
Reduction of the available food sources under the influence of the FPP operations	Reduced food quantity during the exploration operations due to seismic surveys and discharge of mud and technological water (Engas at al. 1998; McCualley et al. 2003).	-1	I		S			E,P
Increase of the available food sources under the influence of the FPP operations	Increased food quantity during the production operation period since fishing is prohibited within 500 m zone from the platform (OG 52/10) (Russel, 2005).	+1	I		M			E
Platform operation reduces the attractiveness of an area	When operating, platforms generate increased levels of noise, mud, technological, formation and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and technological water reduce the abundance of fish (Patun, 1999; Mario, 2002), and diversity of benthic communities which consequently affects quantities of prey and foraging success. Heavy metals contained in the mud tend to bioaccumulate through the food chain A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators. The noise from hydrocarbon extraction and drilling of wells can temporarily chase away the sea fauna, but it eventually adapts to the new circumstances.	-1	I		S			E,P
Concentration increase of floating hydrocarbons during the usual platform operation	Even small quantities of the floating hydrocarbons can adversely affect the watertight layer on birds' feathers, which reduces the efficiency of their thermal insulation. Such floating hydrocarbons occur during mud, formation and technological water spills and during well production capability testing (Ellis, 2013)	-1	I		M			E
Bird deaths resulting from collisions with helicopters	Bird deaths resulting from collisions with helicopters (Thorpe, J. 2003)	-1	N		S			E,P
Use of platforms as resting areas for migratory birds	Migratory birds can rest on platforms during their migrations (Russel, 2005)	+1	N		M			E
Disturbances to usual flyways	Due to reduced visibility, the birds become disoriented by platform lights, which increases the probability of collisions between the birds, and between the birds and platforms (Russel, 2005)	-1	N		M			E
Flaring of hydrocarbon during well production capability testing	During well production capability testing, hydrocarbons are flared on the platform and a flame is burning in the flare stack above the platform. The hydrocarbon combustion efficiency is never 100%. and unburned hydrocarbon components fall into the sea. Seabirds replace such amorphous material for food (Wanless and Harris, 1997;Velando et al. 2005).	-1	N		S			E
Swallowing of improperly disposed waste and getting tangled into such waste	During operations on exploration boats and platforms a certain quantity of solid waste is generated which ends up in the sea (Cadée, G. C. 2002).	-1	I		M			E, P, R

Table 15.3 Potential impacts on the individual groups of birds

Use of habitats	Impact	Clarification

Birds in marine habitats	• Change of breeding colonies conditions due to noise level increase during the implementation of FPP operations • Reduction of the available food sources under the influence of the FPP operations • Increase of the available food sources under the influence of the FPP operations • Platform operation reduces the attractiveness of an area • Concentration increase of floating hydrocarbons during the usual platform operation • Collisions with helicopters	Negative impacts on birds residing in marine habitats are possible during hydrocarbon exploration and production. Disturbances to breeding colonies are the most significant negative impact. The species of this category breed on desert islands and the increased noise level during exploration and production can chase those species away from the breeding sites. The cessation of the disturbance does not grant the return of the species to the breeding area, and therefore a relatively short-term adverse effect can cause a long-term damage to the breeding population. The indirect impacts on this category are possible if the FPP operations affect fish and cephalopods, i.e. the diet source of seabirds. In this context, seabirds could get scared of exploration boats or platforms, or they could accidentally eat the garbage generated on the exploration boats or platforms that ends up in the sea, which could have adverse effects on the abundance of species. On the other hand, safety zones are created around platforms in
Passage migrants	• Bird deaths resulting from collisions with helicopters • Use of platforms for migratory bird stopovers • Disturbances to usual flyways	Both positive and negative impact is possible on passage migrants. A positive impact is possible during hydrocarbon production since installed platforms represent stopover sites for passage migrants. The negative impacts are possible during exploration and production periods due to collisions between passage migrants and helicopters, crashing of passage migrants into platforms and disturbances to birds passing over platforms during periods of reduced visibility. The negative impact of platforms reflects the most on the bird species that migrate at night, while the positive impact of platforms reflects equally on all passage migrants. During
Non-migrating vultures	• Bird deaths resulting from collisions with helicopters • Change of breeding colonies conditions due to noise level increase during the implementation of FPP operations (Eleonoras' falcon)	The passive flight (gliding) of vultures is a possible cause of bird death or injury in case of collisions with helicopters. Such accidents are expected to happen rarely, but since the vultures are mostly monogamous, death of a partner can disturb the stability of a population of particular area for a longer period of time. Increased levels of noise may affect the breeding success rate of *Falco eleonorae*, which can in the end have a significant negative impact on the population of this species in Croatia.
Birds in terrestrial habitats	• No negative impacts are expected for this bird category.	Since this bird group is found solely in terrestrial habitats, the FPP implementation shall not have a negative impact on the species from this group.

15.3.1.2 Impacts on marine mammals

ACCOBAMS (2013) defined groups for classification of negative impacts of noise to marine mammals. The first group includes physical traumas i.e. either temporary or permanent hearing impairment, non-lethal tissue damages and injuries which can become lethal in case of a direct exposure and result in death. Then, there is a group of impacts which cause behavioural changes. The behavioural changes can be

either minor without changing the normal activity of individuals, or more pronounced so that the individuals cease with their usual activities. In the end, there is perturbation under ambient noise level which has no effect on organisms. The FPP implementation enables different types of noise which can have both physiological and behavioural effect on individuals. A potentially significant negative impact is enabled by utilisation of airguns, and negative impacts of lower intensity are possible due to the increased traffic of vessels, construction, utilisation and removal of platforms and intake of either accidentally or deliberately disposed solid waste.

Table 15.4 Potential impacts of the FPP on the marine mammals (+2 likely significant positive impact, +1 likely moderate positive impact, 0 likely no impact, -1 likely moderate negative impact, -2 likely significant negative impact (in accordance with the Guidelines for the Appropriate Assessment of the Project on the Ecological Network); D - direct impact, I - indirect impact; S - short-term impact, M - medium-term impact

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Increased level of airgun noise	2D and 3D surveys utilize airguns which produce short, but explosive impulses of sound. The affected individuals can suffer physiological and behavioural changes of higher or lower intensity with different negative consequences. A direct connection between individuals affected by the airgun noise and their mortality has not been established.	-1	N		S			E,P
Swallowing of improperly disposed waste and getting tangled into such waste	During operations on exploration boats and platforms a certain quantity of solid waste is generated which ends up in the sea. It may happen that this solid waste gets eaten by the marine mammals causing reduced functionality of their digestive system (Tomas J et al. 2002; Casale P. et al. 2008; Simmonds, M. P. 2012).	-1	I		M			E,P R
Platform operation reduces the attractiveness of an area	When operating, platforms generate increased levels of noise, mud, technological, formation and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and technological water reduce the abundance of fish (Patun, 1999; Mario, 2002), and diversity of benthic communities which consequently affects quantities of prey and foraging success. Heavy metals contained in the mud tend to bioaccumulate through the food chain A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators. The noise from hydrocarbon extraction and drilling of wells can temporarily chase away the sea fauna, but it eventually adapts to the new circumstances.	-1	N		M			E,P
Masking of sounds	Masking of sounds is the process which reduces the ability of marine mammals to recognize natural sounds in the environment, eventually causing their disorientation.	-1	N		M			E, P
Presence of production platforms	Since the Ordinance on the Main Technical Requirements on Safety and Security of Offshore Exploration and Production of Hydrocarbons in the Republic of Croatia (OG 52/10) prohibits any activity within a 500 m radius from any mining facility. Oil platforms installed in the sea become artificial reefs abundant with various species of vertebrates and invertebrates.	+1	N		M			E
Supporting operations which increase the traffic and noise in the sea	Collision with vessels and elevated sea ambient noise due to increased traffic negatively affects marine macrofauna (Nowacek, S M. et al. 2001)	-1	N		S			E, P, R
Disturbances to natural environment by the platform construction	The platform construction operations make specific levels of noise and introduces a new element into the area which can reduce the area attractiveness for a short period.	-1	N		S			E
Disturbances to natural environment by the platform removal	The platform removal operations can result in injury and death of organisms (Klima et al., 1988; Gitschalg et al., 2000).	-1	N		S			R

Table 15.5 Potential impacts on marine mammals

Group	Impact	Clarification
Marin e mam mals	• Increased airgun noise • Swallowing of improperly disposed waste and getting tangled into such waste • Platform operation reduces the attractiveness of an area • Masking of sounds • Presence of production platforms • Supporting operations which increase the traffic and noise in the sea • Disturbances to natural environment by the platform construction • Disturbances to natural environment by the platform removal	Potential impacts on the common bottlenose dolphin are mostly expected due to the elevated noise levels during the exploration period, construction of platforms and hydrocarbon production, where the utilization of airguns for 2D and 3D surveys is estimated as the most adverse source of noise. A minor negative effect of collisions with supply vessels is also possible. The impact of the increased noise made by ships is cumulative and adds to the noise levels already present in the Adriatic. The construction of production platforms can even have a minor positive impact due to the prohibition of fishing activities within a 500 m radius from the platform, which results in increased food sources in the vicinity of the platform. It must be emphasised that the real impact intensity will be able to be determined by producing a noise dispersion model.

15.3.1.3 Impact on sea turtles

Potentially significant negative impacts are possible on the species listed in Annex II and IV of the Habitats Directive which reside outside the Croatian ecological network. The species from that list, which this Strategic Study recognized as the most endangered are the loggerhead sea turtle (*Caretta caretta*), the green sea turtle (*Chelonia mydas*) and the leatherback sea turtle (*Dermochelys coriacea*). However, this document elaborates only the loggerhead sea turtle, due to its having the similar biology and ecology to other species and being the most abundant and the most researched sea turtle species in the Adriatic Sea. The recognized potential impacts can be also applied to the other two sea turtle species.

The implementation of the Plan and Programme can potentially have a significant impact on the sea turtle species during the utilization of airguns which can influence the behavioural changes and lead to injuries and death. Lower intensity impacts are possible due to the increased traffic of vessels, construction, utilisation and removal of platforms and intake of accidentally disposed solid waste. Table 6 explains potential impacts and the table below presents recognised impacts on the sea turtle species.

Table 15.6 Potential impacts of the FPP to the sea turtle species

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Increased level of airgun noise	2D and 3D surveys utilize airguns which produce short, but explosive impulses of sound. These sound impulses can cause the affected individuals to experience both physiological and behavioural changes of either higher or lower intensity with different negative consequences. A direct connection between the individuals affected by the airgun noise and their mortality was not established.	-1	N		S			E,P
Swallowing of improperly disposed waste and getting tangled into such waste	During operations on exploration boats and platforms a certain quantity of solid waste is generated which ends up in the sea. It may happen that this solid waste gets eaten by the sea turtles causing reduced functionality of their digestive system (Tomas J et al. 2002; Casale P. et al. 2008; Simmonds, M. P. 2012).	-1	I		M			E, P, R

Platform operation reduces the attractiveness of an area	When operating, platforms generate increased levels of noise, mud, technological, formation and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and technological water reduce the abundance of fish (Patun, 1999; Mario, 2002), and diversity of benthic communities which consequently affects quantities of prey and foraging success. Heavy metals contained in the mud tend to bioaccumulate through the food chain A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators. The noise from hydrocarbon extraction and drilling of wells can temporarily chase away the sea fauna, but it eventually adapts to the new circumstances.	-1	N	□	M	□	□	E,P
Presence of production platforms	Since the Ordinance (OG 52/10) prohibits any activity within a 500 m radius from any mining facility. Oil platforms installed in the sea become artificial reefs abundant with various species of vertebrates and invertebrates.	+1	N	□	M	□	□	E
Supporting operations which increase the traffic and noise in the sea	Collision with vessels and elevated sea ambient noise due to increased traffic negatively affects marine macrofauna (Nowacek, S M. et al. 2001)	-1	N	□	S	□	□	E, P, R
Disturbances to natural environment by the platform construction	The platform construction operations make specific levels of noise and introduces a new element into the area which can reduce the area attractiveness for a short period.	-1	N	□	S	□	□	E
Disturbances to natural environment by the platform removal	The platform removal operations can result in injury and death of organisms (Klima et al., 1988; Gitschalg et al., 2000).	-1	N	□	S	□	□	R

Table 15.7 Potential impacts to the sea turtle species

Group	Impact	Clarification
Sea turtle species	• Increased airgun noise • Swallowing of improperly disposed waste and getting tangled into such waste • Platform operation reduces the attractiveness of an area • Presence of production platforms • Accompanying activities causing increased marine traffic and noise • Disturbances to natural environment by the platform construction • Disturbances to natural environment by the platform removal	Potential impacts on the sea turtle species are mostly expected due to the elevated noise levels during the exploration period, construction of platforms and hydrocarbon production, where the utilization of airguns for 2D and 3D surveys is estimated as the most adverse source of noise. A minor negative effect of collisions with supply vessels is also possible. The impact of the increased noise made by ships is cumulative and adds to the noise levels already present in the Adriatic. The construction of production platforms can even have a minor positive impact due to the prohibition of fishing activities within a 500 m radius from the platform, which results in increased food sources in the vicinity of the platform. It must be emphasised that the real impact intensity will be difficult to estimate since little is known about the noise impact on this group

15.3.1.4 Impact on habitats

Impacts on targeted habitats within the POVS area HR3000099 Brusnik and Svetac, HR3000100 Island of Jabuka underground, HR3000121 Island of Palagruža underground, HR3000122 Islet of Galijula, HR3000423 Jabuka Pit are expected mainly during exploratory well drilling, installing platforms and removing them later. In terms of the time and space, these operations are very limited, they are not conditioned by the marine habitat type, but the sea depth, and therefore, negative impacts are expected only if platforms were installed in exceptionally rare and, in terms of their surface area, small habitats (e.g. coral reefs): Since the seabed of the FPP area is almost unknown, a detailed impact assessment is expected on the lower planning levels. The following table provides an overview of the potential negative impacts of the FPP implementation-related impacts:

Table 15.8 Potential impacts of the FPP to marine habitats

Impact	Description	Intensity of the positive/negative impact	Direct/indirect	Remote	Short-term/ Medium-term/lasting	Cumulative	Synergetic	Implementation period of the project operations
Anchoring of boats	The anchoring operations lead to seabed disturbance	-1	N		M			E, P,
Sedimentation of cuttings during well-drilling operations	Cuttings discharged during well drilling settle on the adjacent seabed contingent upon sea currents strength and grain size	-1	I		M			E,P
Well drilling	Mechanical destruction of habitats in the well area caused by drilling and laying of cement.	-1	N		M			E,P
Installation/construction of mining facilities and supporting infrastructure	Covering and shading of the habitat part affected by the installation of the foundation of a fixed or the mooring system for a floating platform, as well as by the installation of pipelines and cables.	-1	N		M			E
Presence of production mining facilities and plants	Since the Ordinance (OG 52/10) prohibits any activity within a 500 m radius from any mining facility. Oil platforms installed in the sea become artificial reefs abundant with various species.	+1	I		M			E
Platform operation	During the platform operations, certain quantities of formation water, mud and technological water is discharged and they settle on the seabed carried by sea currents.	-1	I		M			E,P
Introduction of invasive organisms	Ship movements may lead to the transfer of invasive alien species to new locations (tanker ballast water, anchor)	-1	I		L			E,P
Removal of mining facilities and plants	The removal of mining facilities leads to seabed disturbance and destruction of the new habitat.	-1	N		S			R

The basic criterion used as a basis for the assessment of potential negative impacts was the presence of target habitats within the FPP area. It is considered that if there are no accidents, the impact on habitats will be limited to the small area in the vicinity of the location where wells and platforms are installed.
The recognized impacts from the previous table are distributed according to their expected effect on the target habitats of the ecological network areas.

Table 15.9 Potential impacts on marine habitats

Code	Habitat	Impact	Clarification
1110	Sandbanks which are slightly covered by sea water all the time	• Anchoring of boats • Deposition of sediment during well drilling • Well drilling • Installation/construction of mining facilities and supporting infrastructure • Platform operation • Removal of mining facilities and plants • Introduction of invasive organisms	Negative impacts on the sandy seabed are possible during the exploration and production period and removal of mining facilities. The majority of impacts refers to the mechanical seabed disturbance, but since it is the case of mobile sediment, the balance will be reestablished in a relatively short period. Therefore, from this perspective, the impacts on the sandy seabed are short-term and of low intensity. The potentially significant negative impact can be caused by the introduction of invasive organisms which can interfere with the structure of natural sandbank communities, but this impact depends on the environmental conditions and therefore, a more precise assessment will be possible after the locations and type of planned operations during the FPP implementation become known. There are potential negative impacts due to the water pollution by discharge of mud, formation and technological water, but the intensity of their effect depends on sea currents and quantity of pollutants, and its assessment is currently not possible.

1120	Posidonia beds (Posidonion oceanicae)	• Anchoring of boats • Deposition of sediment during well drilling • Well drilling • Installation/construction of mining facilities and supporting infrastructure • Platform operation • Removal of mining facilities and plants • Introduction of invasive organisms	Any mechanical disturbance has a potential significant impact on this habitat. Posidonia beds are very slowly recovered, and anchoring of ships, drilling of wells, installation and removal of mining facilities can have lasting consequences for this habitat. The mechanical disturbance works in synergy with the introduction of invasive species, which have more chances of survival in disturbed communities, thus additionally increasing negative impacts. Since *Posidonia oceanica* species is a sea-flowering plant, which is sensitive to sea water turbidity, which can have a potential negative impact. Furthermore, there are potential negative impacts due to the water pollution by discharge of mud, formation and technological water, but the intensity of their effect depends on sea currents and quantity of pollutants. On the present level of the FPP, when the locations of planned activities are not known, the assessment is not possible.
1170	Reefs	• Anchoring of boats • Deposition of sediment during well drilling • Well drilling • Installation/construction of mining facilities and supporting infrastructure • Platform operation • Removal of mining facilities and plants • Presence of production mining facilities and plants • Introduction of invasive organisms	As in the case of posidonia beds, the mechanical disturbances (anchoring of ships, drilling of wells, installation and removal of mining facilities) represents potential significant impacts on reefs. The mechanical disturbance works in synergy with the introduction of invasive species, which have more chances of survival in disturbed communities, thus additionally increasing negative impacts. There are potential negative impacts due to the water pollution by discharge of mud, formation and technological water, as well as turbidity of water by discharge of well cuttings. Their intensity depends on sea currents and quantity of pollutants. On the present level of the FPP, when the locations of planned activities are not known, the assessment is not possible. A potential positive impact of platform installation on reefs was additionally determined. The supporting platform piles, which act as artificial reefs, open a new space for settlement of immovable organisms which are typical for a reef community
8330	Submerged or partially submerged sea caves	• Well drilling • Installation/construction of mining facilities and supporting infrastructure • Removal of mining facilities and plants	Negative impact on sea caves is possible in case of their mechanical disturbance. The intensity of the impact caused by disturbance is hard to assess because it depends on the facility size. Since the connection between the sea caves and external environment is reduced and contingent upon the size, form and number of openings, no significant pollution impact is expected here during the normal platform operation (discharge of mud, formation and technological water and well cuttings).

15.3.1.5 Cumulative nature of the impact of the FPP implementation on the conservation objectives and integrity of the ecological network area

The current Adriatic noise levels have primarily been caused by maritime traffic. On the annual basis 22.000 ships pass through the Adriatic on its longitudinal traffic direction, and added to this must be tourist boat traffic, which is at its peak during summer months. The FPP foresees the additional sources of noise (seismic surveys, operations, installation and removal of platforms and increased boat traffic) with the potential cumulative impact on the Adriatic. Seismic surveys act as the biggest additional source of noise during the FPP implementation operations. The volume of sound waves during seismic surveys is seldom below 200 dB, which is, according to its intensity, the second strongest anthropogenic source of noise in the sea after explosions. Furthermore, the noise of lower intensity will be generated by well drilling, platform installation, hydrocarbon production and lastly, platform removal. Increase of the noise level is additionally expected during all stages of the FPP implementation, as well as from the supply activities carried out by boats and helicopters.

Platform operations i.e. hydrocarbon production operations will produce a constant low-frequency, low-intensity noise (up to 200 Hz), which will last as long as the production operations (20-30 years).

Since the course of the future activities is not known at this FPP stage, and since it depends on the survey results, it is necessary to estimate the natural capacity of the ecosystem for individual blocks on the level of the Appropriate Assessment of the Project on the Ecological Network, and assess if the work plan for the individual blocks exceeds the significance limits considering the conservation objectives and integrity of the ecological network area. On the strategic study level, it has been estimated that the implementation of activities in all blocks would cumulatively have a significant negative impact. This would especially come to the fore if the activities in block were implemented simultaneously. Based on the available data, the optimum number of blocks where the implementation of activities would not have a significant impact cannot be precisely determined. Considering the closed shape of the Adriatic, as well as potential impacts, a preliminary assessment is that the exploration (seismic surveys, exploratory wells) should not be implemented in more that three blocks at the same time. An EIA shall be conducted for the hydrocarbon production operation for each project, within which a Study of the Project Impact on the Environment will be developed, and an appropriate assessment of the project impact on the ecological network shall be conducted within the Study. The appropriate assessment shall estimate the cumulative impact on the conducted operations in the exploration stage as well as in relation to the potential number of production wells.

Ultimately, the FPP implementation will increase the noise levels in the sea, which can have a cumulative impact, with already existing sources of noise, on the target species of macrofauna (bottlenose dolphin and sea turtles).

15.3.1.6 Accidents

The Main Assessment recognizes a potential negative impact of accidents on the ecological network area. Accidents are possible during hydrocarbon exploration and production, whereby two events are singled out based on the significance of their adverse influences:

- oil and gas spills,
- discharge of hydrogen sulfide (H2S).

Oil spills and hydrogen sulphide discharge have and adverse impact on all organisms in the water column, seabed, sea birds and coastal habitats. Impact of accidents threatening organisms may be direct, whereby impact on specimens occurs (suffocation, poisoning) or impact within the trophic network (consummation and bioaccumulation of harmful substance through food). In birds, the contact of feathers and oil causes the removal of protective hydrophobic layers and the birds lose the ability of thermoregulation and floating. Birds usually use their beaks trying to remove the oil from their feathers whereby they swallow it and expose themselves to a great risk of damaging digestive and nerve systems, liver, lungs and other internal organs.

There are only few notes on the direct impact of oil spill on cetaceans, sea turtles or large fish. The impact is usually measured by monitoring the direct mortality, i.e. number of animals found dead. It is considered that cetaceans are able to avoid oil spills since their skin is less prone to contamination by oil i.e. they absorb less oil through skin because of the blubber, a thick layer of fat under the skin. However, the impact varies from species to species and it was determined that possibility of contact of common bottlenose dolphins with oils spills largely depends on the type of the spill and ability of the animals to observe the spill in a particular area.

Unlike direct mortality, in case of turtles and dolphins there is a long-term effect of pollution ("cryptic" mortality) i.e. mortality affecting population (Williams et al. 2011). For example, relatively well documented such impact is loss of 30-40% of two populations of killer whales in the area of Prince William Sound, Alaska after Exxon Valdez oil spill (Matkin et al. 2008). In case of accidental oil spill the most endangered habitats are those in the mediolitteral area (intertidal zone), because if the oil spill reaches the shore, they would be directly covered by oil. Habitats comprising photosynthetic organisms (sea flowering plants and algae are endangered as a result of habitat. A part of hydrocarbons is dispersed in the water column and in case of oil spill, most habitats, i.e. organisms populating them, at the accident site are potentially endangered. It was observed that oil has the potential to persist in the environment long after a spill event and has been detected in sediment 30 years after a spill. (Effects of Oil on Wildlife and Habitat, 2010.).

The potential reasons for the above mentioned accidents, as well as code of practice and methods for reducing the accidents to minimum have been described in the introductory chapter (1.5.5 and 8.3.2.11) of this Strategic Study.

The intensity of impacts caused by oil spills and discharge of hydrogen sulfide is contingent upon the accident location, quantity of the spilt liquid and sea and atmosphere dynamics at the given moment. Since the Plan and Programme does not foresee detailed project locations, this chapter can define risk areas based on a general flow of the Adriatic Sea currents, which, due to complexity of processes that determine the sea current dynamics, does not represent the expected direction of currents around the future locations of wells. However, one rule can apply in this level of strategic assessment: closer areas of ecological network are under higher risk of adverse impacts than the more remote areas (Figure 15.1). The map below shows the distance between the ecological network areas and blocks. The list of all presented areas is included in Annex 5.

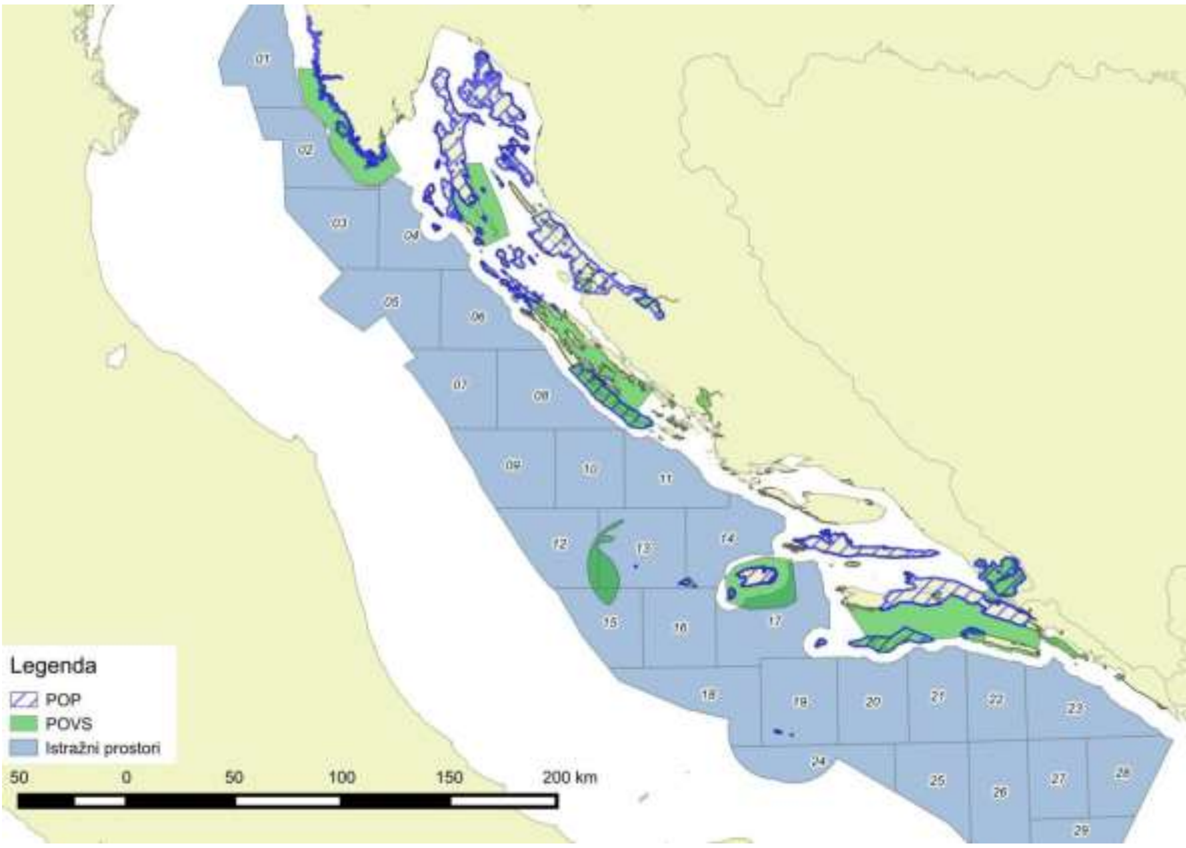


Figure 15.1 The ecological network areas at the highest risk of accidents

15.3.2 Conclusion on the impact of the Framework Plan and Programme on the ecological network

Based on the available information, the Main Assessment recognized sea turtles, marine mammals (common bottlenose dolphin), seabirds, passage migrants and vultures as species on which the FPP implementation can potentially have a significant negative impact.
The information on impacts of hydrocarbon exploration and production on marine mammals, turtles and bird have not always been unambiguous. During the biogeographic seminar held on 29 and 30 September 2014 in Zagreb, the EU Directorate-General for the Environment recognized the lack of data on the species of the loggerhead sea turtle (*C. caretta*) and the common bottlenose dolphin (*T. truncatus*) as a problem that prevents the identification of an appropriate Plan to manage this part of the ecological network in the Republic of Croatia.

Movement areas and feeding locations for seabird species/colonies are data deficient, and can be over 20 km away from breeding colonies. It is therefore, in the current FPP phase, difficult to estimate the FPP impact on the above target species.
The proposed alternative solution moves the FPP operation area 1 km from the current limits of the ecological network, which should protect the breeding colonies from noise disturbances. Since the seabird feeding areas are not known, in order to provide adequate protection, these areas must be determined by the procedure of the appropriate assessment of the project impact on the ecological network for individual blocks and the appropriate protection measures must be prescribed.
Since no impact assessment on the ecological network has been conducted during the current hydrocarbon exploration and production operations, the planned FPP operations represent a new element in the sense of potential cumulative impact assessment. The mutual impact of the expected noise increase level during the implementation of FPP operations (seismic surveys, well drilling and development, helicopters, etc.) and current sources of noise in the Adriatic (22000 of vessels per year on the longitudinal traffic direction, fishing boats, nautical tourism, etc.) can be defined as the most pronounce cumulative impact. Therefore, on the level of this document, noise has been estimated as an important factor of potential impacts. After determining the type and intensity of planned activities for individual blocks, it will be possible to estimate this more precisely.
Despite the lack of information referring to the ecological network conservation objective, the conclusions of the Main Assessment are as follows:

1. During the FPP implementation operation, the highest impact of noise will be on the common bottlenose dolphin (*Tursiops truncatus*) and loggerhead sea turtle (*Caretta caretta*), then on seabirds (*C. diomedea, P. yelkouan, P. aristotelis desmarestii, L. audouinii*) and Eleonora's falcon (*F. eleonorae*) and passage migrants and lastly on the other vultures being the conservation objective of the ecological network area HR1000039 Pučinski otoci.
2. The most significant negative impact are possible during the utilization of airguns, then there are other noise sources and increased traffic as well as increased quantities of improperly disposed solid waste. The Main Assessment recognised potential positive impact as well, the most significant being the impact of the ban of unauthorized activities within a 500 m radius from the platform.
3. Cumulative impacts are possible in all stages of the FPP implementation and they are related to both hydrocarbon exploration and production stage. The implementation of operations in all blocks, can cumulatively have a significant negative impact. This would especially come to the fore if the activities in block were implemented simultaneously. Based on the available data, the optimum

number of blocks where the implementation of activities would not have a significant impact cannot be precisely determined. Considering the closed shape of the Adriatic, as well as potential impacts, a preliminary assessment is that the exploration (seismic surveys, exploratory wells) should not be implemented in more that three blocks at the same time.

Negative impacts of accidents cannot be estimated in detail in the current stage of the Framework Plan and Programme. According to the available information, coastal and marine areas of the ecological network are exposed to the highest risk, and the risk level depends on the distance between the exploration and production facilities and ecological network areas. An important factor is also the type of the discovered and produced hydrocarbon. Impact of the oil-related accidents is proportionally bigger than the impact of the gas-related accidents.

15.4 Environmental Impact of the Framework Plan and Programme

15.4.1 FPP implementation impact assessment

As the FPP deals with planning on a strategic level, technical solutions and locations of the wells inside the blocks are not yet known. In accordance with the legislation in force, the planning system and practice, more detailed planning/design of final solutions, selection of the best technologies and spatial arrangement of projects is foreseen in the subsequent stages of implementation of the FPP, at which point they will also be subjected to the Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network, which will examine the impacts and prescribe the required impact mitigation measures. This document therefore only indicates the mitigation measures and/or recommendations identifiable at the strategic level. Chemical characteristics

15.4.1.1 Chemical properties

Impact ranking:

Negligible negative impact due to impact mitigation measures as the acceptable limits of alterations in the chemical properties of the marine environment will be defined during the assessment of impact on the environment and the ecological network for precisely delineated types of operations, at which point the exact locations of platforms, the operations performed and their schedule, as well as the technological processes and the quantities of substances discharged into the environment will be defined.

Impact	Positive / Negative	Direct	Indirect	Remote	Short-term	Medium-term Permanent		Cumulative	Synergetic
Impact of exploration and production wells on pH value, dissolved oxygen, nutrient and organic concentration levels in the Adriatic	–	□	⦸	□	⦸	□	⦸	□	⦸

Key: + positive impact, - negative impact, □applicable, ⦸not applicable

15.4.1.2 Climate characteristics

Due to all of the above, the impact of pollutants on the air during planned FPP operations is estimated as negligible negative impact.

Impact	Positive/	Direct	Indirect	Remote	Short-term	Medium-term	Permanent		
Impact of emissions		□	⦸	⦸	⦸	⦸	□	□	⦸

Key: + positive impact, - negative impact, □applicable, ⦸not applicable

15.4.1.3 Noise

Impact ranking:

Negligible negative impact due to impact mitigation measures as the operations planned in the FPP (2D and 3D seismic surveying, drilling of exploratory and production wells, increase in marine traffic and accompanying activities (helicopter traffic) will increase the level of noise from anthropogenic sources. Noise levels will have to remain below the upper tolerance limit defined in the noise dispersion model.

	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	Synergetic
Noise level increase	□	□	□	□	□	□	□	□

Key: + positive impact, - negative impact, □applicable, □not applicable

15.4.1.4 Biodiversity

Since there is a significant lack of information on the range, numbers and potential impacts of noise primarily on sea turtles and cetaceans, the impact of noise cannot be explicitly defined at this time. Research done in experimental / induced conditions, as well as monitoring side effects, indicate a possibly significant negative impact which has not been confirmed in natural habitat conditions of the species. Noise caused by seismic surveying and well drilling is limited in duration, and there are interactions with other permanent sources of noise in the marine environment. In order for an impact to be acceptable, suitable mitigation measures must exist which can be prescribed to mitigate the impact..

After implementing the measures prescribed by this Study, it will be possible to determine whether suitable noise impact mitigation measures can be prescribed.

Impact	Positive / Negative	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	Synergetic
Noise impact on cetaceans	–	🗋	🗋	🗋	🗋	🗋	🗋	🗋	🗋
Impact of productio n platforms on cetaceans	+	🗋	⊘	🗋	⊘	🗋	⊘	⊘	🗋

Key: + positive impact, - negative impact, □applicable, □not applicable

15.4.1.4.1 Cartilaginous fishes

15.4.1.4.1.1 Impact of 2D and 3D seismic surveying

The impact is **negligibly negative due to impact mitigation measures.**

15.4.1.4.1.2 Impact of dispersed hydrocarbons (exploratory and production drilling stage; accompanying activities)

Hydrocarbons dispersed in the water column may damage the tissues of gills and the digestive system. Nevertheless, the majority of fish succeed in avoiding the polluted area. Impact on fish is often mediated by the impact on the plankton they consume. Due to hydrocarbon pollution, the plankton may migrate or accumulate pollutants, both of which will have a negative impact on fishes (Luyeye, 2005). As natural fish populations are mobile, the impact of dispersed hydrocarbons is expected to be **negligibly negative.**

Negative.

15.4.1.4.1.3 Impact of accompanying activities (tankers)

Larvae of potentially invasive species of fishes may be transported in ballast waters of cargo vessels such as tankers. Seeing as regulations are in place for cargo vessel transport which lay down procedures to prevent the spreading of invasive species, the impact is assessed as **negligibly negative.**

15.4.1.4.1.4 Impact of light pollution from platforms

During night-time, platform lights may attract zooplankton and ichthyoplankton (fish larvae) and turtle hatchlings. However, the impact of light emissions will be limited to the area surrounding the platform, therefore the impact is considered to be **negligibly negative.**

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	
Impact of 2D and 3D seismic surveying		🗋	⊘	⊘	🗋	⊘	⊘	⊘	⊘
Impact of dispersed hydrocarbons	-	🗋	🗋	⊘	⊘	🗋	⊘	⊘	⊘
Impact of	-	🗋	⊘	⊘	⊘	⊘	🗋	🗋	⊘
accompanying activities (tankers)	-	🗋	⊘	⊘	⊘	⊘	🗋	⊘	⊘

Key: + positive impact, - negative impact, 🗋applicable, ⊘not applicable

15.4.1.4.2 Birds (seabirds and passage migrants)

15.4.1.4.2.1 Impact of 2D and 3D seismic surveying

Seismic surveying could have a direct impact on the birds feeding below water in the immediate vicinity of sonic cannons. As the seismic airguns are deployed at 10 m water depth and directed towards the ground, in the first 10 m of the water column the noise is lower (Caldwell, Dragoset, 2000). Therefore the impact is estimated to be **negligibly negative**.

15.4.1.4.2.2 Impact of exploratory drilling (presence of platforms)

Open sea platforms have 3 main impacts on migratory birds: they serve as stopover sites, disorient nocturnal passage migrants and cause bird deaths through collision.

Birds flying across seas undergo major physiological stress, particularly during springtime when their fat stores are depleted. Excessive accumulation of lactic acid, failure of the nerve-muscle junction, or disturbances of central nervous coordination may occur. Resting on platforms, from several hours up to several days, and even feeding in cases of some species (depending on available food sources), provides the birds with an opportunity to recover. Passage migrants are very selective in their choice of stopover sites, and individual species select specific platform microhabitats (Russell, 2005). This represents **a positive impact.**

It has been noted that platforms attract nocturnal passage migrants which use the Moon and the stars for orientation. This happens more frequently on overcast nights, when platform lights are the only visual cue. Attracted by the lights, birds circle the platforms for up to several hours, which causes unnecessary expenditure of energy and increases the likelihood of collisions between the birds, as well as the birds' collisions with the platform. Collisions with platforms are most common during fall migrations (Russell, 2005). The impact can be reduced by using suitable lighting on platforms, therefore the impact can be described as **negligibly negative due to impact mitigation measures**.

Production platforms often maintain a high level of subsea biodiversity since they act as artificial reefs which are rapidly populated by various marine organisms. Such conditions may attract birds feeding on those organisms (Russell, 2005) and have a **positive impact** on their populations.

15.4.1.4.2.3 Impact of well testing (hydrocarbon flaring)

Nocturnal passage migrants may be attracted to the light from platform flares, which can cause temporary disorientation, or injury and death in case of collision. As flaring operations last for 1 to 2 days per well, the impact is **negligibly negative**.

15.4.1.4.2.4 Impact of hydrocarbon residue

Hydrocarbon residues from process water discharged into the surrounding sea in concentrations permitted by the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) can have a negative impact on birds foraging at sea, even in very small quantities. Hydrocarbons strip the water repellent layer from the birds' plumage, resulting in thermal insulation disturbance (Ellis, 2013). Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms, the quantities of hydrocarbons discharged and the presence of birds in the process water impact zone, in order to give a precise estimate of this impact. The impact is **negligibly negative due to impact mitigation measures.**

Impact of accompanying activities – logistics

Helicopters operating between platforms, exploratory vessels and land may disturb birds, in particular colonies nesting on the coast and the islands. If the standard helicopter routes avoid the locations of known seabird nesting sites, which could abandon their nests in case of disturbance, the impact can be described as **negligibly negative due to impact mitigation measures**.

Impact	Positive/ Negative	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	
Impact of 2D and 3D seismic		🗋	⦸	⦸	🗋	⦸	⦸	⦸	⦸
surveying Presence of platforms	+	🗋	⦸	⦸	⦸	🗋	⦸	🗋	⦸
(stopover sites) Platform lighting (disorientation)	-	🗋	⦸	⦸	⦸	🗋	⦸	🗋	⦸
Presence of platforms (collision)	-	🗋	⦸	⦸	⦸	🗋	⦸	🗋	⦸
Presence of platforms (increased subsea	+	⦸	🗋	⦸	⦸	⦸	🗋	🗋	⦸
biodiversity) Impact of well testing (hydrocarbon	-	🗋	⦸	⦸	🗋	⦸	⦸	⦸	⦸
residues	-	🗋	⦸	⦸	⦸	🗋	⦸	🗋	⦸
Impact of activities – logistics	-	🗋	⦸	⦸	⦸	🗋	⦸	🗋	⦸

Key: + positive impact, - negative impact, [illegible]applicable, [illegible]not applicable

15.4.1.4.3 Invertebrates

Impacts arising from the planned hydrocarbon exploration and production operations will affect a number of marine invertebrates. Notable impacts arise from mud discharges into the sea, hydrocarbons on the surface and in the water column, and seismic surveying. As the sea is populated by organisms belonging to all classes within the informal group of invertebrates, this section presents the impacts on select groups only (corals, bivalves, cephalopods, crustaceans), both for reasons of readability and due to the lack of impact data for individual groups.

15.4.1.4.3.1 Impact of 2D and 3D seismic surveying

Noise in the marine enviroment produced during seismic surveying can have a negative impact on the development of coral and bivalve larvae, as was experimentally demonstrated by Aquilar de Soto (2013), while no impact was noticed in crustaceans (La bella et al., 1996; Christian et al., 2003, 2004). It can also affect adult invertebrates, possibly damaging cephalopod statocysts which may lead to disorientation or death (André, 2011). The potentially negative impact on larvae and adult individuals is most prominent at the site directly exposed to sound, which constitutes a smaller part of the total plankton biomass, and considering the short reproductive cycle of invertebrates, the impact is **negligibly negative due to impact mitigation measures.**

15.4.1.4.3.2 Impact of discharge of drilling mud and well cuttings

Significant impact on benthic invertebrates results from the discharge of drilling mud and well cuttings in the vicinity of the well. Mechanical impact on benthic organisms is to be expected considering the large quantities of discharged drilling mud and well cuttings, as well as the toxic effect of additives in the mud after a longer period of time (Anders Bjørgesæter, 2008.). Mud and well cutting depositions cause secondary pollution of the benthic communities due to the presence of heavy metals and the accumulation of clay. Barium from the mud will mostly appear in the sediment in the form of insoluble $BaSO_4$ (due to high concentrations of sulphates (SO_4) in the marine environment). Chronic exposure to drilling mud containing barium leads to slower growth or even death in certain cases (Cranford et al., 1999), and also has a negative impact on bivalve gill tissues (M.J. Barlow P.F. Kingston, 2001). It has been noted that the presence of barium may alter the composition of benthic communities (Strachan 2010). Communities are covered and anoxia occurs, with lethal effects on seabed fauna (Dodge, 1982). Mechanical impacts on rare benthic communities (coralligenous communities) can be reduced by prescribing a measure which requires that operations are moved away from such habitats. Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms, the type and quantities of drilling mud discharged into the sea, the quantities and composition of well cuttings discharged into the sea, and give a precise estimate of these mechanical and chemical impacts. **The impact is negligibly negative due to impact mitigation measures.**

15.4.1.4.3.3 Impact of platform and pipeline installation and drilling

If located in coral habitats, exploratory wells and production platforms and pipelines have a negative impact on the organisms as their renewal takes several decades, even under the most favourable conditons. Pipeline installation could have a negative impact on benthic organisms living under the pipelines and anchors, and cause water turbidity in the immediate vicinity of the pipelaying site. In general, one kilometre of pipelay is estimated to affect 0,32 ha of the seabed (Cranswick, 2001) The impacts are likely to last for several years. The actual surface affected by anchoring depends on water depth, sea currents, cable length, anchor and cable size, anchor step, etc. Considering the total area of mud and sand flats in relation to the area covered by the pipeline or the platform, the share of benthic habitats which will be converted is negligible. In the case of coral communities, as already indicated, a measure to move the operations away from the habitats will be prescribed as part of the Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network for the Licensee's Programme, therefore the impact is **negligibly negative due to impact mitigation measures.**

15.4.1.4.3.4 Platform removal impact

Production platforms, being present in the marine environment for several decades, become populated by various organisms very soon after installation, and gradually transform into articificial reefs (Rigs to Reefs) which maintain a high level of biodiversity, implying a **positive impact** on invertebrates. Over time, platform legs are overgrown with organisms, i.e. artificial reefs are formed. Growth is periodically removed from the legs so that their weight would not disturb platform stability. Previous experience shows that the presence of marine growth on the legs declines with water depth. According to the overview of growth on the Ivana A platform carried out by experts from the Faculty of Science (Bakran-Petricioli et al., 2007), the growth which developed on the underwater portions of the platform is still dominated (in terms of biomass) by the Mediterranean mussel (*Mytilus galloprovincialis*) and, to a smaller extent, the European flat oyster (*Ostrea edulis*). On the cleaned portion of the platform, at 8 m water depth, the biomass amounts to 30 to 40 kg wet mass/m2, while at deeper portions of the platform (24.5 m) it is around 30 kg/m2. On parts that have not been cleaned since the platform's installation, there are fewer larger mussels than before, at both depths. On parts that were cleaned, from the sea surface up to several meters of depth, mussels are forming again after the cleaning. None of the tested samples contain pre-mutagenic and/or mutagenic xenobiotics, therefore the area surrounding Ivana A can be considered free of pollution (Bakran-Petricioli at al., 2007) Fish are present around the platform in numbers up to 10 times higher than at open sea (Stanley and Wilson, 2000).

If fixed platforms are used, they cover an average of 10 m2 of the seabed, and the level of impact depends on the types of organisms inhabiting the seabed.

15.4.1.4.3.5 Impact of hydrocarbon spills during exploratory drilling and production

Adult bivalves are organisms that primarily feed by filtering sea water, and as such they are susceptible to bioaccumulation of harmful substances. Hydrocarbons created as a byproduct in oil production are dissolved in sea water and accumulate easily in the organs of bivalves, causing disturbances in respiration and filtration, as well as other physiological disturbances (Malins, 1977). . Dispersed hydrocarbons can also have a negative impact on octopus larvae (Longa, 2002). Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms, the type and quantities of hydrocarbons discharged into the sea, and give a precise estimate of this impact on invertebrates. The impact is negligibly negative **due to impact mitigation measures**.

15.4.1.4.3.6 Impact of accompanying activities

The increased number of vessels, especially tankers, increases the possibility of arrival of invasive species that propagate in ballast waters. As regulations are in place for vessel transport which lay down procedures to prevent the spreading of invasive species, the impact is assessed as **negligibly negative**.

15.4.1.4.3.7 Platform and pipeline removal impact

After platform production stops, platforms are removed, thereby also removing the communities growing on them. If the underwater portions of the platform are not removed, and if removal is not performed using explosives, this impact is **negligibly negative due to impact mitigation measures**. During pipeline removal, pollutants are emitted into the water and the seabed is disturbed once again (Scandpower Risk Management Inc., 2004), therefore pipelines should be cleaned and left in their position, resulting in **negligibly negative impact due to impact mitigation measures**

Impact	Positive/	Indirect	Direct	Remote	Short-term	Medium-term	Permanent		
Impact of 2D and 3D seismic surveying	-	☐	⊘	⊘	☐	⊘	⊘	⊘	⊘
of drilling	-	☐	⊘	⊘	⊘	⊘	☐	⊘	⊘
well cuttings									
Impact of platform and pipeline	–	▯	▯	▯	▯	▯	▯	▯	▯
Presen ce of	+	▯	▯	▯	▯	▯	▯	▯	▯
Impact of hydrocarbon spills during exploratory drilling and	–	▯	▯	▯	▯	▯	▯	▯	▯
Platform and pipeline removal	–	▯	▯	▯	▯	▯	▯	▯	▯
Impact of accom	–	▯	▯	▯	▯	▯	▯	▯	▯

Key: + positive impact, - negative impact, ▯▯applicable, ▯▯not applicable

15.4.1.4.4 Plankton

15.4.1.4.4.1 Impact of installation of an exploratory drilling platform

The main impacts from installation of exploratory drilling platforms are seabed disturbances and partial use of habitats. Considering that plankton moves freely in the pelagic zone, no significant impact on this group of organisms is expected Therefore the installation of exploratory drilling platforms has a **negligibly negative impact** on plankton.

15.4.1.4.4.2 Impact of installation of a production platform and pipelines

As the main impact of this activity is related to seabed disturbances and the use of habitats by sedentary species, no impact on plankton is expected as they inhabit the pelagic zone. Therefore, the installation of production platforms and pipelines has a **negligibly negative impact** on plankton.

15.4.1.4.4.3 Impact of exploratory and production drilling

During hydrocarbon exploration and production, specifically during exploratory and production drilling, drilling mud and well cuttings (sludge) are discharged into the area around the well. The larger part of the mud and well cutting mixture deposits on the seabed, while a portion of the particles disperses in the water column. The discharge of drilling mud and wall cuttings (sludge) has an impact on plankton populations if light levels are reduced as a result of dispersion of mud particles, thereby disturbing the daily vertical distribution of the plankton. If substantial water turbidity occurs as a result of the mud discharge, this can lead to reduced growth of phytoplankton (the reduced quantity of light has a negative impact on their ability to photosynthesize) (Luyeye, 2005). Nevertheless, considering the local nature of impact and the total plankton population, no major impact on this group of organisms is expected. In conclusion, the impact of exploratory and production drilling on plankton is **negligibly negative**.

Impact	Positive / Negative	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	Synergetic
Impact of installation of an exploratory and production drilling platform	–	🗋	⊘	⊘	🗋	⊘	⊘	⊘	⊘
Impact of exploratory and production drilling	–	🗋	⊘	⊘	⊘	🗋	⊘	⊘	⊘

Key: + positive impact, - negative impact, 🗋 applicable, ⊘ not applicable

15.4.1.4.5 Habitats

15.4.1.4.5.1 Impact of exploratory drilling

Circalittoral sands and muds are the most common type of habitats present in blocks foreseen by the FPP. The habitats cover a large area, and the organisms inhabiting it are more or less dispersed. During exploratory and production drilling a portion of the habitat is directly occupied, but seeing as wells have a diameter around 1 m, in relation to the total area covered by the habitat such impact is considered **negligibly negative**. Coralligenous communities are characterized by high diversity, but unfortunately their exact distribution in the Adriatic is not known, which hinders their protection. Due to the localised nature and much higher richness of species per unit of area in comparison with circalittoral sands and muds, these habitats are more vulnerable (Natura 2000 poster, Habitat 1170, Reefs), and can be negatively affected by drilling in the area or in the immediate vicinity. Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to ascertain the exact locations of platforms and coralligenous communities, and define platform locations which will avoid those communities. The impact is **negligibly negative due to impact mitigation measures.**
The same impacts apply to deepwater corals communities in the bathyal zone. Drilling, installation of platforms and anchoring on coralligenous communities directly occupies a portion of the habitat. Well cuttings and drilling mud inhibit photosynthesis in autotrophic organisms and prevent heterotrophs from feeding. The impact of hydrocarbons on coralligenous organisms is described in full in the section relating to impact on invertebrates.

15.4.1.4.5.2 Impact of discharge of drilling mud, well cuttings and hydrocarbon residues

Drilling mud and hydrocarbon residues from exploration and production may sink deep into sediments and persist for many years, causing negative impacts on organisms inhabiting it and the food chain (Effects of Oil on Wildlife and Habitat, 2010.). The drilling of exploratory and production wells requires occasional discharge of drilling mud and well cuttings into the sea in the vicinity of the well. . Deposits of mud and well cuttings and the presence of bentonite, barite and heavy metals in the mud have a negative impact on benthic communities. Even mud which is very low in toxicity (water-based drilling mud) affects the seabed communities by causing anoxia. Barium has a tendency to bioaccumulate in macroalgae. Elevated concentrations of barium have been found in species *Sargassum* ssp. (J.M.Neff, 2002). Therefore, before the implementation of FPP, the Licensee's Activity and Exploration Programme must be developed in respect of which procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network must be carried out so as to

ascertain the exact locations of platforms, the type and quantities of drilling mud discharged into the sea, the quantities and composition of well cuttings discharged into the sea, and give a precise estimate of these mechanical and chemical impacts. The impact is **negligibly negative due to impact mitigation measures.**
Drilling mud and well cuttings, as well as formation water, can also have a negative impact on species of **seagrasses**, if discharged in their immediate vicinity. One of the consequences is the reduced level of photosynthesis in seagrasses, which threatens the development of their communities. As seagrass communities inhabit shallow waters (0 - 35 m), the distance from exploratory and production areas is such that there would be no negative impacts indicated above, i.e. the impact is **negligibly negative**.

15.4.1.4.5.3 Impact of production platforms

Production platforms are soon overgrown with different marine organisms and transformed into artificial reefs, which further attracts many other organisms, such as predatory species of fish and birds. The creation of a new type of habitat maintaining a high level of biodiversity represents a **positive impact**.

15.4.1.4.5.4 Impact of pipeline installation

Pipeline installation could have a direct negative impact on benthic organisms living under the pipelines and anchors, and cause water turbidity in the immediate vicinity of the pipelaying site. In general, one kilometre of pipelay is estimated to damage 0,32 ha of the seabed (Gaurina-Međimurec, 2014), As circalittoral sands and muds cover the most part of the Adriatic seabed, the area covered by a single platform (10 m2) or a series of platforms is insignificant in relation to the total size of the area, therefore the impact on this type of habitat is **negligible**. Pipeline laying over coralligenous communities would have a significant negative impact, which can be mitigated by changing the route, therefore the impact is **negligibly negative due to impact mitigation measures**.

15.4.1.4.5.5 Impact of accompanying activities (increased number of tankers)

The increase in marine traffic increases the possibility of arrival of invasive species on anchors and in ballast waters. There are several invasive species of algae in the Adriatic which compete with indigenous species and marine flowering plants. Nevertheless, as regulations are in place for vessel transport which lay down procedures to prevent the spreading of invasive species, the impact is assessed as **negligibly negative.**

Impact	Positive/	Indirect	Direct	Remote	Short-term	Medium-term	Permanent		
Impact of exploratory drilling (circalittoral)	-	□	⊘	⊘	⊘	⊘	□	⊘	⊘
Production drilling	-	□	⊘	⊘	⊘	⊘	□	⊘	⊘
Exploratory a production drilling (coralligenous)	-	□	⊘	⊘	⊘	⊘	□	□	⊘
Discharge of a drilling mud well cuttings, hydrocar bon residues	-	□	⊘	⊘	⊘	□	⊘	⊘	⊘
Presence of production platforms	+	▯	▯	▯	▯	▯	▯	▯	▯
Pipeline installatio	–	▯	▯	▯	▯	▯	▯	▯	▯
Accompanyi ng activities (increased number of	–	▯	▯	▯	▯	▯	▯	▯	▯

Key: + positive impact, - negative impact, ▯applicable, ▯not applicable

15.4.1.4.6 Ecological network

15.4.1.4.6.1 Change of breeding colony conditions due to noise level increase during FPP operations

The noise impact can result in altered or unfavourable breeding conditions. During 2D and 3D surveys and in case of traffic increase, especially increase of helicopter flights, a more significant negative impact is possible for breeding colonies of yelkouan shearwaters (*Puffinus yelkouan*) and Cory's shearwaters (*Calonectris diomedea*) (Sultana, J. and Borg, J. J. 2006). Remote islands and isles (Sv. Andrija, Svetac, Kamnik and Palagruža) are the breeding sites for the only population of yelkouan shearwaters and Cory's shearwaters in Croatia, and impacts resulting from the implementation of FPP could endanger them to the extent that they abandon their breeding sites permanently. This impact is estimated to be **unacceptably negative** and an alternative solution is proposed, as described in chapter 9.

15.4.1.4.6.2 Increased concentrations of floating hydrocarbons during normal platform operations

Hydrocarbon residues from process water discharged into the surrounding sea in concentrations permitted by the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) can have a negative impact on birds foraging at sea, even in very small quantities. Hydrocarbons strip the water repellent layer from the birds' plumage, resulting in thermal insulation disturbance (Ellis, 2013). However, the concentrations of these compounds are so small that their impact at open sea is **negligible**.

15.4.1.4.6.3 Animal deaths in helicopter collisions

Collisions with birds are possible during helicopter flights. As areas of highest risk for collisions have been identified in the Strategic Study, negative impact can be avoided by implementing the mitigation measures prescribed in chapter 10. The impact is therefore estimated as **negligibly negative due to impact mitigation measures.**

15.4.1.4.6.4 Use of platforms for migratory bird stopovers

Birds flying across seas undergo major physiological stress, particularly during springtime when their fat stores are depleted. Excessive accumulation of lactic acid, failure of the nerve-muscle junction, or disturbances of central nervous coordination may occur. Resting on platforms, from several hours up to several days, and even feeding in cases of some species (depending on available food sources), provides the birds with an opportunity to recover. Passage migrants are very selective in their choice of stopover sites, and individual species select specific platform microhabitats. This represents **a positive impact.**

15.4.1.4.6.5 Disturbance of usual migration routes

It has been noted that platforms attract nocturnal passage migrants which use the Moon and the stars for orientation. This happens more frequently on overcast nights, when platform lights are the only visual cue. Attracted by the lights, birds circle the platforms for up to several hours, which causes unnecessary expenditure of energy and increases the likelihood of collisions between the birds, as well as the birds' collisions with the platform. Collisions with the platform are most common during fall migrations. Therefore, the above impact is estimated as: **negligibly negative due to impact mitigation measures.**

15.4.1.4.6.6 Hydrocarbon flaring during well production capability testing

During testing of well production capability, hydrocarbons are burned off on the platform, and the flare-shaped flame rises above the platform. Hydrocarbons are never fully combusted and the unburned components of hydrocarbons end up in the sea. Seabirds can mistake these amorphous masses for food and ingest them, which may result in poisoning (Wanless and Harris, 1997, Velando et al., 2005), The impact is therefore estimated as **negligibly negative due to impact mitigation measures** and monitoring prescribed in chapters 10 and 11.

15.4.1.4.6.7 Swallowing of improperly disposed waste and getting tangled into such waste

Animals frequently swallow pieces of plastic and plastic bags or get entangled in floating waste as they come into contact with waste in the sea accidentally, while searching for food or out of curiosity. The negative impacts of waste affect individual fitness. Waste can become affixed to their extremities or remain undigested in their digestive system, which can ultimately lead to increased mortality of the population. Marine mammals, turtles and birds are at highest risk. There are no measures that could mitigate this impact, as they are already prescribed by law, but waste ends up in the sea nevertheless. The intensity of this impact is not high and it is considered to be **negligibly negative**.

15.4.1.4.6.8 Increased levels of noise caused by airgun operation

2D and 3D surveys utilize airguns which produce short, but explosive impulses of sound. This can result in physiological and behavioural changes in affected individuals of marine macrofauna, in higher or lower intensity and with various negative consequences. A direct connection between individuals affected by the airgun noise and their mortality has not been established so an impact is considered **negligibly negative due to impact mitigation measures.**

15.4.1.4.6.9 Platform operation reduces the attractiveness of an area

When operating, platforms generate increased levels of noise, mud, process water, formation water and domestic waste water which negatively affect the target species or their prey (Mooney T.A. at al. 2012). Toxins from the mud, formation and process water reduce the abundance of fish (Patun, 1999; Mario, 2002) and the diversity of benthic communities which consequently affects quantities of prey and foraging success (seabirds, sea turtles and marine mammals). Heavy metals contained in the mud tend to bioaccumulate through the food chain (Gbadebo A.M. et al. 2000; Neff, 2002) and can have direct consequences on top predators.

The noise from hydrocarbon extraction and drilling of wells can temporarily chase away the sea fauna, but it eventually adapts to the new circumstances.

Based on the analysis conducted, the impact is estimated as **negligibly negative due to impact mitigation measures**.

15.4.1.4.6.10 Presence of production platforms

Sedentary organisms typical for shallow seas grow on the submerged portion of the platform. The creation of new colonies of sedentary organisms ("artificial reefs") leads to the development of new food chains which are atypical for the open sea, increasing the diversity of organisms in their surroundings. This represents **a positive impact.**

15.4.1.4.6.11 Accompanying activities causing increased marine traffic and noise

Collisions with vessels and an increased level of noise due to increased marine traffic have a negative impact on marine macrofauna (Nowacek, S. M. et al., 2001), but on account of the slight increase in marine traffic in comparison with the existing traffic and the rare occurrences of such events the impact is considered to be **negligibly negative**.

15.4.1.4.6.12 Disturbances to natural environment by the platform construction

The platform construction operations make specific levels of noise and introduces a new element into the area which can reduce the area attractiveness for a short period. As a result of the biological processes in the sea, balance will be re-established and the impact is therefore considered to be **negligibly negative**.

15.4.1.4.6.13 Disturbances to natural environment by the platform removal

As in the case of platforms installation, certain levels of noise will be produced and initial environmental conditions will be altered. Since platform removal can be performed using explosives at the base of the piles, the impact is considered to be **negligibly negative due to impact mitigation measures** prescribed in chapter 10.

Impact	Positive / Negative	Direct	Indirect	Remote	Short-term	Medium-term Permanent		Cumulative	Synergetic
Change of breeding colony conditions due to noise level increase during EPP operations	–	🗋	⦸	⦸	⦸	⦸	🗋	⦸	⦸
Increased concentrations of floating hydrocarbons during normal platform operations	–	⦸	🗋	⦸	⦸	🗋	⦸	⦸	⦸
Animal deaths	–	🗋	⦸	⦸	🗋	⦸	⦸	⦸	⦸
Use of platforms for	+	🗋	⦸	⦸	⦸	🗋	⦸	⦸	⦸
Disturbances to usual flyways	–	🗋	⦸	⦸	⦸	🗋	⦸	⦸	⦸
Hydrocarbon flaring during well product	–	🗋	⦸	⦸	🗋	⦸	⦸	⦸	⦸
Swallowing and entanglement into	–	▯	▯	▯	▯	▯	▯	▯	▯
Increased level of airgun noise	–	▯	▯	▯	▯	▯	▯	▯	▯
Platform operation reduces the	–	▯	▯	▯	▯	▯	▯	▯	▯
Presence of	+	▯	▯	▯	▯	▯	▯	▯	▯
Accompanying activities causing increased	–	▯	▯	▯	▯	▯	▯	▯	▯
Disturbances to natural environ	–	▯	▯	▯	▯	▯	▯	▯	▯
Disturbances to natural environm	–	▯	▯	▯	▯	▯	▯	▯	▯

Key: + positive impact, - negative impact, ▯applicable, ▯not applicable

15.4.1.4.7 Fisheries Marine and seabed pollution

15.4.1.4.7.1 Impact of discharging mud into the sea

Impact ranking:
On the basis of the assessment of the impact of drilling mud on the quality of the seabed and the sea, it can be concluded that the implementation of FPP can cause pollution of the seabed and the sea: however assuming the mitigation measures are implemented, the impact could be reduced to **negligibly negative impact due to impact mitigation measures**.

Impact	Positive / Negative	Direct	Indirect	Remote	Short-term	Medium-term		Cumulative	Synergetic
Impact of discharging mud into the sea	–	🗋	⦸	⦸	⦸	🗋	⦸	🗋	⦸

Key: + positive impact, - negative impact, applicable, not applicable

15.4.1.4.8 Economic characteristics

15.4.1.4.8.1 Fisheries

15.4.1.4.8.1.1 Impact of increased marine traffic

Impact ranking:

It may be concluded from the above that fishing activity could decrease during the implementation of FPP as a result of increased marine traffic, but as the number of additional vessels is relatively low, the impact is estimated to be **negligibly negative.**

15.4.1.4.8.1.2 Seismic surveying noise impact

According to the data available, operations related to 2D and 3D seismic surveying impact the physical condition and the behaviour of fishes. Physical effects (mortality, changes in hearing) caused by seismic surveying are described in chapter 3. Behavioural changes in fish exposed to sounds from seismic surveying vary greatly and are species-dependent. They range from mild agitation and reduced reaction to other stimuli to much stronger responses, such as modified swimming speed and direction and changes in vertical distribution /Blaxter et al., 1981, Pearson et al., 1992). Different fish species have different sensitivity and therefore a different response to sounds produced during seismic surveying. It has also been noted that fish with different living patterns had different responses. Fish species inhabiting the seabed reacted to sounds by withdrawing into hiding places, and no difference in vertical and horizontal distribution was noticed (Skalski et al., 1992, Wardle et al., 2001). Unlike these species that stay close to the seabed, fish belonging to species *Gadidae* (e.g. *Merlangius merlangus* and *Micromesistius poutassou*), whose living patterns are similar to the hake's (*Merluccius merluccius*) in that they undertake significant vertical migrations, reacted to seismic noise by withdrawing to greater depths and moving away from the source of noise. Based on the above, it may be concluded that seismic surveying can have a negative impact on fisheries in the surveyed area as the fish tend to move away from the source of noise (Slotte et al., 2004). On account of such fish behaviour, greater fishing efforts will have to be made for the same amount of catch, which has a negative impact on the economic feasibility of fishing.
The majority of fishing operations in the Adriatic take place year-long in the following blocks:
- purse seiners:
West coast of Istria (blocks 1 and 2),
Lošinj Archipelago (block 4), Zadar
archipelago (blocks 6, 8 and 10),
- bottom trawlers:
the area surrounding the Jabuka Pit (blocks 10, 11, 12, 13, 14, 15, 16, 17 and 19), areas
of South Adriatic (blocks 23 and 28)
- tuna purse seiners:
the area surrounding the Jabuka Pit (block 12).

Impact ranking:
It can be assumed from the overview above that fishing operations could be reduced due to seismic surveying, but since the surveying operations are limited in duration, it can be assumed that after they are performed, in compliance with the mitigation measures prescribed in this Study, as well as those that will be defined during the Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network, the situation in a certain area will return to its original state. Therefore the impact is estimated as **negligibly negative due to impact mitigation measures.**

15.4.1.4.8.1.3 Impact due to platform and supporting infrastructure installation and exploratory and production drilling

The physical presence of platforms, as well as noise and light associated with the drilling operations, will impact the populations of fish species in the vicinity. Impact on fisheries as a branch of the economy will be evident through the reduction of areas where fishing is permitted. The majority of fishing operations take place year-long in the following blocks:

PURSE SEINERS:

- West coast of Istria (blocks 1 and 2),
- Lošinj Archipelago (block 4),
- Zadar archipelago (blocks 6, 8 and 10),

BOTTOM TRAWLERS:

- the area surrounding the Jabuka Pit (blocks 10, 11, 13, 14, 15, 16, 17 and 19),
- areas of South Adriatic (blocks 23 and 28),

TUNA PURSE SEINERS:

- the area surrounding the Jabuka Pit (block 12).

Pipeline installation will have a negative impact on benthic organisms, including benthic fish species. Water turbidity in the immediate vicinity of the pipelaying site will have a negative impact on fish populations. As a consequence of the above, fish inhabiting the affected area will move away from the impact site. These activities will have an impact on fisheries in the affected area. The installation of pipelines will limit the possibility of fishing operations in the immediate vicinity of the installed infrastructure, thereby reducing the area where fishing operations can be carried out. On the other hand, fishing pressure will increase in areas where fishing operations are allowed.

Impact ranking:

Vessel anchoring and deepwater fishing is prohibited in safety zones surrounding platforms up to a distance of 500 m. The ban on fishing inside safety zones, if located inside one or more of the significant fishing areas, will have a negative impact on fisheries as it will reduce fishing pressure and increase pressure in other areas where fishing is allowed. Provided that measures described in chapter 10 are carried out, this impact is assessed as **negligibly negative due to impact mitigation measures**.

15.4.1.4.8.1.4 Platform removal impact

Positive impact on fisheries is expected after platform removal due to restored availability of fishing areas. By opening the areas for fishing, the pressure on neighbouring areas caused by the ban on fishing in this area will be removed.

Impact ranking:

Positive impact is expected due to the restored availability of fishing areas.

Impact	Positive/	Direct	Indirect	Remote	Short-term	Medium-term	Permanent	Cumulative	
Impact of increased marine	-	🗋	⦸	⦸	⦸	⦸	🗋	⦸	⦸
traffic Seismic surveying	-	🗋	⦸	⦸	🗋	⦸		⦸	⦸
Impact due due to installation of and exploratory and production	-	🗋	⦸	⦸	⦸	⦸	🗋	⦸	⦸
drilling pipeline	-	🗋	⦸	⦸	⦸	⦸	🗋	⦸	⦸
and supporting infrastructure	+	🗋	⦸	⦸	⦸	⦸	🗋	⦸	⦸

Key: + positive impact, - negative impact, applicable, not applicable

15.4.1.4.8.2 Tourism

15.4.1.4.8.2.1 Impact of platforms on "sun and sea" tourism

The negative impacts of FPP on the "sun and sea" tourism could primarily manifest in landscape features being disturbed by the installation of platforms in areas of very high tourist appeal. Tourist perception of hydrocarbon production platforms is mostly negative and the visibility of platforms from the mainland is perceived as disturbing the view which may significantly reduce an area's attractiveness for the tourism.

Impact ranking:

During the Environmental Impact Assessment, potential negative impacts of platforms on the landscape and tourism must be analysed in detail, in particular in relation to their visibility from beaches and tourist settlements. Provided that measures described in chapter 10 are carried out, this impact is assessed as **negligibly negative due to impact mitigation measures**.

Impact	Positive/	Indirect	Direct	Remote	Short-term	Medium-term	Permanent		
Impact of on 🗋	⦸	🗋	⦸	⦸	🗋	⦸	⦸		

Key: + positive impact, - negative impact, applicable, not applicable

15.4.1.4.8.2.2 Impact of platforms on nautical tourism

The negative impacts of FPP on nautical tourism could primarily manifest in landscape features being disturbed by the installation of platforms in areas of very high appeal for nautical tourism. This primarily implies the areas of national parks "Kornati", "Krka" and "Mljet", nature parks "Telašćica" and "Lastovo Archipelago", as well as areas of high appeal for nautical tourism such as the wider areas of the islands of Žirje, Šolta, Brač, Hvar, Korčula, Vis, Lastovo and the area connecting them. The attractiveness of the area for nautical tourism is closely linked to landscape features, which is why the installation of platforms, mostly perceived as negative by the nautical tourists, may cause them to avoid the areas where platforms are visible.

Impact ranking:

During the Environmental Impact Assessment, potential negative impacts of platforms on nautical tourism must be analysed in detail, in particular in relation to their visibility from points of highest nautical appeal and from the busiest nautical routes. Provided that measures described in chapter 10 are carried out, this impact is assessed as **negligibly negative due to impact mitigation measures**.

Impact	Positive / Negative	Direct	Indirect	Remote	Short-term	Medium-term Permanent		Cumulative	Synergetic
Impact of platforms onnautical	–	🗋	⦸	🗋	⦸	⦸	🗋	⦸	⦸

Key: + positive impact, - negative impact, applicable, not applicable

15.4.1.4.8.3 Maritime shipping, maritime transport and waterways

15.4.1.4.8.3.1 The impact of FPP implementation on maritime shipping, maritime transport and waterways

In terms of impact on maritime transport and vise versa, hydrocarbon exploration and production can be an activity covering larger areas in a certain period of time (exploration vessel surveys), an activity carried out for a period of time at the same location (exploratory drilling), as well as long-term occupation of an area during hydrocarbon production, considering that no other operations are allowed in the 500 m zone surrounding the platform. In accordance with the FPP, the exploration stage can have a duration of up to 5 years (option extended for another year), and the production stage a maximum of 25 years.

When operating and surveying, exploration vessels navigate across an area defined in advance, using low speeds (up to 5 knots) and a long towing line, usually between 3 – 8 km or even longer. Exploratory drilling is performed by rigs which remain at the same location for a longer period of time. As a rule, such units must not be forced to abandon the exploratory drilling site. Interference with transport routes may occur during exploration. In this regard, drilling which takes place in the immediate vicinity of longitudinal routes according to the FPP is a sensitive matter, considering that a large number of vessels operate on the route and have large amounts of kinetic energy, and harmful consequences can occur in case of impact.

During the planned operations of the FPP requests will be submitted for modifications of transport routes in the Adriatic, and the bodies competent for their approval will find them acceptable, therefore the impact on shipping, maritime transport and waterways is estimated as **negligibly negative due to impact mitigation measures.**

Impact	Positive/	Indirect	Direct	Remote	Short-term	Medium-term	Permanent	Cumulative	
Impact of FPP on shipping, maritime		🗋	⦸	⦸	⦸	🗋	⦸	🗋	⦸

Key: + positive impact, - negative impact, applicable, not applicable

15.4.1.4.9 Waste management

Waste products, such as mud and well cuttings, waste and produced water, will be discharged into the sea during the exploration drilling. However, as these waste products undergo a purification process before being discharged into the sea, which is governed by applicable national and international regulations, their significant impact on marine pollution is not expected. This impact is therefore defined as a **negligible negative impact**.

However, one may expect that during the exploration and production period in each block awarded to the concessionaire under the contract one or more wells will be drilled, thus making the quantity of mud and well cuttings discharged into the sea, as well as the seabed surface on which mud and well cuttings will precipitate, proportional to the number of wells. This will result in changes of the seabed contours, barium

concentrations and, potentially, concentrations of other metals. These changes occur primarily within the area approximately 500 m around each drilling platform and can last for several years.
In order to maintain the good quality of marine environment concentrations of heavy metals in marine environment during the execution of these activities should be monitored. Chapter 11 defines mandatory monitoring of pollutants in the marine environment in order to monitor the possible impact of waste products discharged into the sea.

Impact	Positive / Negative	Direct	Indirect	Remote	Short-term	Medium-term Permanent		Cumulative	Synergetic
Impact of exploratory and production	–	🗋	⦸	⦸	⦸	⦸	🗋	⦸	⦸

Key: + positive impact, - negative impact, applicable, not applicable

15.4.1.4.10 Socioeconomic characteristics

15.4.1.4.10.1 Financial model in the Republic of Croatia (source: Croatian Hydrocarbon Agency)

Under the Regulation on the fee for the hydrocarbon exploration and production (Official Gazette no. 37/14 and 72/14), the Croatian Government opted for a model based on the production distribution. The Regulation lays down the method of determining, the amount and distribution proportion of the fee for hydrocarbon exploration and production. The total fee includes seven components, six of which are payable in the form of pecuniary fee, while one is based on the production distribution.

Following the above, taking into account that the Republic of Croatia does not bear the costs of exploration, development and production of hydrocarbons, estimated total direct financial benefits for the Republic of Croatia amount to 58% of the total profit from the project. Also, the indirect impact on the state budget from value added tax, the impact of taxes and contributions from and on earnings of workers employed by the investor, and other fiscal and quasi-fiscal payments and other fees, cannot be neglected.

15.4.1.4.10.2 Economic impacts

Economic impacts of hydrocarbon exploration and production differ in various implementation stages, but as they refer to foreign direct investments, their impact on the gross domestic product of the state is important, as well as the contribution to the overall modernization of the economy of the country receiving the investment. Foreign direct investments have the clearest impact on growth in the manufacturing and related services sector and contribute to increasing the productivity of the economy and the introduction of new business processes, the transfer of technology and know-how, management skills and training employees.

Based on the experience and current costs of offshore hydrocarbon exploration and production, investments during the exploration and production at the research stage can amount to HRK 300 million to 1.1 billion, and to several dozen billion at the hydrocarbon development and production stage, depending on the form of the final solution for the production and plant type. The final production method and selection of production plant type for each block will be based on various factors such as sea depth, distance from shore, fluid characteristics, the existing infrastructure, the amount of resources, shape and size of fields, techniques for production improvement and the availability of local resources and workforce.

15.4.1.4.10.2.1 Direct economic impacts

The direct impacts of exploration and production can be expected in industries directly related to hydrocarbon exploitation, but also in indirectly related industries. Certain activities during hydrocarbon exploration and production affect gross domestic product and employment differently. Each stage of hydrocarbon exploration and production process has a specific impact on the economy of a state where activities are performed.

15.4.1.4.10.3 Direct economic impacts in the hydrocarbon exploration period

Based on global practices and applicable comparisons, at the exploration stage the necessary investment can amount to HRK 300 million to 1.1 billion in each block. The exploration stage economic impact is primarily reflected in the development of logistic and industrial support to seismic surveys and exploration drilling in the Adriatic. Offshore exploration will thus result in the development of the port and other transport infrastructure, greater utilization of maritime and shipping services, and have positive effects on employment.

During seismic surveys and other possible analyses, as well as exploration drilling one or more supply bases in an Adriatic port, strategically located in relation to blocks, should be established. It will include logistic support offices, a port for supply and crew ships, a storage area for pipes and other equipment, storage tanks for fuel and liquids, telecommunications stations, installations for the supply of special cement materials and mud, a helicopter base for transporting staff to and from a drilling plant, waste disposal systems, food preparation services, cleaning, etc.

15.4.1.4.10.3.1 Direct economic impacts in the hydrocarbon production field development exploration period

The development stage is the most intense part of the hydrocarbon production process due to the engagement of the largest number of workers and supporting activities related to the functioning of the process. Therefore, its effects have a significant impact on employment, as well as on gross domestic product, resulting in significant benefits for the Croatian economy. Taking into account experienced and highly skilled workforce, available port facilities, shipbuilding experience and a long tradition of hydrocarbon production in the Republic of Croatia, a significant part of needs for the purpose of hydrocarbon exploration and production are expected to be met in Croatia.

The example of the development of a medium-depth block in the Adriatic shows that the investments necessary for the installation of two fixed production and processing jacket platforms with eight legs fixed to the seabed, and the hydrocarbon transportation system, can amount to approximately HRK 18.5 billion, based on global practices in developing installations at similar depths and current market prices. Such plant is intended for the case of medium reserve quantities and includes underwater installations, fixed steel platforms, floating production systems and installations for loading hydrocarbons onto tankers. According to examples of developed industrial countries and countries with a long history of hydrocarbon production, the best practice would be to retain up to 60% of total investments within the Croatian borders, meaning that up to HRK 11.1 billion of investments could be directly channelled into the Croatian economy for the development of a medium hydrocarbon field.

In order to support the construction of mining facilities in the Adriatic and the merging stage during the development activities, additional office and storage facilities should be established in the country. When such plants become operational, the storage will be used for storing new supplies and spare parts. Office facilities will become an operational location fro providing support and a place for employees in charge of daily operations.

15.4.1.4.10.3.2 Direct economic impacts in the hydrocarbon production period

The production stage is extensive in the first part during the construction of production plants which engage human resources and shipyard infrastructure, thus having a positive impact on gross domestic product. The later phases of the production stage are less intensive, but still including favourable impact on employment.

The above examples of the financial model show that the cumulative income of the Republic of Croatia in the production period from the fee for recovered amounts of hydrocarbons, the production distribution, the fees laid down by Regulation on the fee for hydrocarbon exploration and production and direct taxes, will exceed HRK 1.5 billion in case of only one block (at the assumed hydrocarbon production amount of 10 million barrels of oil equivalent, at the price of USD 83.00 per oil barrel, or USD 51,00 per barrel of oil equivalent for gas respectively during the production period from 2021 to 2035). The supply base will also be used to transport equipment and supplies to offshore mining facilities. Besides logistical needs, it is realistic to expect that the income of industries producing parts and performing overhaul of hydrocarbon production plants, will increase due to the activities in the Adriatic. Needs for various types of equipment and services (electrical, construction, telecommunications, metal processing, etc.) are part of the activities required during the construction of the hydrocarbon production plants. Operating costs (the cost of processing fluids, transport costs, power supply, fuel, the maintenance of production platforms' fixed structures, the maintenance of production equipment at wells, lubricants, etc.) during the production may amount to additional HRK 1.5 billion per year according to the example of the plant from the chapter on the development.

15.4.1.4.10.3.3 Indirect economic impacts

Indirect economic impacts are also significant, although more difficult to measure. They are reflected primarily in the benefits for suppliers and industries directly related to the hydrocarbon exploration and production activities in the Adriatic. Within this category an increase in the demand for power supply, construction materials and the construction of steel structures, fuel, petrochemical products, etc., can be realistically expected. Indirect impacts also include the increase in purchasing power resulting from income growth from the hydrocarbon exploration and production activities, resulting in greater demand for consumer goods and other services. A possible decrease of energy costs in the Republic of Croatia resulting from lower transport costs of hydrocarbons recovered in the Adriatic to destinations within Croatia should also be mentioned. Since the hydrocarbon market has been liberalised, it is important to note that the production growth is unlikely to result in a decrease in the price of raw materials, but the proximity of its location results in lower transport costs to final destination, thus reducing the energy costs for the end consumer. Lower energy costs may be very beneficial to the state's general economy in terms of competitiveness growth and the reduction of end-user prices of services and goods.

15.4.1.4.10.3.4 Public opinion

In the period between 29 August 2014 and 29 September 2014 Internet consultation with the public regarding the Decision on the Development of the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic and the Decision on the Implementation of the Procedure for Strategic Assessment of the Environmental Impact of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic was held. Twenty parties who agreed to making their opinions public, participated in the consultation. Private individuals oppose hydrocarbon exploration and production in the Adriatic on the grounds that it is the economic activity which threatens biodiversity, clean sea and harms other economic activities. Comments from associations, besides the explanation of possible adverse impact, include complaints about the deficiencies in the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic, as well as the content deficiencies in the Strategic Study and the Decision on Conducting Strategic Environmental Assessment of the Framework Plan and Programme for Hydrocarbon Exploration and Production in the Adriatic.

During the course of strategic assessment and following the decision of the expert commission the Strategic Study will be published for public debate. At that stage it is realistic to expect public comments and suggestions, which can be incorporated into the final version of the study and become an integral part thereof. Then, a table with public attitude on the FPP will be possible.

Impact	Positive/	Direct	Indirect	Remote	Short-term	Medium-	Perma	Cumulative	Synergeti
Income increase	Negative	N							

Key: + positive impact, - negative impact, applicable, not applicable

15.4.1.4.11 Impact of the physical characteristics (waves and sea currents) on the FPP implementation

15.4.1.4.11.1 Impact of waves

Big waves may affect platforms and associated ships. Waves, especially higher than 2 or 3 m, affect the ships by changing the speed and direction of ship navigation, heavy slant and overloads on board. including direct damage. Sharp decline and sudden prance, including extreme tilting, are the most dangerous and obvious. A wave will not have the same effect on a little or big ship, meaning a ship will behave differently in small or big waves. This means that there is a connection between waves of certain properties (wave height, length, period, wave refraction, direction and speed, etc.) affecting a ship of certain properties (shape and dimensions of underwater and above water parts of the ship, speed, cargo, etc.) depending on the depth of the sea (or rather shallow water) and the shape of the coastline and islands near waterways. Thus, 2 to 4 meter waves represent a major threat to small ships, while big, a hundred or more meters long ships, barely feel the impact of such waves. On the other hand, several hundred meter high waves cause big difficulties to the big ship, while the small one navigates easily through them. Wavelength plays a very important role, especially when it is of the same order of magnitude as ship length. If a ship's bow and stern are supported by two wave peaks, while the middle part of the ship is in the valley of the wave, or when the bow and stern are in the valley, and the middle part of the ship is at the peak, there will be large loads to and transverse bending of the ship. Such overloads and bending will probably go unnoticed on a new ship, but microcracking still occurs and after some time becomes more obvious, even resulting in ship fractures.

Waves reduce a ship's speed depending on the height and direction of the waves. The speed decreases as waves grow bigger. A ship navigating towards oncoming waves loses speed much faster than in case of waves hitting the ship on the side. The least loss is when the waves hit the ship on the back. It is worth mentioning that the ship starts to navigate slightly faster when small waves, up to 1 meter high, hit it on the back.

In general, the waves do not facilitate, but to a greater or lesser extent hinder navigation. Due to the complexity of waves' actions on the ship, for each ship there are certain recommendations and regulations for ship management in cases of high seas. The basic principle of navigation is to reduce the speed of the ship and point its bow towards the oncoming waves. In case the bow cannot be pointed towards the oncoming waves, the stern may also be pointed towards them. The worst, and even dangerous, thing to do is to expose the ship's side to the oncoming waves. Sometimes the bow can be leaned away from the direction of the oncoming waves, but not more than 10 to 20°. This is done in case of resonance phenomena on-board the ship. Namely, by reducing (and only exceptionally by increasing) the ship's speed and slight turning away from the direction of the oncoming waves resonant phenomena should be mitigated. Otherwise, the speed needs to be reduced, and sometimes the ship needs to stop (engines need to be turned on), but it is important to keep control of the ship, i.e. one should "listen" to the ship's rudder. If stormy weather with high waves is expected to hit and there is no access to the protected part of a port, a larger ship at berth or at anchor should set sail, as this reduces the risk of direct damage to the ship.

Platforms are in a way part of the land or ship. It all depends on how they are designed (anchored) and their location at sea. In this case the Northern Adriatic is referred to as shallow sea (20 – 150 m), while the Southern Adriatic is referred to as deep sea (200 – 1,233 m). During several days of jugo wind (scirocco) blowing relatively high waves of 3 to 5 m may develop. The highest waves recorded so far at open sea were 10.8 meter high. It occurred on a platform in the Northern Adriatic. Although bura wind is known for its high speed, due to the blowing on the coast, waves are not so high. The highest waves recorded in the North Adriatic were 7.2 meter high. Statistically, during the centennial return period in the Adriatic the height of the highest wave is 13.5 m. Besides the height, there are other characteristics of the waves.

The waves on platforms have similar effects as the ones onshore. Protection includes removing all items and fixing them reliably. It should be noted that the height of the working space at a platform must meet the specified wave hits (besides wind). The height should preferably be above the wave reach height, which is not always easy to implement, both technically and financially.

15.4.1.4.11.2 Impact of sea currents

Sea currents in the Adriatic, either surface or deep, are not especially strong, but the transfer of certain substances may still occur, and if those are pollutants, the situation will not be harmless to the environment.

Sea currents generally occur at the surface or in the depth. Along the eastern coast of the Adriatic there is incoming (NW) current, more pronounced in winter, bringing water from the Levantine Sea, while along the western coast the outflow of water is more pronounced in summer. These surface currents are related to the distribution of the thermohaline properties of water (temperature, salinity), i.e. density, but there is also a common impact of wind changing direction. In summer mistral (NW wind) is important, and in winter jugo wind. A closed circuit in the southern part of the Adriatic, where the sea is the deepest, should be mentioned. Speed of surface currents are 0.55 to 0.80 ms^{-1}, while the largest exceeds 1.0 ms^{-1} along Kamenjak (in the south of the Istrian peninsula). The above is essential for transmission of pollution, regardless of whether it includes solid or liquid substances. Gases, less dense than water, come out into the atmosphere and spread through other processes (wind, diffusion, etc.). The density of solid or liquid substances in relation to water means that less dense substances float at or near the water surface and are transmitted by surface currents together with diffusion processes. Solid or liquid substances more dense than water sink quickly or slowly carried by currents in the depths of the sea. Certain proportion of reaches the bottom of the sea, where it precipitates , and another proportion moves farther where it either precipitates or "dissolves" in water, which becomes contaminated. Therefore, deep way water flows play an important role.

In the deeper layers of the Adriatic the flow is influenced by thermohaline gradients. Along the eastern coast there is the entry into the Levantine waters of high salinity, while in layers along the bottom of the Strait of Otranto there are outflows of south Adriatic water. Thick north Adriatic water flows to the Central and Southern Adriatic in the bottom layer, at speeds up to 0.20 m/s, changing the thermohaline properties of the Central and Southern Adriatic.

15.4.1.4.12 Accidents

Since it is not possible to define criteria for the assessment of impact of accidents on the environment at the level of assessment carried out by the Strategic Study, nor carry out the assessment of the impact on individual environmental components accordingly, the Study provides only

an overview of potential accidents on individual environmental components, established on the basis on scientific data, is described below.
It is expected that a detailed analysis of accidents' impact on environment for individual hydrocarbon exploration and production projects will process, during further procedures, assessments of the project impact on the environment/Appropriate assessment of the project impact on the ecological network.
The big ecological disaster caused by an oil spill in the Gulf of Mexico in April 2010 was the reason for the adoption of a new, specific regulatory framework at EU level in order to increase safety standards and environmental protection measures in order to protect European sea and prevent the occurrence of such accidents in the future. In June 2013 the Directive 2013/30/EU of the European Parliament and of the Council of 12 June 2013 on safety of offshore oil and gas operations, was adopted. The Directive is aimed at preventing the occurrence of accidents associated with offshore oil and gas activities and limiting the consequences of such accidents should they occur so as to ensure rapid response in order to minimise the consequences. The Directive itself is primarily aimed at ensuring the protection of marine environment and coastal economies against pollution. The Directive sets out the conditions for safe offshore exploration and production of oil and gas and at the same time improves risk management mechanisms.

The Directive defines a major accident as:

- an incident involving an explosion, fire, loss of well control, or release of oil, gas or dangerous substances involving, or with a significant potential to cause, fatalities or serious personal injury;
- an incident leading to serious damage to the installation or connected infrastructure involving, or with a significant potential to cause, fatalities or serious personal injury;
- any other incident leading to fatalities or serious injury to five or more persons who are on the offshore installation where the source of danger occurs or who are engaged in an offshore oil and gas operation in connection with the installation or connected infrastructure; or
- any major environmental incident resulting from the above incidents.

For the purposes of the Directive 'offshore oil and gas operations' means all activities associated with an installation or connected infrastructure, including design, planning, construction, operation and decommissioning thereof, relating to exploration and production of oil or gas, but excluding conveyance of oil and gas from one coast to another, while 'offshore' means situated in the territorial sea, the Exclusive Economic Zone or the continental shelf of a Member State within the meaning of the United Nations Convention on the Law of the Sea.

Offshore oil and gas industry is developed in many regions of the Union, and in the offshore waters of Member States there are potentials for new regional development, since the development of technology allows drilling in more demanding conditions. Production of offshore oil and gas is an important factor for the security of energy supply in the Union.

Risks associated with large offshore oil and gas accidents are significant. By reducing the risk of pollution of offshore waters, this Directive should therefore contribute to ensuring the protection of the marine environment and in particular to achieving or maintaining good environmental status by 2020 at the latest.

Although general authorizations in accordance with Directive 94/22/EC guarantee exclusive rights of exploration and production to holders of authorizations in areas to which it applies, offshore oil and gas activities in this area shall be subject to continuous expert regulatory monitoring of Member States in order to ensure the establishment of effective controls in order to prevent major accidents and limit their effects on people, the environment and security of energy supply.
During hydrocarbon exploration and production there are mobile and stationary offshore units. Mobile offshore drilling units in transit are typically ships, while platforms, especially for production are usually considered stationary offshore units. Operations of mobile offshore units are regulated by international maritime conventions. **According to MARPOL 73/78 ships, including ships for exploratory drilling must have a contingency plan in emergency situations occurring during oil pollution.**

The Directive on safety of offshore oil and gas operations contains detailed terms and conditions with respect to documentation that an operator (concessionaire) must prepare and submit to the competent national regulatory authority for the purpose of performing offshore oil and gas operations. Thus, for example, the operator must submit to the competent regulatory authority the following documentation: **corporate major accident prevention policy, safety and environmental management systems, a report on major accidents, internal emergency response plan, reports on well operations, etc. In addition, operators shall establish appropriate monitoring systems and periodic reviews of these reports at least every five years.**

Member States should ensure that the competent authority is legally authorized and has sufficient resources to undertake effective, proportionate and transparent implementation measures, including, if necessary interruption of operations if operators and owners do not achieve satisfactory results in terms of safety and environmental protection.

Safety and environmental aspects associated with licenses
In proceedings to assign or transfer licenses for performing operations related to offshore oil and gas, Member States shall comply with additional requirements when assessing the capability of an applicant. In particular, when assessing the technical and financial capability of the applicant for a licence, due account shall be taken of the applicant's financial capabilities, including any financial security, to cover liabilities potentially deriving from the offshore oil and gas operations in question including liability for potential economic damages where such liability is provided for by national law. Before granting or transferring a licence for offshore oil and gas operations, the licensing

authority shall consult, where appropriate, the competent authority. A licence shall not be granted unless the applicant presents evidence that they have made or will make adequate provision to cover liabilities potentially deriving from the applicant's offshore oil and gas operations. A licensee shall maintain sufficient capacity to meet their financial obligations resulting from liabilities for offshore oil and gas operations.
The licensing authority or the licensee shall appoint an operator (i.e. entity) which (directly) performs offshore oil and gas operations. Where the operator is to be appointed by the licensee, a prior approval of the licensing authority should be obtained. If the licensing authority objects to issue such approval or if during the performance of activities the operator is found to be non-compliant with the requirements of the Directive, the licensee shall be required to appoint a suitable alternative operator or assume the responsibilities of the operator under this Directive.
When assessing the technical and financial capability of the applicant, due account shall be taken of all ecologically sensitive marine and coastal environments, in particular, for example, marine protected areas or areas covered with Natura 2000 network, etc.

Liability for environmental damage

The key requirement of the Directive for Member States is to ensure that the licensee is financially liable for the prevention and remediation of environmental damage as defined in the Directive on environmental liability (Directive 2004/35/EC), caused by offshore oil and gas operations carried out by, or on behalf of, the licensee or the operator. Thus, the licensee without the status of the operator remains responsible under the Directive on environmental liability. Furthermore, the Directive amends the legal definition of water damage contained in the Directive on environmental liability in a way that the present definition now covers EU Member States marine waters. In other words, responsibility for the environment pursuant to the provisions of the Directive on environmental liability was extended and applies to marine waters.

Independent regulatory authority

The Directive requires the appointment of a national independent authority in charge of a series of regulatory functions such as assessing and accepting reports on major hazards, assessing design notifications, and assessing notifications of well operations, overseeing compliance by operators and owners with this Directive, including inspections, investigations, making annual plans, etc.
For the purpose of preventing conflicts of interest Member States are generally required the regulatory functions of the competent authority to be carried out within an authority that is independent of any of the functions of Member States relating to the economic development of the offshore natural resources and licensing of offshore oil and gas operations, including the collection and management of revenues from those operations.

Obligation of reporting major accidents with offshore oil and gas operations conducted outside the Union

In accordance with the Directive, Member States shall require companies registered in their territory and conducting, themselves or through subsidiaries, offshore oil and gas operations outside the Union as licence holders or operators to report to them, on request, the circumstances of any major accident in which they have been involved.

Cooperation between Member States

Each Member State shall ensure regular exchanges of knowledge, information and experience, in particular, regarding the functioning of the measures for risk management, major accident prevention, reporting on major accidents with other competent authorities, inter alia, through the European Union Offshore Oil and Gas Authorities Group (EUOAG).

Preparedness measures and notifications in case of major accidents

Member States are required to prepare external emergency response plans covering all offshore oil and gas installations or connected infrastructure and potentially affected areas within their jurisdiction.

Furthermore, Member States shall ensure that the operator or, if appropriate, the owner notifies without delay the relevant authorities of a major accident or of a situation where there is an immediate risk of a major accident. In the event of a major accident, the operator or the owner shall take all suitable measures to prevent its escalation and to limit its consequences. Also, the Directive contains specific provisions with respect to preparedness measures and information in the event of a major accident with transboundary effects on the environment in another Member State.

The application and impact of new rules on Croatian legislation

CONTINGENCY PLAN FOR ACCIDENTAL MARINE POLLUTION (Official Gazette no. 92/08) is a document of sustainable development and environmental protection, which defines the procedures and measures for predicting, preventing, restricting and preparing for and responding to accidental marine pollution and the unusual natural occurrences in the sea for the protection of the marine environment. The Contingency Plan is harmonised with international treaties governing the area of
marine environment protection to which the Republic of Croatia is a party. Entities involved in the implementation of the Contingency Plan are: Headquarters for the implementation of the Contingency Plan, Maritime Rescue Coordination Centre - Rijeka and County Operational Centre.

Although existing Croatian regulations for hydrocarbon exploration and production, in particular:

- Act on Exploration and Production of Hydrocarbons (Official Gazette no. 94/13 and 14/14),
- Mining Act (Official Gazette no. 56/13 and 14/14),

- Ordinance on main technical requirements on safety and security of offshore exploration and production of hydrocarbons in the Republic of Croatia (official Gazette no. 52/10)

lay down basic obligations and protection measures of nature and environment, health and safety of people and property in the performance of oil and gas exploration and production operations, further legislative changes to the existing or the adoption of a new legal framework in order to timely comply with all requirements and obligations under the Directive, will be required.

In general, Member States with access to the sea are obliged to transfer the provisions of the Directive into national law by 19 July 2015.

The Directive provides for the following transitional deadlines for compliance with national legislation transposing the provisions of Directive:

- **no later than 19 July 2016** in relation to owners, operators of planned production facilities and operators planning or carrying out well operations
- **no later than 19 July 2018** in relation to the existing plants.

Finally, in addition to operators INAgip d.o.o. (joint operating company established by INA d.d. and Italian oil company ENI) and Edina (established by INA d.d. and Italian company EDISON SPA) given the existing gas exploration and production operations in the Northern Adriatic, all selected tenderers who will be issued a license and granted a concession for hydrocarbon exploration and production in the Adriatic following the bidding procedure, will have to comply with the new rules and requirements of the Directive.

15.4.1.4.13 Cross-border impacts

Cross-border impacts are the result of certain activities which may cause a change in environment components in countries adjacent to the territory of the country where a certain activity is taking place. The Act on the Ratification of the Convention on Environmental Impact Assessment in a Transboundary Context (OG IT 6/96, entered into force with respect to the Republic of Croatia on 10 September 1997) defines the cross-border impact as a *"Transboundary Impact"* referring to any impact, not exclusively of a global nature, within an area under the jurisdiction of a Party caused by a proposed activity the physical origin of which is situated wholly or in part within the area under the jurisdiction of another Party.

The basic international treaty regulating the cooperation related to the cross-border environmental impact is the Convention on Environmental Impact Assessment in a Transboundary Context ("Espoo Convention"). The Convention sets out the obligations of Parties to assess the environmental impact of certain activities at an early stage of planning. It also lays down the obligation of States to notify and consult each other on all major projects under consideration that are likely to have a significant adverse environmental impact across boundaries. At the European Union level, the Convention is complemented with the Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (as amended with the Directive 2014/52/EU), and Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment. Also, Directive No. 2013/30/EU on the safety of offshore oil and gas operations and amending Directive 2004/35/EC in one of its parts deals with the transboundary impact related to offshore exploration and production of hydrocarbons and defines that the Member State in which activities are planned, and if considered necessary, before the commencement of operations, forwards the relevant information to the potentially affected Member State and shall endeavour, jointly with that Member State, to adopt measures to prevent damage.

In case of the FPP for exploration and production in the Adriatic, the potential cross-border impact refers to the countries with which the Republic of Croatia shares the open sea area and the epicontinental belt. Those are Italy and Slovenia as EU Member States, and Montenegro which is not an EU Member State. FPP covers a number of various activities, at various sea depths (from 50 m to 1215 m) and in the area of various physical systems, so that cross-border impacts are possible, with regards to a certain type of activity, and their level can be assessed during the appropriate assessment for the ecological network / environment. For activities such as geomechanic testing of the seabed, laying of installation to the seabed or sailing of supply ships, the cross-border impact is not expected, while for activities such as seismic surveys and certain stages of well drilling as well as the hydrocarbon exploration itself, it is realistic to expect a cross-border impact.

In accordance to the above stated, a separate Appropriate Assessment of the impact on ecological network will be drafted for each project, Assessment of the need for an EIA and consequently, assessment of the cross-border impact as a part of procedures of Environmental Impact Assessment.

For the purposes of the assessment of the potential cross-border impact, blocks defined in FPP overlap with Natura 2000 areas of Slovenia and Italy.

15.4.1.4.13.1 The Republic of Slovenia

In the part of the Republic of Slovenia ≈ 17 km away from the block 1 there are four SCI areas - types and habitats (SI3000238 Strunjanske soline s Stjužo, SI3000247 Piranski klif, SI3000249 Med Izolo in Strunjanom – cliff and SI3000307 Med Strunjanom in Fieso) and an SPA area - birds (SI5000031 Strunjan). With regards to the distance from the closest exploration block 1 point, the impact on the Natura 2000 areas in Slovenia is not expected. Cross-border impact is possible in case of accidents. The distance of the closest protection areas from the exploration block 1 is less than 17 km and impact on these areas is not expected.

15.4.1.4.13.2 The Republic of Italy

The perimeter of exploration blocks 1, 2, 3, 5, 7, 9, 12, 15, 18, 24, 25, 26 and 29 borders with the epicontinental belt of the Republic of Italy. Peripherally, in the northern part of the exploration block 1, there is a Natura 2000 area IT3330009 Trezze san Pietro e Bordelli (SCI) and a cross-border impact on that area cannot be excluded should the FPP implementation activities take place in the exploration block 1. In view of the above stated, before projects related to the exploration and production of hydrocarbons in the exploration block 1, consultations with the Republic of Italy should be conducted. Alternatively, it is suggested to reduce the surface of the exploration block 1 in its northern part. Perimeters of exploration blocks 18 and 24 are ≈ 22 km away from Natura 2000 areas IT911001 Isole Tremiti (SCI) and IT9110040 Isole

Tremiti (SPA) - Figure 8.10. With regards to distance from exploration blocks, the cross-border impact on Natura 2000 areas in Italy is not expected, except in case of possible accidents.
Protected sea areas in Italy are situated more than 20 km away from the exploration blocks so that the cross-border impact thereon is not expected.

15.4.1.4.13.3 Republic of Montenegro

FPP exploration blocks 28 and 29 border with the territorial sea of Montenegro. By inspecting the map of protected areas, as well as the Emerald Network based on which ecological network areas will be established, it can be concluded that a significant cross-border impact on the protected areas or on the Emerald Network areas in Montenegro is not to be expected.

15.4.1.4.14 Cumulative Impacts

With regards to described impacts possible in the course of FPP implementation, it can be concluded that carrying out of activities on all exploration blocks would cumulatively have a significant negative impact on the environment. This would especially be seen should the activities in the blocks be carried out simultaneously. Based on available data, the optimum number of exploration blocks in which implementation of operations would not significantly impact the environment, cannot be precisely determined. However, with regards to the Adriatic sea being a closed sea, as well as with regards to possible impacts, the framework assessment is that exploration (seismic exploration, well drilling) should not take place on more than three exploration blocks simultaneously. For hydrocarbon production operations, an assessment of the impact on the environment shall be carried out for each project within which a Study of the project impact on the environment will be developed which will assess the cumulative impact in relation to implemented operations in the exploration phase as well as in relation to a potential number of exploratory wells.

15.4.1.4.15 Assessment of the Fulfilment of Strategic Study Environmental Goals

Environment Component	Environmental Goal	Impact on the Fulfilment of Environmental Goal
Chemical Characteristics Noise Biodiversity Ecological Network Tourism Fisheries Marine and seabed pollution	Good status of the sea and the seabed	FPP implementation shall have multiple impacts on this environmental goal. All impacts range from insignificantly negative to positive, apart from the Ecological Network which in the part of a possible impact on birds shows an unacceptable negative impact. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions for impacts assessed as unacceptably
Chemical properties Noise Biodiversity Ecological network Fisheries	Good status of the marine species and habitats with a special emphasis on the marine mammals, turtles, fish, invertebrates and birds	FPP implementation shall have multiple impacts on this environmental goal. All impacts range from insignificantly negative to positive, apart from the Ecological Network which in the part of a possible impact on birds shows an unacceptable negative impact.

		negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions for impacts assessed as unacceptably
Cultural and historical heritage Tourism	Protected submarine cultural heritage and natural landscape	From the tourism aspect, the FPP implementation will have an insignificantly negative impact with regards to this environmental goal due to the implementation of measures of impact mitigation. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions. The impact on the cultural & historical heritage was not analysed separately, but the Study defines an implementation measure within this environment
Chemical Characteristics Noise Fisheries Tourism Maritime shipping, maritime transport and waterways Waste Management Socio-economic characteristics	Harmonised implementation of the Programme with regards to other economic activities	FPP implementation shall have multiple impacts on this environmental goal. All impacts range from insignificantly negative to positive. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the FPP implementation and has laid down alternative solutions.
Climate characteristics	Preserving the existing air quality and climate conditions	FPP implementation shall have an insignificantly negative impact on this environmental goal. The strategic study suggests regular follow up of the air quality condition.
Chemical properties Human health andQuality of life Waste Management Socio-economic characteristics Tourism	Protection of human health and the quality of life	FPP implementation shall have an insignificantly negative to insignificantly negative impact due to the implementation of measures of mitigation of impact on this environmental goal. The strategic study has defined measures to mitigate negative impacts and increase positive impacts of the
Chemical Characteristics Climate characteristics Biodiversity Ecological Network Marine and seabed pollution Fisheries Tourism Maritime shipping, maritime transport and waterways Shipping, marine Waste management Human health and Quality of life Socioeconomic characteristics Infrastructure	Mitigated accidents risk	Since it is not possible to define criteria for the assessment of impact of accidents on the environment at the level of assessment carried out by the Strategic Study, nor carry out the assessment of the impact on individual environmental components accordingly, the Study provides only an overview of potential accidents on individual environmental components, established based on the scientific data. It is expected that a detailed analysis of accidents' impact on environment for individual hydrocarbon exploration and production projects will process, during further procedures, assessments of the project impact on the environment/Appropriate assessment of the project impact on the ecological network. However, the Strategic Study has defined FPP improvement measures with the purpose of increasing positive impacts of the FPP implementation, and it also suggests regular follow up of various environment

15.5 Environmental protection measures

Component	Impact	FPP mitigation and improvement measures	Justification of the measure
Chemical propertie s	Changes in sea water pH, oxygen saturation, sea water nutrient and organic concentration levels resulting from the hydrocarbon exploration and production operations	1 In the area affected by the FPP implementation, in order to measure sea water pH, oxygen, nutrient and organic substance levels in the environment prior to the commencement of the operations, and to ensure their continuous monitoring during the operations and, in the case that the set parameter values are outside the estimated permitted interval, additional	As it may be concluded from previous monitoring results, the largest fluctuations of sea water dissolved oxygen and nutrient salt concentrations and pH were observed at stations with direct anthropogenic effects; in the immediate vicinity of exploration and production platforms, it may be expected that the values of these parameters will change.
Noise	Noise level increase	1 In the area affected by the FPP implementation, in order to build a noise dispersion model which takes into account the expected noise level and frequency caused by the FPP implementation as well as other noise	The noise dispersion model will provide a parameter to allow the assessment of noise pollution impacts on species endangered by it.
Marine and seabed pollution	Impact of discharging mud into the sea	1 Use water-base drilling mud. If there is a need to use other types of mud (oil-base, synthetic-base), it is required to obtain prior approval of competent authorities.	Water-base drilling mud has a significantly lower toxicity than synthetic-base or oil-base drilling mud.
Fisheries	Seismic surveying noise impact Impact of platform installation and exploration and production drilling Impact due to pipeline and supporting infrastructure installation Impact of platform removal	1. No exploitation of hydrocarbons in the immediate area of the Jabuka depression (surface area 305.38 km^2), 2. In the wider area of the Jabuka depression, which includes areas important for the spawning and recruitment of fish species, and in other areas important for fisheries, it is required to harmonize the FPP implementation with authorities and shareholders in the fisheries sector, 3. Harmonizatin of the time and place of seismic surveys and other exploration works with authorities competent for activities of fishing vessels, 4. Harmonization of the planned platform and pipeline locations with trawling areas.	The Jabuka depression is the main spawning grounds of economically significant fish species. Fishing activities take place in a part of exploration blocks, so it is required to harmonise the FPP implementation with competent authorities.
Tourism	Impact of platforms on "sun and sea" tourism	1 Production platforms and supporting infrastructure have to be located so that they do not disturb the view-points of interest for the "sun and sea" tourism. Platforms may not represent a dominant view from beaches, settlements and tourist zones	The visibility of platforms from the mainland is perceived as the one disturbing the view and may significantly reduce area attractiveness for the "sun and sea" tourism. This branch of the tourism sector is one of the key economic branches and it is closely linked with
	Impact of platforms on nautical tourism	2 Modification of blocks 14 and 17 by excluding highly attractive nautical tourism areas and, for block 11, in agreement with the Ministry of Tourism, adaptation and harmonization of hydrocarbon exploration and production operations with nautical tourism activities.	The installing of, primarily production, platforms may result in disturbance of landscape features of highly attractive nautical tourism areas. The islands of Central and Southern Adriatic are areas particularly attractive for nautical tourism, which represents an important and prosperous economic branch.

Biodiversity – whales and sea turtles	The impact of noise, primarily generated by seismic surveys and well drilling during the FPP operations	Prior to implementing the FPP operations: 1. make detailed noise dispersion models based on actual data on the environment in which operations will be conducted,	As sea turtles and whales are especially sensitive to increased noise levels, special protection measures are proposed for them.
		2. determine the range, number and potential seasonality of presence of individual vulnerable species, - determine the acceptable variation in resulting values, 3. determine a detailed operating procedure for monitoring and protection of the listed species during performance of each particular operation representing a source of noise, 4. apply the Guidelines to address the	
Other biodiversity	Noise generated by FPP operations	1 Prior to implementing the FPP for the licensee's Programme of exploration activities, procedures of Environmental Impact Assessment/Appropriate	In order to avoid cumulative effects of seismic surveys, they must be time-delayed in individual blocks.
	Occupying a part of the water area	2 Prior to exploratory drilling, which involves anchoring of drilling vessels, it is necessary to determine the composition of the habitat at the position for drilling in order to determine potential presence of the	Marine habitats in Croatia are mostly unexplored, so locations of rare habitat types, such as the Coralligenous habitats, are unknown.
	Discharge of Drilling Mud and Well Cuttings	3 It is proposed to use a cuttings dryer which removes drilling mud from cuttings in order to prevent the forming of noticeable cuttings formations on the seabed in the area around the platform.	With the additional removal of drilling mud from well cuttings, they become cleaner and less toxic to the marine environment. The cumulative effect of cuttings and mud formations on the seabed is avoided by keeping the distance for mud and cuttings discharge (one platform discharges mud in a 500 m radius).
	Well testing (hydrocarbon flaring)	4 Use of high-efficiency flares on platforms, with combustion efficiency of 99%.	In order to reduce an incomplete combustion and potential falling of hydrocarbon drops into the sea, high efficiency flares (burners) are used.
	Discharge of formation and technological water (release of hydrocarbons)	5 Monitoring of the sea surface when testing hydrocarbon reservoir deliverability.	Ensurance that there is no visible glow on the sea surface.
	Light pollution	6 For lighting platforms, the lighting that is least attractive to birds should be used.	Change of type of lighting will attract birds to a lesser extent, resulting in reduced number of bird deaths from collision with the platform.
	Increased traffic of vessels and helicopters	7 Regular helicopter routes should be defined so that sea-bird nesting areas are avoided, at least during a specific part of the year.	The helicopter noise may result in leaving the nest, therefore it is required that helicopters do not fly near sea-bird nesting areas.
	Production platform and pipeline removal	8 After the end of production stage, the platform and pipeline constructions should be decommissioned as in the Rigs-to-Reef programme. Pipelines should be subject to chemical neutralization and left in the sea.	Over several decades, a sea platform is overgrown with different organisms, transforming it into an artificial reef. The removal of the platform would also remove the newly created ecosystem. The removal of the pipeline disturbs the seabed again and increases the possibility of marine pollution.

Ecological network	Noise impact on bird nesting	1 The project zone should be moved 1 km from the relevant area of the ecological network Pučinski otoci (Pelagic Islands).	Precautionary measure for birds nesting on Pučinski otoci
	- reduction in food sources for sea-birds - bird deaths due to collision with platforms and hydrocarbon flaring - removal of platforms	2 After implementing the appropriate assessment of the project impact on the ecological network, appropriate mitigation measures need to be prescribed.	As the locations of planned activities are unknown at this FPP stage, appropriate measures will be prescribed depending on the exact location and scope of the project.
Maritime shipping, maritime transport and waterways	Changes in usual shipping routes	1 Alignment of possible corrections in usual shipping routes with competent maritime traffic authorities.	Considering the increased maritime transport and possible construction of new platforms, all maritime-traffic activities of the FPP implementation should be harmonized.
Cultural and historical heritage	-	1 If the exploration phase of the FPP implementation results in finding new unrecorded cultural heritage sites, it is required to suspend all works and inform the competent authority thereof	Cultural heritage in the Adriatic is a part of the rich cultural and historical heritage of the Republic of Croatia which should be preserved.
Cross-border impact	Impact on the ecological network area IT3330009 Trezze san Pietro e Bordelli	1 Reduction of the surface area of the northern part of the block.	Precautionary measures for conservation objectives of Natura 2000 area

15.6 Environmental monitoring

Component	Indicator	Indicator monitoring tool	Person responsible for monitoring	Data source	Monitoring timeframe
Chemical properties	Sea water pH value in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Oxygen saturation level in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Nutrient concentration (dissolved inorganic nitrogen, orthophosphates, orthosilicates, etc.) in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Organic substance level (DOC, TOC, POC) in the immediate vicinity of the discharge point of all substances discharged into the sea during FPP	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Climate characteristi cs	Chemical composition of all gases discharged into the environment during hydrocarbon exploration and production	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Noise	Noise level in the sea in all areas covered by FPP operations	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Marine and seabed pollution	Pollutant concentration (ecotoxic metals, organotin compounds, persistent organic pollutants) in the sea and on the seabed in the immediate vicinity of exploratory and production wells	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
Fisheries	Quantity of commercial sea species in the Adriatic	Regular monitoring	Fisheries authority	Regular reports	During exploration and production operations
	Distribution of commercial sea species by age	Regular monitoring	Fisheries authority	Regular reports	During exploration and production operations
Biodiversity	Number and distribution of loggerhead sea turtle (*Caretta caretta*) in the blocks	Regular monitoring	Licensee	Regular reports	Baseline, during exploration, during production and

Component	Indicator	Indicator monitoring tool	Person responsible for monitoring	Data source	Monitoring timeframe
					during decommissioning
	Number and distribution of common bottlenose dolphin (*Tursiops truncatus*) in the blocks	Regular monitoring	Licensee	Regular reports	Baseline, during exploration, during production and during decommissioning
	Number and distribution of European shag (*Phalacrocorax aristotelis desmarestii*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number and distribution of Cory's shearwater (*Calonectris diomedea*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number and distribution of yelkouan shearwater (*Puffinus yelkouan*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number and distribution of Audouin's gull (*Larus audouinii*) in the blocks*	Regular monitoring	Licensee	Regular reports	Baseline, during exploration and during production
	Number of collisions of common crane (*Grus grus*) with mining facilities*	Regular monitoring	Licensee	Regular reports	During exploration and production operations
	Monitoring of marine pollution by surface hydrocarbons in the immediate vicinity of mining facilities	During well production capability testing	Licensee	Report upon activity completion	During exploration operations
	Monitoring of bird migration in the immediate vicinity of mining facilities during hydrocarbon flaring	During well production capability testing	Licensee	Report upon activity completion	During exploration operations

* This monitoring measure should by applied if the FPP operations are conducted in an area in which they can affect the above strictly protected species

15.7 Conclusions and recommendations

The Strategic Study of the Likely Significant Environmental Impact of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic has identified potentially significant impacts of the FPP implementation on respective environmental components and proposes appropriate measures which should mitigate the identified impacts. All operations to be carried out within the FPP implementation shall require the procedures of Environmental Impact Assessment/Appropriate Assessment of the project impact on the ecological network in accordance with regulations.

15.8 Impact on Tourism

The visibility of platforms from the mainland is perceived as disturbing the view and may significantly reduce area's attractiveness for the "sun and sea" tourism. This branch of the tourism sector is one of the key economic branches and it is closely linked with landscape features. The installing of, primarily production, platforms may result in disturbance of landscape features of highly attractive nautical tourism areas. Islands of the Central and Southern Adriatic are areas particularly attractive for nautical tourism, which represents an important and prosperous economic branch.

Recommendation: Production platforms and supporting infrastructure have to be located so that they do not disturb the view-points of interest for the "sun and sea" tourism. Platforms may not represent a dominant view from beaches, settlements and tourist zones. Blocks 14 and 17 should to be modified in order to exclude highly attractive nautical tourism areas. For block 11, in agreement with the Ministry of Tourism, adaptation and harmonization of hydrocarbon exploration and production operations with nautical tourism activities is needed.

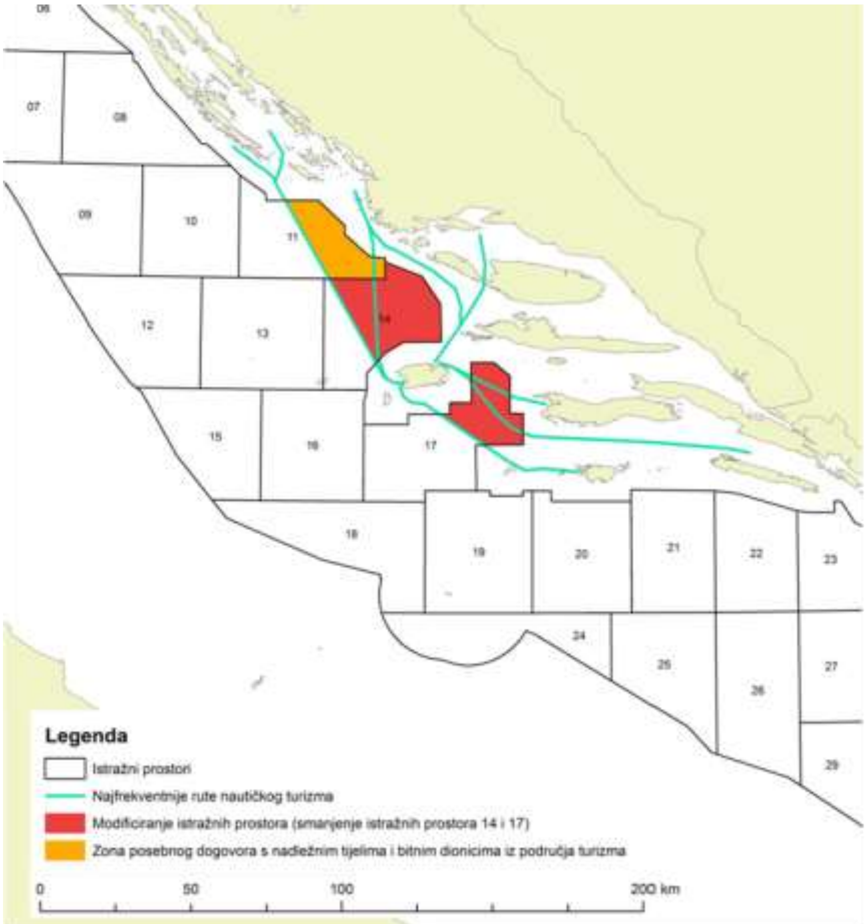


Figure 15.2 Proposed modifications of blocks in order to prevent conflicts between FPP and nautical tourism

15.8.1 Impact on Fisheries

Impacts on fisheries are possible in different phases of FPP implementation. Based on the baseline studies analysis regarding fishing vessels, areas specifically important for fishery have been defined. The immediate area of Jabučka kotlina (surrounding the island of Jabuka) is particularly sensitive, as well as its surrounding area where, in order to protect this extremely important fishery resource area, a zone of prohibition regarding trawling is planned to be implemented, as well as a no-take zone. The boundaries of this area have been determined based on the scientific research conducted by Croatian and Italian scientists. The known impacts on fisheries refer to the impact created by noise during seismic surveys, the impact of platform installations and of exploratory and production drilling, the impact arising from installing pipelines and the accompanying infrastructure, as well as the impact from platform removal.

Recommendation: No petroleum production is to be carried out in the immediate area of Jabučka kotlina (surface area of 305.38 square kilometres), while seismic surveys and exploratory drilling shall not be carried out during the spawning and recruitment of fish species (parts of blocks 12, 13 and 15). In the surrounding area of Jabučka kotlina (a future no-take zone, parts of blocks 10, 11, 12, 13 and 15), FPP activities involving a possible impact on fish spawning shall be carried out in agreement with the Department of Fisheries. In other areas economically important for fisheries, FPP activities shall be carried out in agreement with the competent authorities and important stakeholders in the area of fisheries (parts of

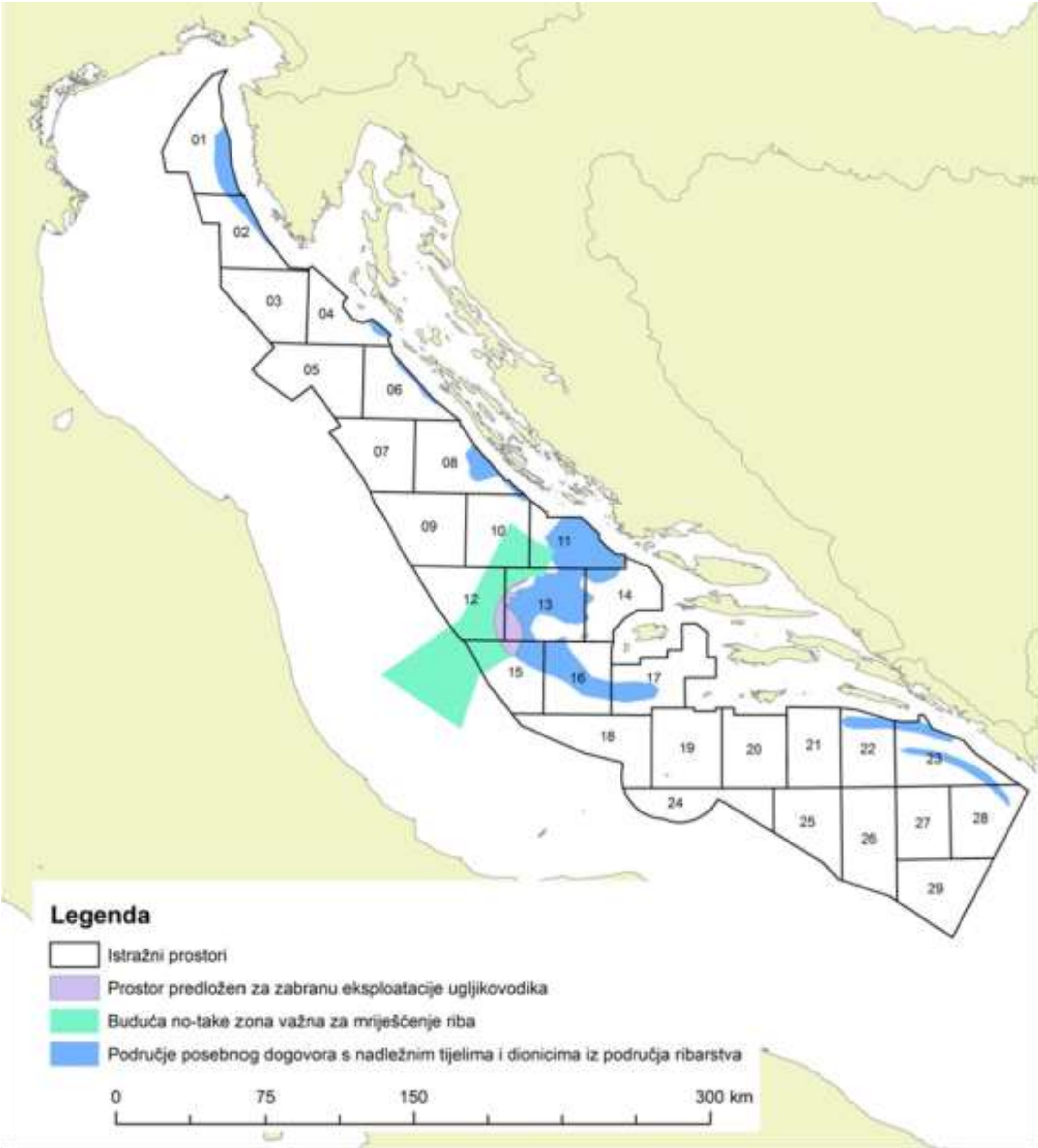


Figure 15.3 Areas important for fisheries in relation to blocks

15.8.2 Impact on biodiversity

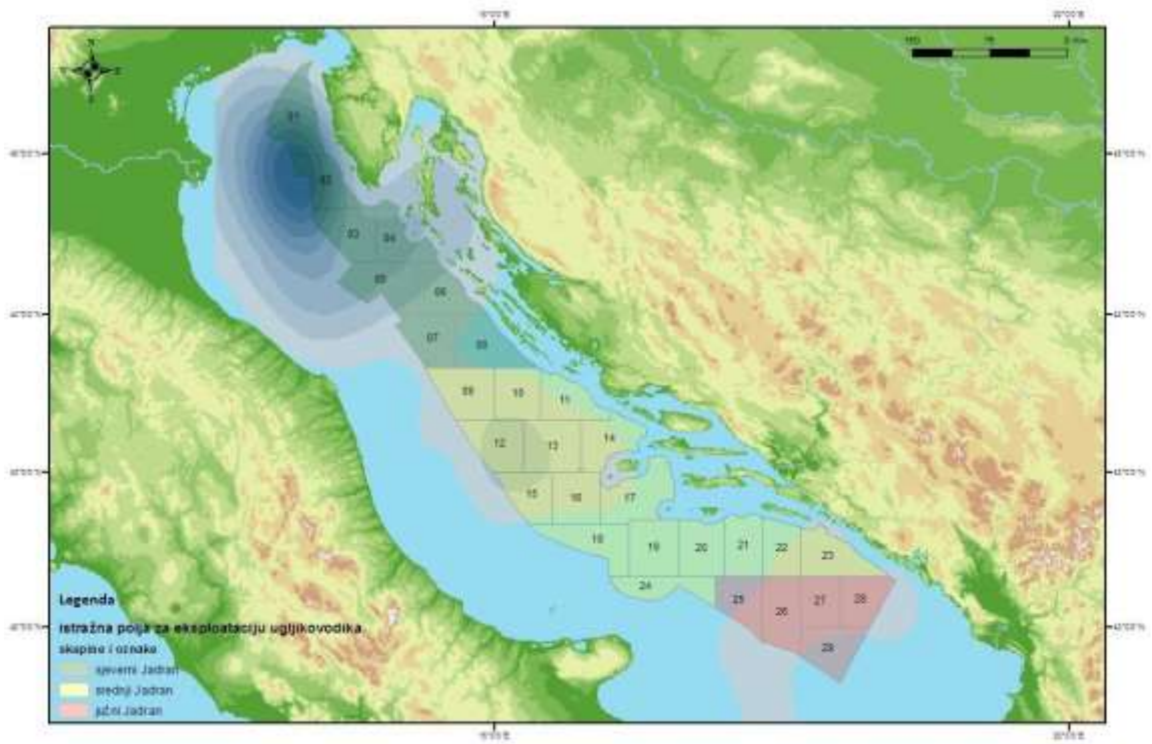
15.8.2.1 Cetaceans and sea turtles

The impact of noise, primarily generated by seismic surveys and well drilling during operations of the FPP, is the most significant impact on cetaceans and sea turtles. The impact of noise pollution on cetaceans is especially significant, as they are greatly dependent on sound which they use as the primary sense, which plays an important role in social interactions and sense biology. The impact of anthropogenic noise can cause simple problems with sound detection, but can also lead to disturbance, changes in behaviour, hearing damage and serious injuries. The effect will largely depend on the exposure time, sound pressure and total sound wave energy, as well as their frequency. The development of criteria to assess the impact of noise on cetaceans has been proposed by various researchers. Different criteria are used to establish impact zones and enable the assessment of risks and adoption of impact mitigation measures. At the same time, virtually no measures have been actually tested in the natural environment, which means their efficiency is questionable.

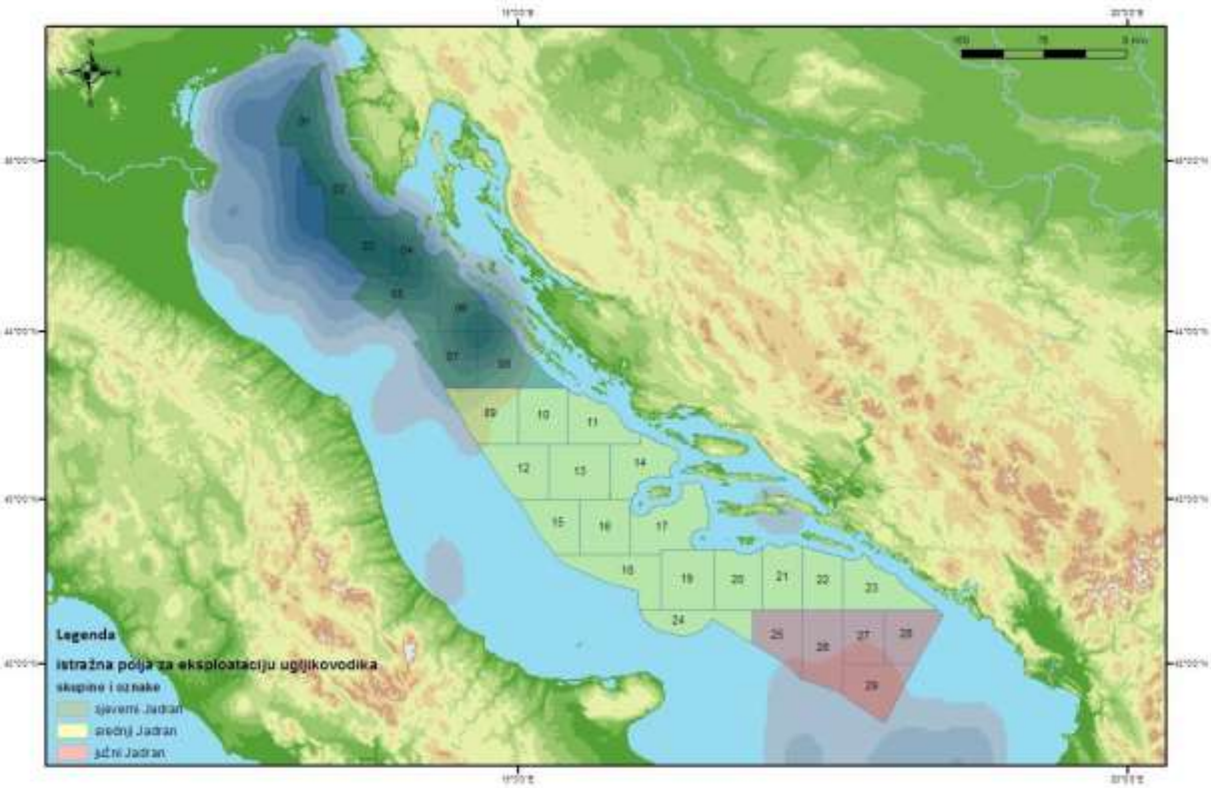
Anthropogenic noise may have varied impact on sea turtles, which can be classified in the following categories: death and injury, effects on hearing, effects on behaviour; and population-level effects on fitness and survival.

Currently it is not possible to unambiguously define the impact of noise on them, as there is a significant lack of information on the distribution, abundance and the possible impact of noise. Research done in experimental / induced conditions, as well as monitoring side effects, indicate a possibly significant negative impact which has not been confirmed in natural habitat conditions of the species. Noise caused by seismic surveying and well drilling is limited in duration, and there are interactions with other permanent sources of noise in the marine environment.

Recommendation: Prior to implementing the FPP activities it is necessary to make detailed noise dispersion models based on actual data about the environment in which the activities will be conducted, determine the range, number and potential seasonality of presence of individual vulnerable species, determine the acceptable variation in resulting values and determine a detailed operating procedure for monitoring and protection of the listed species during performance of each particular operation representing a source of noise. For the entire time of the FPP implementation, it is necessary to apply the Guidelines to address the impact of anthropogenic noise on cetaceans in the ACCOBAMS area.



Dobri dupin (Tursiops truncatus) - područje velike brojnosti - Izvor: ISPRA i BWI



Glavata želva (Caretta caretta) - područje velike brojnosti - Izvor: ISPRA i BWI

15.8.2.2 Ecological network

Possible impacts of implementing the FPP on the species and habitats of the ecological network can be sorted by steps defined by the FPP in three groups: impacts during exploration, impacts during production and impacts during the removal of mining facilities and plants. The impacts defined in this way tell us about the time interval when they can be expected. The impacts during the exploration period are expected in the first 2-7 years during the exploration works. Then, there are impacts of platforms and pipelines installation, hydrocarbon production and additional exploration. These impacts are expected during the next 25 years, at least, depending on the capacity of the discovered reservoirs. The last category of impacts is expected during the removal of mining facilities and plants. Impacts on targeted habitats within the POVS area HR3000099 Brusnik and Svetac, HR3000100 Island of Jabuka underground, HR3000121 Island of Palagruža underground, HR3000122 Islet of Galijula, HR3000423 Jabuka Pit are expected mainly during exploratory well drilling, installing platforms and removing them later. In terms of the time and space, these operations are very limited, they are not conditioned by the marine habitat type, but the sea depth, and therefore, negative impacts are expected only if platforms were installed in exceptionally rare and, in terms of their surface area, small habitats (e.g. coral reefs): The analysis of possible impacts indicates a potentially significant negative impact on nesting populations of seabirds. Pučinski otoci (Pelagic islands and islets) (sv. Andrija, Svetac, Kamnik and Palagruža) are the only nesting locations of populations of the *Puffinus yelkouan* (Yelkouan shearwater) and *Calonectris diomedea* (Cory's shearwater) species in Croatia, as well as the majority of the *Falco eleonorae* (Eleonora's falcon) population which could be endangered by the impacts caused by the FPP implementation to such an extent that they permanently leave the nesting area.

Recommendation: Moving the project zone 1 km from the relevant area of the ecological network Pučinski otoci (Pelagic Islands) is recommended as a precautionary measure for birds nesting on Pučinski otoci (blocks 13, 14, 16 and 19). Conducting measure defined for cetaceans and sea turtles is also recommended.

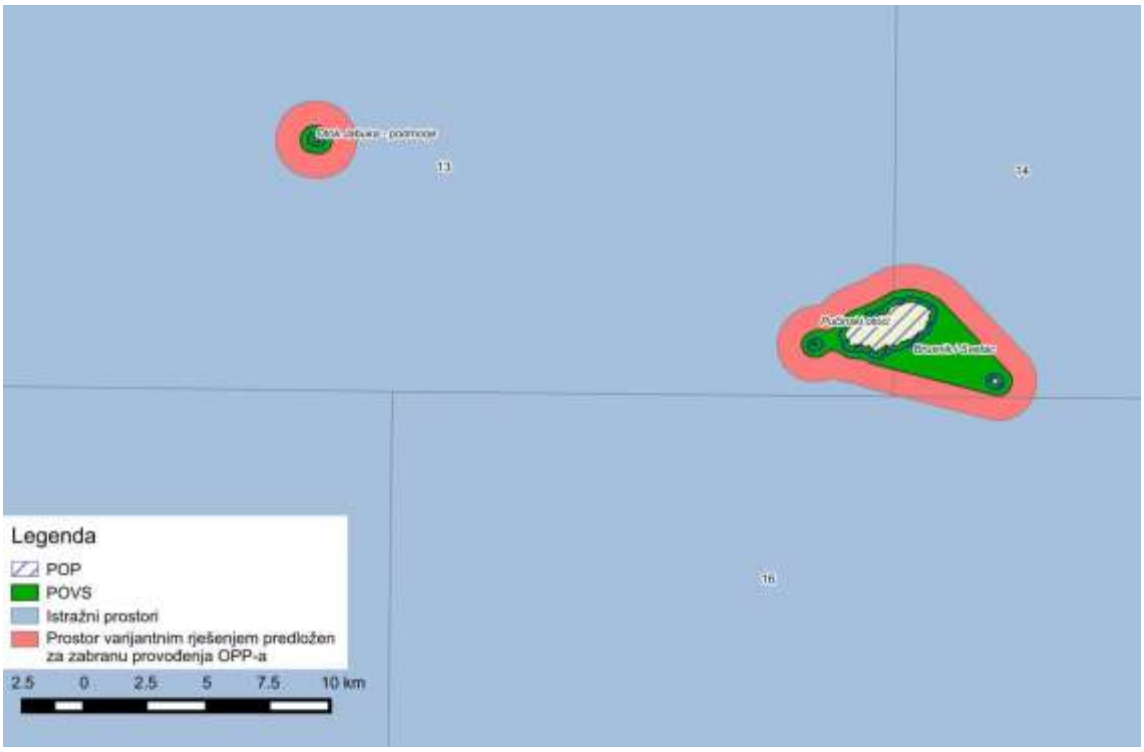


Image 15.4 Proposed modifications of blocks for the protection of conservation goals of the Ecological network NATURA 2000 in the areas: Island of Jabuka - underground, Pelagic Islands, and Brusnik and Svetac

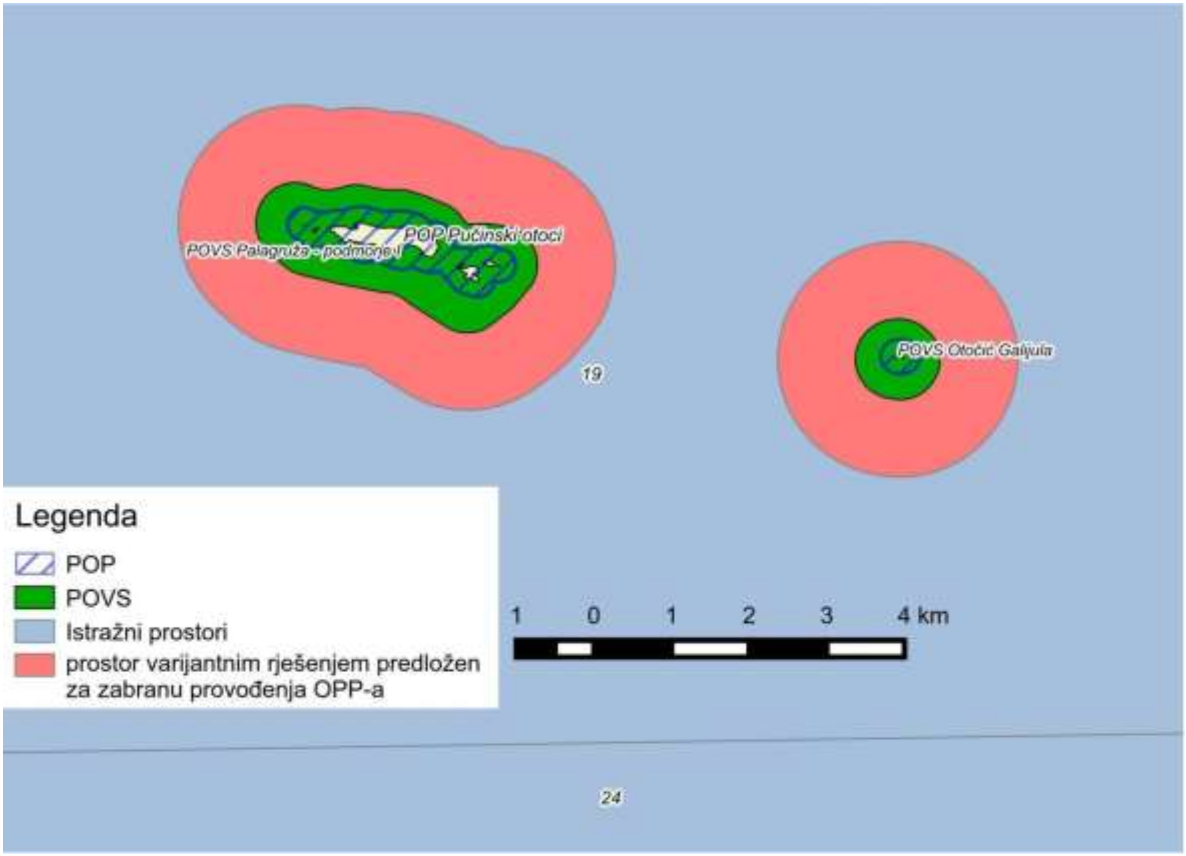


Image 15.5 Proposed modifications of blocks for the protection of conservation goals of the NATURA 2000 ecological network in the areas: Island of Palagruža - underground, Pelagic Islands and Islet of Galijula

15.8.2.3 Coralligenous communities

A part of the water area will be occupied due to the implementation of the FPP operations. Marine habitats in Croatia are mostly unexplored, so locations of rare habitat types, such as the Coralligenous habitats, are unknown.

Recommendation: Prior to exploratory drilling, which involves anchoring of drilling vessels, it is necessary to determine the composition of the habitat at the position for drilling in order to determine potential presence of the coralligenous

15.8.3 Cultural and historical heritage

To this day, numerous underwater sites which significantly contributed to the improved knowledge of maritime history have been discovered and explored and their value for both Croatian and world's culture and science is indisputable (such as remarkably preserved and artistically exquisite statue from the Antiquity known as the Croatian Apoxyomenos discovered near Lošinj or numerous shipwrecks from the antiquity period carrying amphorae or more recent shipwrecks such as the Baron Gautsch shipwreck. Exact locations of the sites will be forwarded to investors awarded licenses granting them the right to explore hydrocarbons and direct grant of a concession in the event of a commercial discovery. On each of the sites all protection measures provided for protected underwater archaeological sites need to be taken, in the 300m diameter area, which constitutes a site's safety zone.

Recommendation: On each of the sites all protection measures provided for protected underwater archaeological sites need to be taken, in the 300m diameter area, which constitutes a site's safety zone. If the exploration phase of the FPP implementation results in finding new unrecorded cultural heritage sites, it is required to suspend all works and inform the competent authority thereof.

15.8.4 Cross-border impact

The FPP analysis found a possible cross-border impact on the Natura 2000 IT3330009 Trezze san Pietro e Bordelli (SCI) Area, located on the edge of the northern part of Block 1.

Recommendation: Reduction of the surface area of the northern part of block 1.

Figure 15.6 Proposal for forming Block 1 (reduce peak area)

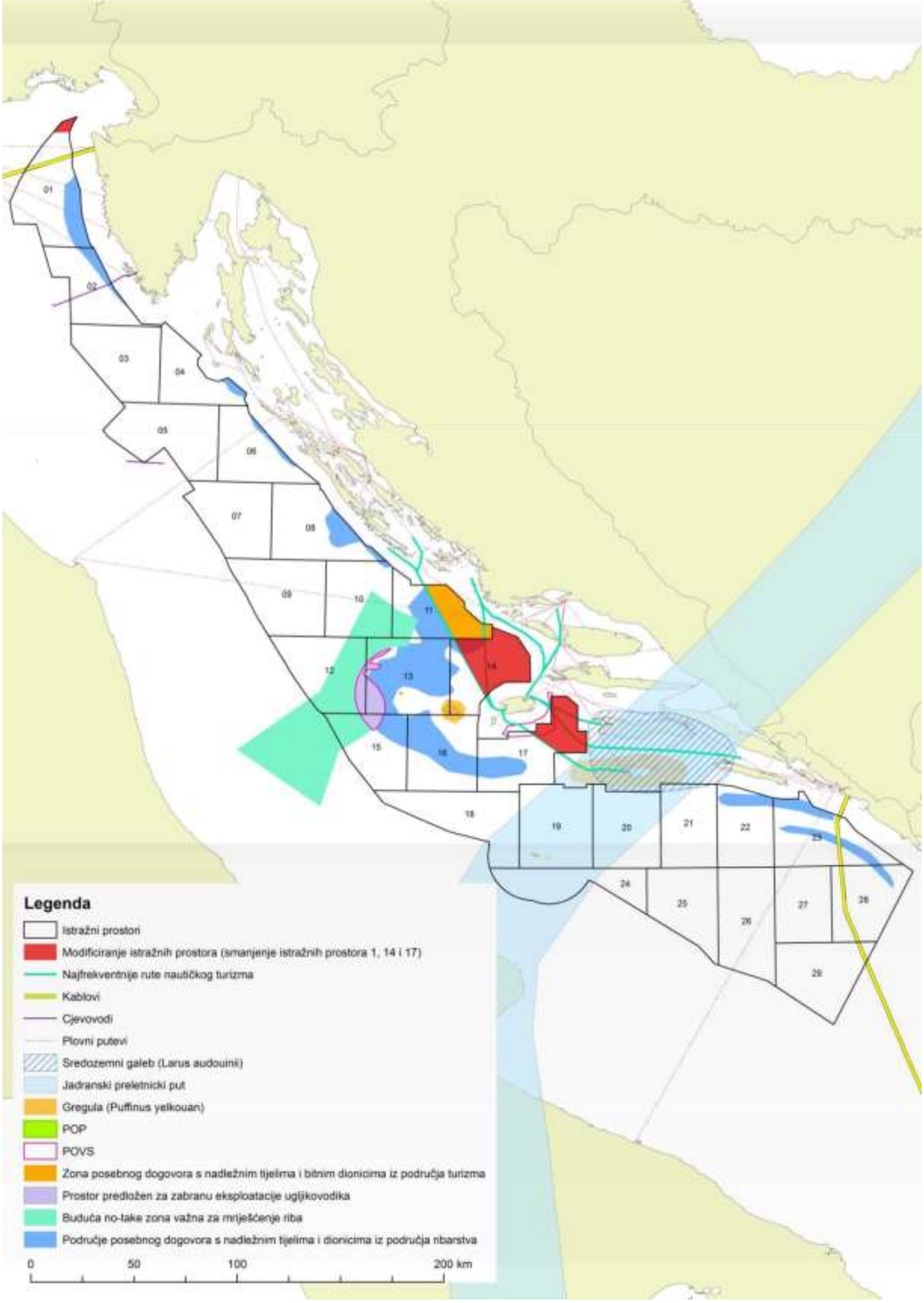
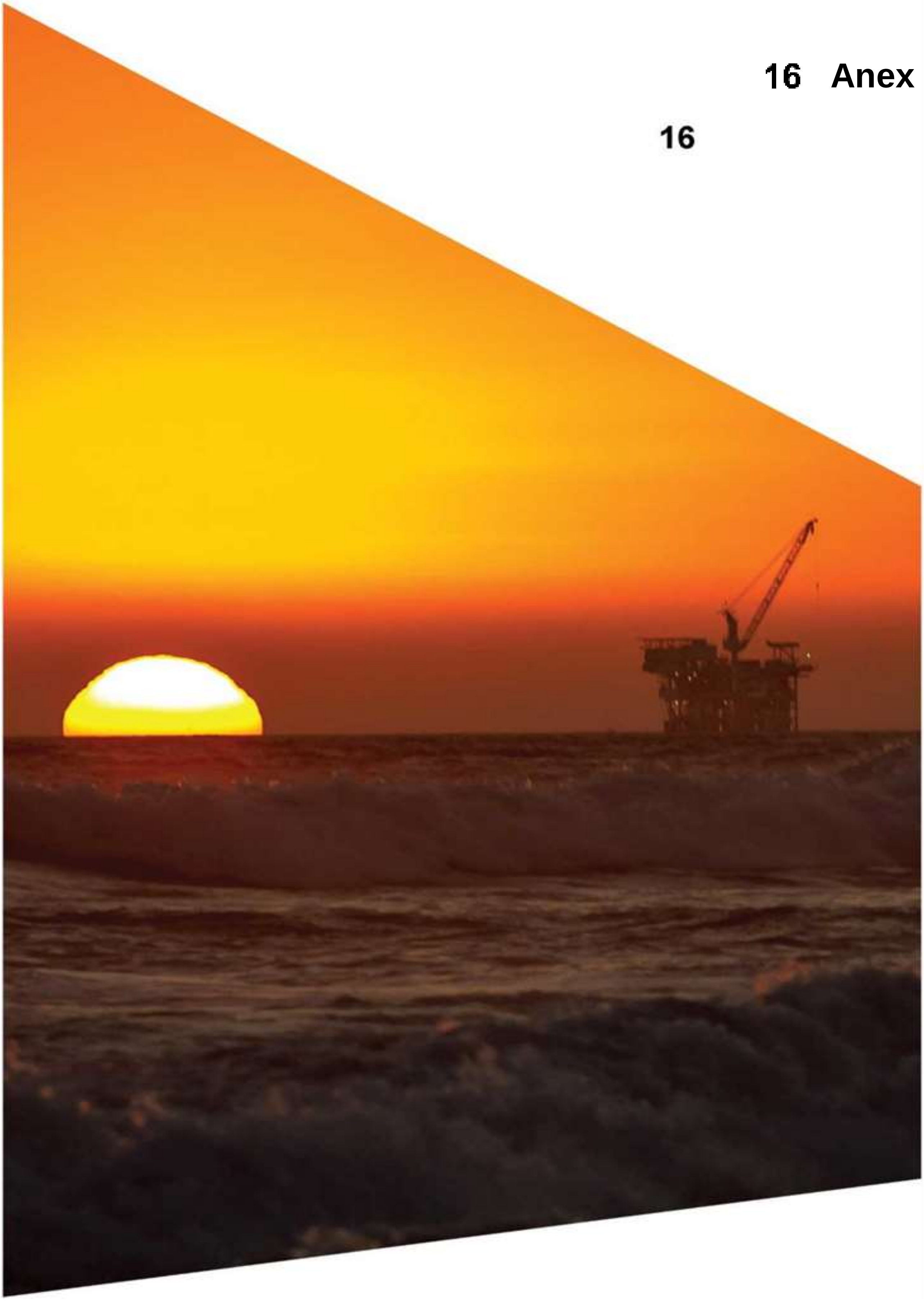


Figure 15.7 Overview of environmental components that may be impacted by FPP implementation

Based on the environment components status and assessment of potential FPP implementation, protection measures and monitoring of the environment was proposed. Based on the above, changes in size and shape of blocks were defined: 1 (due to possible cross-border effect), and 14 and 17 (due to possible conflict with nautical tourism). The following recommendation refers to the ban on hydrocarbon production in the narrow area of the Jabuka Pit – covering the area of 305.38km2, as well as the ban on seismic exploration and exploration wells during spawning and recruitment of fish species (parts of blocks 12, 13 and 15). Due to the estimated impact on the Natura 2000 areas, it is recommended to move the exploration and production of hydrocarbons zone 1 km from the area of the ecological network in fields 13,14,16 and 19 where the Pelagic Islands (Pučinski otoci) are located. For block 11, in agreement with the Ministry of Tourism, adaptation and harmonization of hydrocarbon exploration and production operations with nautical tourism activities is needed. Due to possible effects on fishery on parts of blocks 1, 2, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17, 22, 23 and 28, petroleum operations should be performed in agreement with competent authorities and significant stakeholders from the fisheries sector. A possible impact on whales and sea turtles was assessed as well, which is why before implementing FPP, sound propagation models need to be created. These models will be based on actual data about the environment in which the activities will be performed, distribution, numbers and possible seasonality with regard to certain sensitive species determined, allowed variation of determined values established and detailed operational procedure for monitoring and protection of these species when carrying out each activity which acts as a source of noise determined,. The conclusion from the assessment of a possible cumulative impact was that the exploration should not be conducted on more than three blocks simultaneously.

16 Anex

16



Annex 1

Decision on implementing the procedure of Strategic Environmental Assessment of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic

Pursuant to Article 66 of the Environmental Protection Act (Official Gazette 80/13) and Article 4, paragraph 2 of the Regulation on strategic environmental assessment of plans and programmes (Official Gazette 64/08), the Minister of Economy hereby issues the

DECISION

on implementing the procedure of Strategic Environmental Assessment of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic

I

With the adoption of this Decision, the procedure of Strategic Environmental Assessment of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic (hereinafter: strategic assessment) shall be initiated.

II

The strategic assessment shall be implemented by the Ministry of Economy (hereinafter: the Ministry) competent for preparing a draft proposal of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic.

III

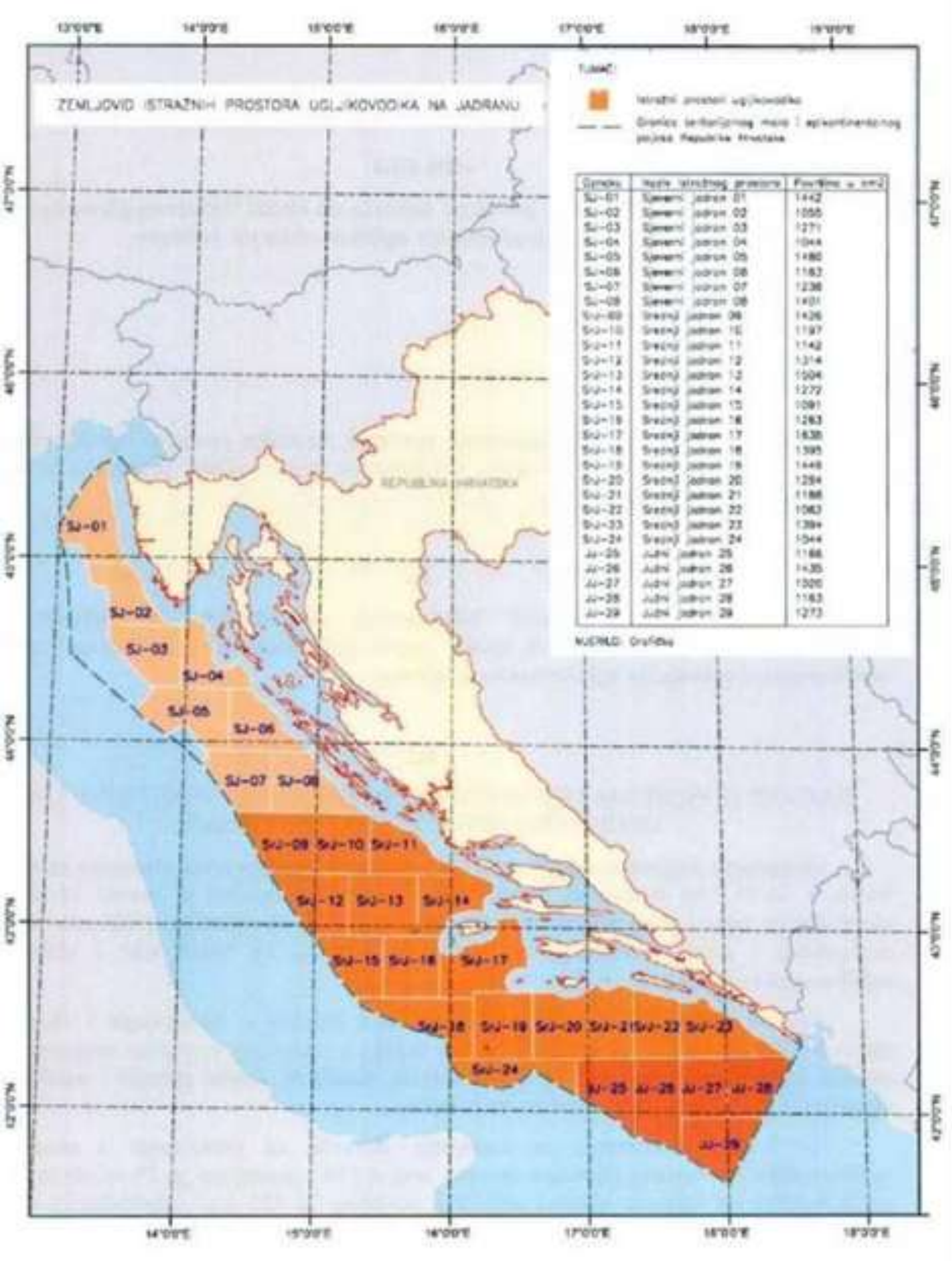
REASONS FOR ADOPTION AND IMPLEMENTATION OF THE STRATEGIC ENVIRONMENTAL ASSESSMENT OF THE FRAMEWORK PLAN AND PROGRAMME

The entry into force of the Act on Exploration and Production of Hydrocarbons (Official Gazette 94/13 and 14/14) on 30 July 2013 allowed the development of exploration and production of oil and gas in the Republic of Croatia in line with global practices, thus allowing for the public tendering for issuing licences for exploration and production of hydrocarbons in the Adriatic.

The public tendering, pursuant to provisions of the Act on Exploration and Production of Hydrocarbons, shall bring about the opening of the market, in line with the best global practices, to foreign investors who will, complying with the highest nature and environmental protection standards, be able to explore and exploit hydrocarbons in the Adriatic.

The 1st offshore licensing round for licences for the exploration and production of hydrocarbons (Official Gazette 42/14) included 29 hydrocarbon blocks in the Adriatic on the total approximate surface of 36,822 km^2, divided based on their water depth (Northern Adriatic, Central Adriatic and Southern Adriatic - Figure 1), considering protected areas and subsea geological structures.

Figure 1 Hydrocarbon blocks in the Adriatic



In accordance with the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic (hereinafter: the Framework Plan and Programme - Annex 1), the flow and the scope of the activities are divided into the exploration and the production period. Exploration operations shall be performed for the initial 5 years, with a possibility of 1-year extension. The said operations include primarily 2D and 3D seismic acquisition and exploratory drilling, as well as many other analytical studies the joint purpose of which is to collect geological and geophysical data with the aim of obtaining accurate hydrocarbon potential assessment and recognition of geological structures (gravity, geochemical, magnetic, magneto-telluric, transient electro magnetic, and bathymetric surveys, seabed sampling, satellite gravity survey, environmental baseline survey, environmental impact assessment of operations). In the case of positive results, this will be followed by the production period whose main characteristics are development of the reservoir development studies, development drilling and well completion, construction of production plants and, finally, production of hydrocarbons. The foreseen term of the production period is 25 years, with a possibility of extension.

The Framework Plan and Programme is developed with the aim of as accurate as possible monitoring of the operations concerning exploration and production of hydrocarbons in the Adriatic, issuance of licences, conclusion of agreements, determination of fees, infringement provisions and quality inspection, monitoring and foreseeing of the status of hydrocarbon reserves in the Adriatic, as determined under the Act on Exploration and Production of Hydrocarbons. The implementation of the Framework Plan and Programme is also essential for better efficiency and management of hydrocarbons, as also guaranteed under the Constitution of the Republic of Croatia.

The listed Framework Plan and Programme was drafted pursuant to the Decision of the Government of the Republic of Croatia, CLASS: 022-03/14-04/98, REG. NO: 50301-05/18-14-4 of 27 March 2014, on the Implementation of the Procedure for Issuing Licences and Publication of Public Tendering for Issuing Licences for Exploration and Production of Hydrocarbons in the Adriatic and the Decision of the Government of the Republic of Croatia, CLASS: 022-03/14-04/98, REG. NO: 50301-05/18-14-2) of 27 March 2014 on the Content, Terms and Conditions and Selection Criteria in the Tender for Exploration and Production of Hydrocarbons in the Adriatic. In accordance with the listed decisions, on 2 April 2014 the Government of the Republic of Croatia published the documentation for the first licensing round for licences for exploration and production of hydrocarbons in the Adriatic o, which set out the provisions for potential hydrocarbon exploration and production operations as well as borders of blocks, for which opinions and approvals were provided by:

- Ministry of Construction and Physical Planning, Directorate for Physical Planning, Sector for the Physical Planning System,
- Ministry of Environmental and Nature Protection,
- Ministry of Environmental and Nature Protection, Nature Protection Directorate,
- Ministry of Maritime Affairs, Transport and Infrastructure, Ministry of Defence.
- Ministry of Tourism,
- Ministry of Culture,
- Ministry of the Interior.

Although a series of aforementioned activities relating to exploration and production of hydrocarbons in the Adriatic has already been present for several decades, the former practice failed to include the development of the strategic assessment. However, by the accession of Croatia to the European Union as well as by adoption of a whole series of directives and documents relating to environmental and nature protection measures, the development of the strategic impact study became mandatory.

Considering that the listed activities of the Framework Plan and Programme of Exploration and Production of Hydrocarbons may have particular impact on the area of the Adriatic Sea, and for the purpose of preventing adverse impacts, the strategic assessment shall be developed in an integrated and systematic approach, taking into account the existing environmental conditions and complying with the national and European legislative framework.

The development of the strategic assessment complies with the European legislative system, namely Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment, Directive 92742/EEC on the conservation of natural habitats and of wild fauna and flora, Directive 97/11/EC on the assessment of the effects of certain public and private projects on the environment and Directive 2009/147/EC on the conservation of wild birds, which prescribed the implementation of the strategic assessment for plans and/or programmes that may have impacts on the ecological network of special conservation areas (Natura 2000).

IV

SCOPE OF STRATEGIC ASSESSMENT OF THE FRAMEWORK PLAN AND PROGRAMME OF EXPLORATION AND PRODUCTION OF HYDROCARBONS IN THE ADRIATIC

The Programme includes a portion of the Croatian continental shelf and the territorial sea, covering the area of 36,822 km^2, in which 29 hydrocarbon blocks are situated, the sizes of individual blocks ranging from 1,020 to 1,635 km2. The blocks that are subject to public tendering are divided in three groups (Northern Adriatic, Central Adriatic and Southern Adriatic) based on their water depth. The shallow offshore (Northern Adriatic), covering depths up to 100 m, includes 8 hydrocarbon blocks, the central offshore (Central Adriatic), with sea depths over 100 m, includes 8 hydrocarbon blocks and the deep offshore (Southern Adriatic), with sea depths over 1,000 m, includes 5 hydrocarbon blocks.

The eastern border of the tendering area is determined by the line 10 km away from the coast, and 6 km away from the external island line, while the remaining borders of the project area are determined by the international agreements concluded with the neighbouring countries.

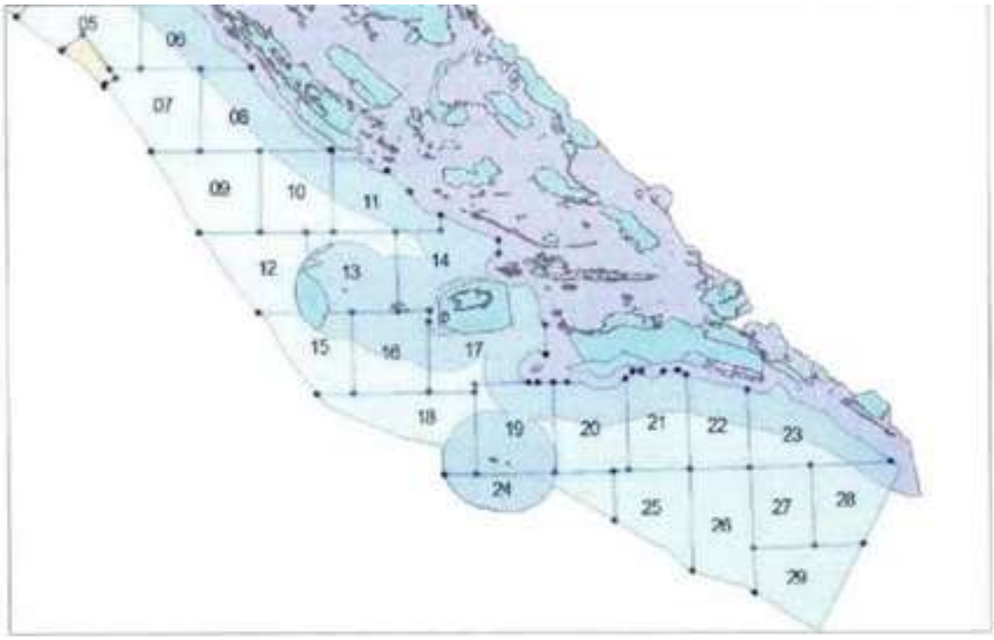
Considering the fact that the Republic of Croatia is a part of the coherent European ecological network NATURA 2000 and that there is overlapping of separate habitats of special interest with four proposed blocks (blocks 12, 13 15 and 17 - Figure 2.), these areas shall be subject to additional consideration for the purposes of assessment of protection measures.

These are separate areas called the Jabuka depression, seabed area of the island Jabuka, Pučinski otoci (separate habitat under Directive 2009/147/EC on the conservation of wild birds), Galijula and Palagruža.

The estimated time for developing the strategic assessment is 4 to 6 months and the final completion date is February 2015.

The study shall be prepared in Croatian and English language.

Figure 2 Overlapping of separate habitats of special interest with four proposed blocks



V

STRATEGIC ASSESSMENT OUTLINE

The purpose of strategic assessment is to define, describe and assess the likely significant environmental impacts of implementing the Framework Plan and Programme and alternative options, taking into account the objectives and geographical scope of the Framework Plan and Programme. As the Framework Plan and Programme is implemented in the area where historical data in the field of exploration and production of hydrocarbons already exist, those data shall be taken into account.

The strategic environmental assessment shall contain in particular:

1. Brief outline of the contents and main objectives of the Framework Plan and Programme.

2. Outline of the existing data on the current state of the environment and the likely evolution thereof without implementation of the Framework Plan and Programme, which shall contain the following:

    - physical data on meteorological and oceanographic conditions, state of the seabed and state of the air,

    - biological data on plankton communities (phyto and zoo) benthic communities (vagile and sessile benthic organisms), benthic flora on, in or near the seabed, fish communities in the sea water column, bird communities, sea mammals, turtles and other protected and/or endangered animals,

    - socioeconomic data on commercial fisheries, fish farming, tourism, telecommunications (underwater cables), etc., maritime shipping, maritime transport, waterways, archaeological sites and cultural heritage.

3. Description and types of activities related to exploration and production of hydrocarbons expected in the relevant block and their consequent environmental impacts (such as impacts of air waves during 2D and 3D seismic surveying, discharge of liquid waste e.g. mud,

seabed disturbances generated by drilling, sea water column disturbances generated by support vessels, disturbances generated by helicopters, etc. (Table 1).

4. Description of the existing control and protection measures, including the measures to prevent, reduce, mitigate and offset adverse environmental effects of implementing the Framework Plan and Programme, and existing and envisaged monitoring measures.

5. Identification of the likely impacts that the expected activities of the Framework Plan and Programme could have on the environment and selection of special areas related to Natura 2000 habitats.

6. Recommended additional control, protection and monitoring measures.

7. List of potential alternative options (if established and if any).

8. Summary of the above presented in non-technical language.

Table 1

PERIOD	ACTIVITY	LIKELY IMPACT OF FACTORS
EXPLORATION	2D and 3D seismic surveying	impact of air-blasts on sea mammals and turtles, fish and planktons
		impact on the maritime traffic and fisheries
		temporary impact of the cable network on sea mammals and turtles
	supply ships	impact on the maritime traffic and fisheries
	exploratory drilling	discharge of mud
		physical impact on the seabed and flora and fauna
		likely noise and lighting of the drilling rig
		physical impact on the sea water column
		impact of helicopter flights
PRODUCTION	development drilling, mining facilities and plants	discharge of mud
		physical impact on the seabed and flora and fauna
		physical impact on the sea water column

VI

Operations to be performed in the procedure of Strategic Environmental Assessment of the Framework Plan shall be implemented in accordance with provisions of the Environmental Protection Act, the Regulation on strategic environmental assessment of plans and programmes as well as provisions of special regulations in the order of implementation as defined in Annex II, which is an integral part of this Decision.

VII

The bodies and persons listed in Annex III, which is an integral part of this Decision, shall participate in the procedure of strategic assessment.

VIII

The Ministry shall inform the public of this Decision pursuant to provisions of the Environmental Protection Act and provisions of the Regulation on information and participation of the public and public concerned in environmental matters (Official Gazette 64/08).

IX

This decision shall enter into force on the day of its adoption.

CLASS: 310-01/14-03/280
REG. NO: 526-04-02-01/1-14-02
Zagreb, 25 August 2014

MINISTER
Ivan Vrdoljak
<hand signature>
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ANNEX 1

FRAMEWORK PLAN AND PROGRAMME OF HYDROCARBON EXPLORATION AND PRODUCTION OPERATIONS IN THE ADRIATIC

The **Framework Plan and Programme of Hydrocarbon Exploration and Production Operations in the Adriatic** was prepared pursuant to the Decision of the Government of the Republic of Croatia, CLASS: 022-03/14-04/98; REG. NO: 50301-05/18-14-4 of 27 March 2014, on the Implementation of the Procedure for Issuing Licences and Publication of Public Tendering for Issuing Licences for Exploration and Production of Hydrocarbons in the Adriatic and the Decision of the Government of the Republic of Croatia, CLASS: 022-03/14-04/98; REG. NO: 50301-05/18-14-2) of 27 March 2014 on the Content, Terms and Conditions and Selection Criteria in the Tender for Exploration and Production of Hydrocarbons in the Adriatic.

The preliminary analysis of seismic and other available data shows that the Croatian part of the Adriatic is insufficiently explored. In comparison with Italy, Republic of Croatia possesses the area of the Adriatic similar in size to the area possessed by Italy, while at the same time has only 10% of the number of wells and less than 10% of discovered hydrocarbon reserves compared to Italy.

By applying international practice and taking into account the protected areas, sea depth and subsea geological structures, it was concluded that around 36,822 km^2 of the Adriatic would be subject to public tendering. The final proposal defined 29 hydrocarbon blocks, ranging from 1,020 to 1,635 km^2 in size that were the subject of public tendering, so the tender for granting of licences and concessions on the proposed 29 hydrocarbon blocks in the Adriatic was initiated.

The blocks subject to public tendering are divided in three groups (Northern Adriatic, Central Adriatic and Southern Adriatic) based on the water depth criterion. The shallow offshore (Northern Adriatic), covering depths up to 100 m, includes 8 hydrocarbon blocks, the central offshore (Central Adriatic), with sea depths over 100 m, includes 16 hydrocarbon blocks and the deep offshore (Southern Adriatic), with sea depths over 1,000 m, includes 5 hydrocarbon blocks.

Considering the duration of the public tendering for issuing licences for exploration and production of hydrocarbons in the Adriatic, the sequence and scope of activities may only be indicated by taking account of international practice.

As the blocks in the Adriatic are divided into groups based on their water depth, the indicative planned operations are classified according to their dynamics regarding the position of an block and the phase of operations.

1. EXPLORATION PERIOD

Offshore exploration of hydrocarbons is accompanied by numerous activities. In the initial period of exploration for hydrocarbons, the emphasis will be on 2D and 3D seismic surveying. In parallel with seismic surveying activities, other testing will also be performed in order to attain the best possible knowledge on hydrocarbon reservoirs. The testing planned to be performed in the area of the Adriatic Sea shall include the following: gravity surveys, geochemical testing, magnetic surveys, magneto-telluric surveys, transient electro magnetic surveys, bathymetric surveys, seabed sampling, satellite gravity surveys, environmental baseline surveys and environmental impact assessment of operations.

1.1. Shallow offshore (Northern Adriatic)

Considering the fact that, historically, exploration and production operations were mostly related to the northern part of the Adriatic Sea and, as a result, more data are available for that part, drilling operations are planned in the first exploration period.

After the performance of additional seismic surveying, reprocessing of the existing and interpretation of new results, the drilling of wells is expected. The duration of drilling operations is planned to last between 40-60 days per one borehole, depending on the water depth at the well site, depths of targeted hydrocarbon reservoirs and the scope of technological testing during drilling.

After the first exploration phase, it is planned to perform new 3D seismic surveying, after which the resulting data will be reviewed and the study on the location of the second confirmation well will be developed.

1.2. Central offshore (Central Adriatic)

The area of central offshore covers the largest portion of the total area subject to public tendering. As water depths in that area exceed 100 m, operations to be performed in that area depend on the area's specific characteristics.

In the first part of the agreement period, operations relating to seismic surveying, with an increased share of 3D seismic surveying in the area, are planned. As this area's configuration is more complex, an extension of the first 6-month exploration period, in which the drilling of wells will begin, is expected. It is expected that the well drilling process will last between 60-80 days per one borehole, depending on the water depth, the depth of targeted hydrocarbon reservoirs and the scope of technological testing during drilling.

Consequently, the second exploration period would start 6 months after the expiry of the first exploration period, when additional 3D seismic surveying will be performed, on the basis of which the study of the block will be developed and the location of the new confirmation well determined.

1.3. Deep offshore (Southern Adriatic)

The deep offshore is the most technologically demanding part of the Adriatic. The deepest point is at 1,250 m, which requires more complex and expensive technological solutions. Due to the area's complexity, it is assumed that investors will extend the exploration period to the prescribed maximum of one year (6+6 months).

Preparatory operations, including seismic surveying and other testing focused on obtaining data on the subsoil, are planned to last until the end of the first exploration period, while the initial exploratory drilling could begin after the initial extension of the first exploration period. It is expected that drilling operations in the deep offshore will last between 70-120 days per one borehole, depending on the exact water depth, the depth of targeted hydrocarbon reservoirs and the scope of technological testing during drilling.

Additional 3D seismic surveying and a detailed subsoil study would be performed during the second exploration period, so new drilling operations would start after the second extension of the second exploration period.

2. PRODUCTION PERIOD

When hydrocarbon reserves are discovered during the exploration period, the Investor shall inform the competent Ministry thereof and perform development operations, including an assessment of the quantity and quality of reserves.

Production operations comprise development of the reservoir and exploitation of balance reserves of hydrocarbons. Main operations in the production period comprise drilling and equipping of production wells, construction of mining facilities and plants (production and, as required, compressor platforms) and, after the expiry of concession, decommissioning of the production field. Production operations to be performed largely depend on the water depth in the area with certified balance reserves of hydrocarbons, type of hydrocarbons (oil, gas or condensate), certified quantities of hydrocarbons and situation on the energy market.

Based on international practice, hydrocarbon production follows approximately 7 years after discovery.

The start of the production period in the Adriatic is planned after the expiry of the first and second exploration periods (and their potential extensions up to the maximum of one year).

Pursuant to the Act on Exploration and Production of Hydrocarbons, the maximum term of the production period is 25 years, with a possibility of extension.

ANNEX II

SEQUENCE OF ACTIVITIES TO BE CARRIED OUT IN THE STRATEGIC ENVIRONMENTAL ASSESSMENT OF THE FRAMEWORK PLAN AND PROGRAMME OF EXPLORATION AND PRODUCTION OF HYDROCARBONS IN THE ADRIATIC

1 The Ministry shall commence the strategic environmental assessment of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic within eight days from the date of the adoption of this Decision.

2 When determining the content of the Study, the Ministry shall:

2.1 request opinions from authorities competent for respective environmental components and burdening (e.g. the sea, nature, air, seabed, landscape, archaeological sites, noise, waste, etc.) on the content of the strategic study. A discussion with the above authorities shall be carried out in order to align opinions on the required content of the strategic study. These activities shall be conducted pursuant to the provisions of Articles 6 to 9 of the Regulation on strategic environmental assessment of plans and programmes. The authorities requested for their opinion shall submit such opinion within 30 days from the days they receive the request from the Ministry.

2.2 The Ministry shall publish the Decision on the drawing up of the Framework Plan of Exploration and Production of Hydrocarbons in the Adriatic on its official website, and inform the public about the manner of participation in the strategic assessment procedure, pursuant to the provisions of Articles 5, 6 and 12 of the Regulation on strategic environmental assessment of plans and programmes. The public shall participate by submitting opinions and proposals in writing.

2.3 Within the above deadline of 30 days, the Ministry shall coordinate and conduct one or several discussions with the representatives of authorities and/or persons requested for their opinion in order to align opinions on the content of the strategic study and establish the final content of the strategic study.

2.4 After obtaining opinions from authorities referred to in item 2.1, the Ministry shall render a decision on the required content of the strategic study pursuant to Article 9, paragraph 1 of the Regulation on strategic environmental assessment of plans and programmes and publish it on its official website for a period of 30 days.

3 The Ministry shall commence the process of determining the authorised person within 8 days from the adoption of the Decision on the content of the strategic study.

4 Within 8 days from the adoption of the Decision on the content of the strategic study, the Ministry shall deliver it to the Authorised person who shall prepare the strategic study (pursuant to Article 11 of the Regulation on strategic environmental assessment of plans and programmes).

5 The Minister shall appoint a Committee within eight days from the adoption of the Decision on the content of the strategic study. The appointment procedure and the functioning of the Committee are laid down in the Ordinance on the strategic assessment committee (Official Gazette, No. 70/08).

6 Within eight days from the receipt of the strategic study from the authorised person, the Ministry shall deliver it to the Expert Committee, which shall assess the integrity and scientific soundness of the strategic study in relation to its established content and the draft Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic. In doing so, the Committee shall evaluate the results of the strategic study and give its opinion on them. These activities shall be carried out pursuant to Article 13 of the Regulation on strategic environmental assessment of plans and

programmes, and pursuant to Article 9 and 10 of the Ordinance on the strategic assessment committee (Official Gazette, No. 70/08).

7 After it considers the Committee´s opinion, the Ministry shall render a decision on putting the strategic study and the draft Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic to a public debate pursuant to Article 15 of the Regulation on strategic environmental assessment of plans and programmes, of which it shall inform the public on its website.

8 When putting the strategic study and the draft Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic to the public debate, the Ministry shall also, at the same time, send them to authorities competent for respective environmental components and burdening for their opinion.

Authorities and/or persons competent for respective environmental components and burdening shall deliver their opinion to the Ministry within 30 days (if an opinion is not delivered within the stipulated deadline, it shall be deemed that, pursuant to special regulations, there are no particular impacts and circumstances relating to environmental protection that need to be taken into account in the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic).

9 The procedure of public participation in the public debate on the strategic study and the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic shall be carried out pursuant to Article 15 of the Regulation on strategic environmental assessment of plans and programmes.

10 Following the public debate, and before sending the draft of the final proposal for the Programme to the adoption procedure, the Ministry shall, pursuant to Article 18 of the Regulation, obtain an opinion of the Ministry of Environmental and Nature Protection on the conducted strategic assessment, whereby the Ministry of Environmental and Nature Protection shall deliver its opinion on the strategic assessment to the Ministry within 30 days from the receipt of the documentation.

11 Upon completion of the public debate, the Ministry shall deliver all received opinions, comments and proposals to the authorised person and the person who prepared the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic for their opinion. After it receives their opinion, it shall prepare the draft of the final proposal for the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic.

12 If the Committee assesses that the implementation of the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic could significantly affect the environment and/or human health in another country, the Ministry shall, pursuant to Article 17 of the Regulation on strategic environmental assessment of plans and programmes, notify the Ministry of Environmental and Nature Protection thereof for the purpose of commencing the procedure directed at this country.

13 Following the adoption of the programme, the Ministry shall prepare a Report on the conducted strategic assessment and the monitoring programme pursuant to Article 19 of the Regulation on strategic environmental assessment of plans and programmes.

14 The Report on the conducted strategic assessment and the adopted Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic shall be published by the Ministry on the website pursuant to Article 19 of the Regulation on strategic environmental assessment of plans and programmes.

15 Following the adoption of the Framework Plan and Programme, the Ministry shall adopt an environmental monitoring programme relating to the implementation of the plan and programme

pursuant to Article 20 of the Regulation on strategic environmental assessment of plans and programmes.

ANNEX III

LIST OF AUTHORITIES WHICH ARE, UNDER SPECIAL REGULATIONS, OBLIGED TO PARTICIPATE IN THE STRATEGIC ASSESSMENT PROCEDURE IN LINE WITH THEIR COMPETENCE FOR RESPECTIVE ENVIRONMENTAL COMPONENTS, I.E. BURDENING, IN ORDER TO GIVE OPINIONS ON THE CONTENT OF THE STRATEGIC STUDY, AND OPINIONS ON THE STUDY AND THE DRAFT PROPOSAL FOR THE FRAMEWORK PLAN AND PROGRAMME

1 Ministry of Construction and Physical Planning, Directorate for Physical Planning
2 Ministry of Environmental and Nature Protection, Directorate for Environmental Protection and Sustainable Development
3 Ministry of Environmental and Nature Protection, Nature Protection Directorate
4 Ministry of Maritime Affairs, Transport and Infrastructure
5 Ministry of Agriculture, Directorate for Fisheries
6 Ministry of Foreign and European Affairs
7 Ministry of Health
8 Ministry of Defence
9 Ministry of Tourism
10 Ministry of Culture
11 Ministry of the Economy, Directorate for Energy and Mining
12 Ministry of the Interior
13 Ministry of Science, Education and Sports
14 Croatian Hydrocarbon Agency
15 Istria County
16 Primorje-Gorski Kotar County
17 Zadar County
18 Split-Dalmatia County
19 Šibenik-Knin County
20 Dubrovnik-Neretva County

16.2 Annex 2

Decision on the content of the Strategic Study under the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic

Pursuant to Article 68, paragraph 3 of the Environmental Protection Act (Official Gazette, number 80/13 and 153/13), and Article 9, paragraph 2 Regulation on Strategic Environmental Assessment of Plans and Programmes (Official Gazette, number 64/08), the Minister of Economy hereby adopts the following

DECISION

on the content of the Strategic Study under the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic

I

This Decision shall establish the content of the Strategic Study of the Environmental Impact under the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic (hereinafter referred to as: the Framework Plan and Programme). This Decision is adopted within the framework of the strategic environmental assessment procedure initiated by the Decision on the implementation of the strategic environmental impact assessment procedure under the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic (Class: 310-01/14- 03/280., REG. NO: 526-04-02-01/1-14-03 of 26 August 2014).

Programme starting points, objectives and the scope of the Framework Plan and Programme

II

The Act on the Exploration and Production of Hydrocarbons (Official Gazette number 94/13 and 14/14) enables the development of exploration and production of hydrocarbons in the Republic of Croatia in accordance with international practice, and thereby also enables a public tender for licences for the exploration and production of hydrocarbons in the Adriatic. Under the 1st offshore licensing round for licences for the exploration and production of hydrocarbons (Official Gazette number 42/14) 29 offshore blocks are offered, with the total area of approx. 36 822 km^2, divided according to the sea depth (North Adriatic, Central Adriatic and South Adriatic), also taking into account the protected areas and subsea geological structures.

In accordance with the programme of the Framework Plan and Programme, the flow and the scope of the operations are divided into the exploration and the production period. Exploration operations shall be carried out in the first 5 years, with the possibility of 1-year extension. The aforementioned activities include 2D and 3D seismic survey and exploratory drilling, as well as many other analytical studies the joint purpose of which is to collect geological and geophysical data with the aim of obtaining accurate hydrocarbon potential assessment and recognition of geological structures (gravity, geochemical, magnetic, magneto-telluric, transient electro magnetic, and bathymetric surveys, seabed sampling, satellite gravity survey, environmental baseline survey and the environmental impact assessment of works). In case of positive results, this will be followed by a production period. Its main characteristics include development of the reservoir development studies, development drilling and well completion, construction of production plants and finally production of hydrocarbons. The planned duration of the production period is 25 years, with the possibility to extend it.

The Framework Plan and Programme are developed with the aim of accurate monitoring of the operations concerning exploration and production of hydrocarbons in the Adriatic, issuance of licences, conclusion of agreements, determination of fees, infringement provisions and quality inspection, monitoring and foreseeing of the status of hydrocarbon reserves in the Adriatic, as determined under the Act on Exploration and Production of Hydrocarbons. The implementation of the Framework Plan and Programme is also essential for better efficiency and management of hydrocarbons, as also guaranteed under the Constitution of the Republic of Croatia.

Mandatory content of the Strategic Study

III

The Strategic Study shall contain the following chapters:

- short overview of the content and main objectives of the Framework Plan and Programme and their relation to other relevant strategies, plans and programmes;
- overview of the existing information on the state of the environment and the possible development of the environment without the implementation of the Framework Plan and Programme, that will include the following::
  a) physical information: climate characteristics and air quality, hydrographic and oceanographic conditions (physical and chemical) and sea chemistry, noise,
  b) geological information - stratigraphy, recent sedimentation, tectonics, geophysics (earthquakes and geological risks),
  c) biological information - planctonic communities, benthic communities, nectonic communities (fish and marine invertebrates), bird communities, marine mammals, marine turtles and other protected and/or endangered animals,
  d) social and economic information - fisheries and mariculture, tourism, telecommunications, marine transport, cultural heritage and archaeological sites;
- environmental characteristics of the areas likely to be significantly affected by the implementation of the Framework Plan and Programme;
- existing environmental problems which are relevant to the plan or programme including, in particular, those relating to any areas of a particular environmental importance, such as areas designated pursuant to the special environmental protection regulations;
- environmental protection objectives, established at the conclusion of international treaties and agreements, which are relevant to the plan or programme and the way those objectives and any environmental considerations have been taken into account during its preparation;
- description and type of operations with regard to exploration and production of hydrocarbons to be expected on the area concerned, and their resulting impact on the environment, impact of possible exceptional occurrences and accidents, and intervention plans;
- recognition of likely significant effects (secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects) on the environment, including biodiversity, people, flora and fauna (particularly on the strictly protected species sensitive to the planned operations), soil, water, air, climate, social and economic factors, material assets, cultural and historical heritage, landscape and

protected areas pursuant to the nature protection Act (Official Gazette, number 80/13), taking into consideration their interrelationships, which the expected operations under the Framework Plan and Programme could have on the environment, and singling out the special areas relating to the habitats under the Natura 2000 programme;

- environmental protection measures, including the measures for the preventing, reducing, mitigating and offsetting adverse effects of the implementation of the plan and programme on the environment:
- short outline of the reasons for selecting the alternatives dealt with, statement of reasons for the most acceptable alternative of the plan and programme for the environment, and a description of how the assessment was undertaken including any difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information;
- description of the measures envisaged concerning monitoring
- short summary of information under indents 1 to 10 above, with wording easily understandable to the public (non-technical summary)

In addition to the mandatory chapters, the Strategic Study should include the chapter "Main Assessment of the Acceptability for the Ecological Network", pursuant to the decision of the Ministry of Environmental and Nature Protection, CLASS: UP/I 612-07/14-71/160; REG. NO. 517-07-2-1-14-4; of 23 September 2014 that will include:

- information on the ecological network (description of the ecological network that may be affected by the implementation of the Framework Plan and Programme);
- map of the ecological network area in the appropriate scale;
- description of possible significant impact of the Framework Plan and Programme implementation on the ecological network (probability, duration, frequency, intensity and cumulative nature considering other planned projects), possible impact on the conservation objectives and integrity of all ecological network areas that could be affected by the operations under the Framework Plan and Programme;
- overview of other suitable possibilities (alternatives under the Framework Plan and Programme) and the impact of such alternatives on the conservation objectives and integrity of ecological network areas;
- proposal of measures for mitigating adverse effects of the Framework Plan and Programme implementation on the ecological network;
- conclusion (final assessment of the acceptability of the Framework Plan and Programme for the ecological network with the application of the proposed mitigation measures);

In addition to the aforementioned mandatory chapters, the Strategic Study shall include requirements established when determining the strategic study content in the process of obtaining the opinions from authorities and/or persons set out in special regulations and bodies of local (regional) self-government units:

- all impediments resulting from the sea surface delimitation regarding the existing and planned projects in the area (for example, pipelines, energy cables, waterways, etc.);
- risk assessment, control and management, procedures and measures in the event of accidents;
- physical information should be shown in the coordinate system for map projection HTRS96/TM;
- description of methodology used.

List of authorities and/or persons set out in special regulations and bodies of local (regional) self-government units that participated in the process of establishing the content of the strategic study, and informing the public

IV

The Decision on the implementation of the strategic environmental assessment under the Framework Plan and Programme was delivered to the following authorities which are, under special regulations, obliged to participate in the strategic assessment procedure in line with their competence for respective environmental components, i.e. burdening, in order to give opinions on the content of the strategic study, and opinions on the study and the draft proposal for the Framework Plan and Programme:

1 Ministry of Construction and Physical Planning, Directorate for Physical Planning
2 Ministry of Environmental and Nature Protection, Directorate for Environmental protection and Sustainable Development
3 Ministry of Environmental and Nature Protection, Directorate for Nature Protection
4 Ministry of Maritime Affairs, Transport and Infrastructure
5 Ministry of Agriculture, Directorate for Fisheries
6 Ministry of Foreign and European Affairs
7 Ministry of Health
8 Ministry of Defence
9 Ministry of Tourism 10 Ministry of Culture
11 Ministry of Economy, Directorate for Energy and Mining
12 Ministry of the Interior
13 Ministry of Science, Education and Sport
14 Croatian Hydrocarbons Agency
15 Istra County
16 Primorje-Gorski Kotar County
17 Zadar County
18 Split-Dalmatia County
19 Šibenik-Knin County
20 Dubrovnik-Neretva County

During the period for delivering opinions and proposals with regard to the strategic study content, opinions and proposals were delivered by:

1 Ministry of Environmental and Nature Protection
2 Ministry of Economy
3 Ministry of Construction and Physical Planning
4 Ministry of Tourism
5 Ministry of Foreign and European Affairs
6 Ministry of Defence

7 Ministry of the Interior
8 Ministry of Science, Education and Sport
9 Ministry of Agriculture
10 Ministry of Health
11 Ministry of Culture
12 Ministry of Maritime Affairs, Transport and Infrastructure
13 Zadar County
14 Istra County
15 Split-Dalmatia County
16 Dubrovnik-Neretva County
17 Primorje-Gorski Kotar County

In accordance with Article 8, paragraph 3 of the Regulation on Strategic Environmental Assessment of Plans and Programmes On 29 September 2014, the Ministry of Economy and the Croatian Hydrocarbons Agency organised a discussion in order to align opinions on the content of the strategic study and establish the final content of the strategic study.

With the purpose of informing the public, information on the implementation of the procedure for establishing the content of the strategic study of the significant environmental impact of the Framework Plan and Programme were published on the Ministry of Economy website (www.mingo.hr) in the period from 29 August 2014 to 29 September 2014. In this period, opinions and proposals with regard to the content of the strategic study were received from the public. 21 comments were received, and responses to these comments were provided. The comments and responses were published on the Ministry of Economy website (www.mingo.hr) for the participants who agreed to such publication.

Basic information on the author of the programme

VI

The Ministry of Economy shall be responsible for adopting the Framework Plan and Programme. The author of the Framework Plan and Programme shall be the Croatian Hydrocarbons Agency.

Competence for drawing up the strategic study

VII

The strategic study shall be developed by a legal entity having the approval by the Ministry of Environmental and Nature Protection for performing professional activities in the field of the environment protection - drawing up studies of significant environmental impact of strategies, plans and programmes and drawing up chapters and studies of acceptability assessment of strategies, plans, programmes and projects with regard to ecological network, in accordance with Article 4 of the Ordinance on requirements for issuing approvals to legal persons for performing professional environmental protection activities (Official Gazette, 57/10).

Publication of the Decision on the content of the strategic study

VIII

In accordance with Article 160, paragraph 1 of the Environmental Protection Act, Article 7, paragraph 5 of the Regulation on Strategic Environmental Assessment of Plans and Programmes, and Article 5, paragraph 1, item 2 of the Regulation on information and participation of the public and public concerned in environmental matters (Official Gazette, number 64/08), the Ministry of Economy shall publish this Decision as prescribed on its website (www.mingo.hr) with the purpose of informing the public.

CLASS: 310-01/14-03/280
REG. NO: 526-04-02-01/1-14-23
Zagreb, 23 October 2014

MINISTER
Ivan Vrdoljak
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16.3 Annex 3

Table 16.1 Overview of operations and their impacts as provided for in the Programme

Operations provided for in the FPP	Detailed explanation of planned operations in the context of the FPP implementation based on existing relevant practice	Operations arising from the FPP that might generate significant impacts
OPERATIONS FORESEEN DURING THE EXPLORATION PERIOD		
• **2D and 3D seismic survey** • **Other operations during the exploration period** (gravity, geochemical, magnetic, magneto-telluric, transient electromagnetic, and bathymetric surveys, seabed sampling, satellite gravity survey, environmental baseline survey) • **Exploratory drilling** • **Installation of an exploratory drilling platform** • **Accompanying activities – logistics** • **Accidents**	Exploration of hydrocarbon potential covers a combination of exploration methods and operations, such as seismic survey and testing, geological and electromagnetic surveys, exploratory wells, sampling and sample analysis, etc. As regards environmental impact, seismic survey and testing-related methods and exploratory wells out of all foreseen exploration methods create the most significant impact in relation to all foreseen exploration methods. Other above mentioned exploration methods have no impact or only negligent impact on the environment. Seismic surveys and 51 exploratory wells have been completed in the block concerned to date. Due to the strategic FPP level, at this programming stage it is impossible to anticipate the volume, i.e. the actual need for all foreseen exploration methods in individual blocks. On the basis of the above and the FPP, the following assumptions have been defined for the purpose of the strategic survey: ■ According to the FPP, 29 blocks are divided in 3 regions (Northern Adriatic – up to 100 m deep, Central Adriatic – 100 to 1000 m deep and Southern Adriatic – over 1000 m deep) based on their water depth. The Strategic study anticipates that all mentioned exploration methods will be applied in a manner fit for the respective water depth, i.e. that they will not be applied in case the water depth limits the implementation due to technical, technological or economic reasons. ■ All above mentioned exploration methods will be applied at least once during the exploration period in all blocks, where this is justified for technical, technological and economic reasons. ■ All above mentioned exploration methods will be applied pursuant to national and international law, while observing international regulations, agreements and good practice examples when conducting the operations. ■ Exploratory wells (both discovery and confirmation) will be drilled only in case the results of the previous exploration methods justify further exploration. Where necessary, already applied exploration methods (e.g. 3D seismic survey) may be repeated between the discovery and the confirmation well). Therefore, in waters over 100 m deep, the beginning of the confirmation well drilling is anticipated 6 months after the beginning of the discovery well drilling, and in waters over 1000 m deep 12 months after the beginning of the discovery well drilling. ■ The time necessary for one exploratory well drilling depends on water depth. In waters less than 100 m deep it takes 40 to 60 days, in waters from 100 to 1000 m deep 60 to 80 days, and in waters over 1000 m deep 70 to 120 days, depending on the total depth of a well. ■ Depending on the water depth in the observed block, exploratory wells may be drilled using jackups (Northern Adriatic), semisubmersibles or drillships (Central or Southern Adriatic). ■ Upon completion of exploration operations, exploratory wells will be suspended or abandoned in accordance with international standards and best oil industry practice. ■ Water-base mud and well cuttings, as well as other wastewater will be discharged from platform, in accordance with national and international requirements and limitations.	■ Maritime transport ■ Use of a part of the water area ■ Application of various exploration methods: ◦ 2D and 3D seismic survey ◦ Gravity survey ◦ Geochemical testing ◦ Magnetic survey ◦ Magneto-telluric survey ◦ Transient magnetic survey ◦ Bathymetric survey ◦ Seabed sampling ◦ Satellite gravity survey ◦ Exploratory drilling ■ Accompanying activities (increased maritime and air transport/helicopters) ■ Accidents

Operations provided for in the FPP	Detailed explanation of planned operations in the context of the FPP implementation based on existing relevant practice	Operations arising from the FPP that might generate significant impacts
OPERATIONS FORESEEN DURING THE PRODUCTION PERIOD AND THE REMOVAL OF MINING FACILITIES AND PLANTS		
• Installation of a production platform and pipelines • Production drilling (presence of a production drilling platform) • 2D and 3D seismic survey • Accompanying activities – logistics • Removal of mining facilities and plants • Accidents	The hydrocarbon production period may entail operations related to drilling and production well completion, process plant construction, exploratory well installation, subsea pipeline installation, hydrocarbon production and removal of mining facilities and plants after production. No hydrocarbon production operations have been conducted in the area of the observed blocks so far. However, three production fields in the Northern Adriatic ("Izabela", "Northern Adriatic" and "Marica") have been subject to the production of natural gas and its transport to the mainland for a number of years. Due to the strategic FPP level, at this programming stage it is impossible to anticipate the volume, i.e. the actual need for all foreseen works for the purpose of production as they depend on the results of the exploration period and the characteristics of hydrocarbon reservoirs in respective blocks. On the basis of the above and the FPP, the following assumptions have been defined for the purpose of the strategic survey: ■ We can assume that hydrocarbon production will require one of the following production platforms: jacket platforms fixed to the seabed (there are already 19 such platforms in the Northern Adriatic) or floating production platforms, e.g. floating production storage and offloading units (FPSO) or floating storage and offloading units (FSO), as well as subsea completion and connection of wells to an existing platform capable of receiving, processing and transporting hydrocarbons, floating production systems, remotely controlled subsea systems. The method will be selected in the production planning stage based on the characteristics of respective production fields, such as: water depth, type and characteristics of a discovered hydrocarbon reservoir, proximity of the existing energy infrastructure etc. ■ Production platforms are equipped with process plants in which recovered hydrocarbons are processed to the level fit for transport. Further processing of hydrocarbons can be conducted in specialized facilities, i.e. onshore plants. Since the FPP does not provide for the construction of such facilities or other solutions (processing in the existing facilities or plants), they are not subject to further elaboration of this strategic study. ■ In the course of production various exploration operations may be repeated. These activities have been elaborated within the exploration period and shall not be repeated within the production period. ■ Based on international practice, hydrocarbon production follows approximately 7 years after discovery.	■ Maritime transport ■ Use of a part of the water area ■ Implementation of additional exploration methods ■ Exploratory well drilling ■ Installation and/or construction of production facilities, infrastructure and plants ■ Hydrocarbon production ■ Accompanying activities ■ Accidents

An assessment of the significance of impacts on the respective environment component has been prepared for each identified operation resulting from the FPP likely to have an impact on the environment. In this strategic study, an impact is considered significant if it will likely result in the following:

- Changed life conditions and/or threatened species and habitats
- Permanent conflict with other activities in the area, such as fisheries, transport, energetics, telecommunications, tourism
- Permanent pollution of and/or harm to natural resources
- Worsened environmental baseline to a point exceeding limitations and standards stipulated by law
- Threatened human health, safety and quality of life
- Threatened cultural heritage and disrupted natural landscape
- Increased revenue from hydrocarbon activities

The results of the FPP implementation impact assessment for respective environment components are presented in the following table – the symbols related to the impact assessment have the following meaning:

+ + Potential significant positive impact
+ + Potential positive impact
0 No impact
– Potential negative impact
– – Potential significant negative impact

Table 16.2 Overview of the anticipated FPP implementation-related impacts on respective environment components

OPERATIONS DURING THE EXPLORATION PERIOD																												
Assessment of the significance of impacts on a respective environment component																												
Operations	Climate characteristics	Air	Seabed	Sea	Natural heritage		Cultural and historical heritage	Landscape features	Noise	Electromagnetic radiation	Chemical radiation	Physical features	Human health and quality of life	Waste management	Ecological network	Socioeconomic characteristics	Geological and oil-geological characteristics	Hydrogeology	Economic characteristics						Infrastructure			Clarification
					Biodiversity	Geodiversity													Tourism	Forests and forestry	Agriculture	Fisheries	Transport	Game and hunting	Water Supply	Sewage	Telecommunications and energetics	
Maritime transport	–	–	0	–	0	0	0	0	–	0	0	0	0	0	–	0	0	0	0	0	0	–	–	0	0	0	0	Increase in maritime transport may lead to increased marine, air and noise pollution. Moreover, the ecological network may be affected by increased maritime transport in the area or in the immediate vicinity of the ecological network. Since an increase in transport leads to GHG emissions, the FPP implementation might affect climate characteristics to a certain extent. In some cases, increased transport will affect activities which are already being performed in the area (fisheries, transport). However, none of the above impacts are considered potentially significant.
Use of a part of the water area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	–	0	0	0	0	In line with the Decree on main technical requirements on safety and security of offshore exploration and production of hydrocarbons in the Republic of Croatia (Official Gazette No. 52/10) and applicable international marine regulations, a safety zone is placed around each platform which only authorized vessels may enter. In the safety zone, any anchoring or fishing activity in the area (having a 500-meter radius from the platform central point), i.e. in the subsea pipeline corridor is prohibited.

Operations		Climate characteristics	Air	Seabed	Sea	Natural heritage: Biodiversity	Natural heritage: Geodiversity	Cultural and historical heritage	Landscape features	Noise	Electromagnetic radiation	Chemical radiation	Physical features	Human health and quality of life	Waste management	Ecological network	Socioeconomic characteristics	Geological and oil-geological characteristics	Hydrogeology	Economic characteristics: Tourism	Economic characteristics: Forests and forestry	Economic characteristics: Agriculture	Economic characteristics: Fisheries	Economic characteristics: Transport	Economic characteristics: Game and hunting	Infrastructure: Water Supply	Infrastructure: Sewage	Infrastructure: Telecommunications and energetics	Clarification
Various exploration operations	Northern Adriatic	–	–	–	–	– –	0	– –	0	– –	0	0		0	– –	0	0	0	0	0	0	0	– –	– –	0	0	0	0	Various exploration operations will increase the noise level in the sea (seismic surveys and drilling), thus affecting marine flora and fauna. Exploration will entail discharge of gases into the air, as well as of fuel, oil and lubricants. This could have adverse impact on several components. Biodiversity and the ecological network would be exposed to the most significant adverse impacts during exploration. In case exploration works are performed on the locations of archaeological cultural heritage, that environment component might be negatively affected.
	Central Adriatic	–	–	–	–	– –	0	– –	0	– –	0	0		0	–	– –	0	0	0	0	0	0	–	–	0	0	0	0	
	Southern Adriatic	–	–	–	–	– –	0	– –	0	– –	0	0	0	0	–	0	0	0	0	0	0	0	–	–	0	0	0	0	
Installation of an exploratory platform		–	–	– –	– –	–	0	– –	– –	–	0	–	0	0	–	– –	0	0	0	0	0	0	–	–	0	0	0	0	Installation of an exploratory platform may have an adverse impact on the seabed and the sea, as well as cultural-historical and landscape features. This operation can also have an adverse impact on biodiversity and the ecological network.
Exploratory drilling		–	–	– –	– –	– –	0	– –	0	– –	0	–	0	0	–	– –	0	0	0	0	0	0	– –	–	0	0	0	–	Exploratory drilling may have potential significant negative impacts on the seabed due to the installation of a fixed or the mooring of a floating platform, discharge of drilling mud and well cuttings into the sea, and their sedimentation on the seabed. Furthermore, noise generated by drilling and seabed disturbance may affect biodiversity, the ecological network and fisheries. Where works are performed on the archaeological cultural heritage (e.g. historic

Table title: Assessment of the significance of impacts on the respective environment component

																												shipwrecks), this component may also be negatively affected.

Assessment of the significance of impacts on the respective environment component																											
Operations	**Climate characteristics**	**Air**	**Seabed**	**Sea**	**Natural heritage**		**Cultural and historical heritage**	**Landscape features**	**Noise**	**Electromagnetic radiation**	**Chemical radiation**	**Physical features**	**Human health and quality of life**	**Waste management**	**Ecological network**	**Socioeconomic characteristics**	**Geological and oil-geological characteristics**	**Hydrogeology**	**Economic characteristics**						**Infrastructure**			**Clarification**
					Biodiversity	**Geodiversity**													**Tourism**	**Forests and forestry**	**Agriculture**	**Fisheries**	**Transport**	**Game and hunting**	**Water Supply**	**Sewage**	**Telecommunications and energetics**	
Accompanying activities	–	–	0	–	–	0	0	0	–	0	0	0	0	0	–	0	0	0	0	0	0	–	–	0	0	0	0	Accompanying activities imply additional maritime and air traffic, with potential negative impacts on biodiversity and the ecological network.
Accidents	– –	– –	– –	– –	– –	0	–	–	0	0	– –	0	– –	– –	– –	– –	–	0	– –	0	0	– –	– –	0	0	0	– –	Accidents may have potential significant negative impacts on the majority of environment components, human health and some other activities performed in the area such as fisheries, transport, tourism and infrastructure.

OPERATIONS DURING THE PRODUCTION PERIOD																												
Assessment of the significance of impacts on the respective environment component																												
Operations	Climate characteristics	Air	Seabed	Sea	Natural heritage		Cultural and historical heritage	Landscape features	Noise	Electromagnetic radiation	Chemical radiation	Physical features	Human health and quality of life	Waste management	Ecological network	Socioeconomic characteristics	Geological and oil-geological characteristics	Hydrogeology	Economic characteristics						Infrastructure			Clarification
					Biodiversity	Geodiversity													Tourism	Forests and forestry	Agriculture	Fisheries	Transport	Game and hunting	Water Supply	Sewage	Telecommunications and energetics	
Maritime transport	–	–	0	–	0	0	0	0	–	0	0	0	0	0	–	0	0	0	0	0	0	–	–	0	0	0	0	Increase in maritime transport may lead to increased marine, air and noise pollution. The ecological network may be affected by increased maritime transport in the area or in the immediate vicinity of the ecological network. Moreover, since an increase in transport leads to GHG emissions, the FPP implementation might affect climate characteristics to a certain extent. In some cases, increased transport will affect activities which are already being performed in the area. However, none of the above impacts are considered potentially significant.
Exploratory well drilling	–	–	– –	– –	–	0	– –	0	– –	0	–	0	0	–	– –	0	0	0	0	0	0	–	–	0	0	0	–	Exploratory drilling might have potential significant negative impacts on the sea and seabed due to the installation of a fixed or the mooring of a floating platform, discharge of drilling mud and well cuttings into the sea, and their sedimentation on the seabed. Subsea noise generated by drilling and seabed disturbance may affect biodiversity, the ecological network and fisheries. Where works are performed on the archaeological cultural heritage (e.g. historic shipwrecks), this component may also be negatively affected.

Assessment of the significance of impacts on the respective environment component																													
Operations		Climate characteristics	Air	Seabed	Sea	Natural heritage		Cultural and historical heritage	Landscape features	Noise	Electromagnetic radiation	Chemical radiation	Physical features	Human health and quality of life	Waste management	Ecological network	Socioeconomic characteristics	Geological and oil-geological characteristics	Hydrogeology	Economic characteristics						Infrastructure			Clarification
						Biodiversity	Geodiversity													Tourism	Forests and forestry	Agriculture	Fisheries	Transport	Game and hunting	Water Supply	Sewage	Telecommunications and energetics	
Installation and/or construction of production facilities, infrastructure and plants		–	–	–	– –	–	0	– –	–	–	0	0	0	0	0	– –	0	0	0	0	0	0	– –	– –	0	0	0	–	Installation and/or construction of production facilities, infrastructure and plants (including pipelines) may have potential negative impacts on the seabed and sea, limit the activities which are already being carried out in the area, increase maritime transport, affect flora and fauna, as well as the ecological network and cultural heritage in case they are constructed within the ecological network, i.e. archaeological discovery sites, but also landscape features if several platforms are installed in one block.
Hydrocarbon production and presence of a platform		– –	– –	0	–	–/+	0	0	–	–	0	–	0	0	–	– /+	++	0	0	0	0	0	–	–	0	0	0	–	Oil and gas production is expected to exert a significant positive impact on the Croatian economy and energy economics, as well as a positive impact on biodiversity / ecological network due to the creation of an area in which species will not be disturbed. Production may affect maritime traffic routes and fisheries, as well as cause pollution and generate noise.
Potential additional exploration operations	**Northern Adriatic**	–	–	–	–	– –	0	– –	0	– –	0	0	0	0	–	0	0	0	0	0	0	0	–	–	0	0	0	0	The part regarding climate is missing. Different exploration operations will increase the noise level (seismic survey and exploration – particular impact on marine flora and fauna), discharge of gases into the air,
	Central Adriatic	–	–	–	–	– –	0	– –	0	– –	0	0	0	0	–	– –	0	0	0	0	0	0	–	–	0	0	0	0	

	Southern Adriatic	–	–	–	–	– –	0	– –	0	– –	0	0	0	0	–	0	0	0	0	0	0	0	–	–	0	0	0	0	as well as of fuel, oil and lubricants during exploration, and seabed disturbance on sampling locations. In case such works are performed on the locations of archaeological cultural heritage and the ecological network area, that environment component might be significantly affected.
Accompanying activities		–	–	0	–	– –	0	0	0	–	0	0	0	0	0	–	0	0	0	0	0	0	–	–	0	0	0	0	Accompanying activities imply additional maritime and air traffic, with potential negative impacts on biodiversity and the ecological network due to increased noise and other impacts on birds.
Accidents		– –	– –	– –	– –	– –	0	–	–	0	0	– –	0	– –	– –	– –	– –	–	0	– –	0	0	– –	– –	0	0	0	– –	Accidents may have potential significant negative impacts on the majority of environment components, human health and some other activities performed in the area such as fisheries, transport, tourism and infrastructure. In comparison to the exploration period, hydrocarbon production and transport may cause accidents of a larger scale.

Assessment of the significance of impacts on the respective environment component

Operations	Climate characteristics	Air	Seabed	Sea	Natural heritage		Cultural and historical heritage	Landscape features	Noise	Electromagnetic radiation	Chemical radiation	Physical features	Human health and quality of life	Waste management	Ecological network	Socioeconomic characteristics	Geological and oil-geological characteristics	Hydrogeology	Economic characteristics						Infrastructure			Clarification
					Biodiversity	Geodiversity													Tourism	Forests and forestry	Agriculture	Fisheries	Transport	Game and hunting	Water Supply	Sewage	Telecommunications and energetics	
ACTIVITIES DURING REMOVAL OF MINING FACILITIES AND PLANTS																												
Removal of mining facilities and plants	–	–	–	–	–	0	+	+	–	0	0	0	0	0	–	0	0	0	0	0	0	–/+	+	0	0	0	0	Removal of mining facilities may have a negative impact on biodiversity due to the destruction of a newly formed habitat. The impact on fisheries is two-fold. Positive impact is reflected in the reclaimed territory for fishing activities, and negative in the destruction of newly created habitats occupied by fish. Maritime transport in that area is fully restored after the removal of facilities and plants.
Accidents	– –	– –	– –	– –	– –	0	–	–	0	0	– –	0	– –	– –	– –	0	–	0	– –	0	0	– –	– –	0	0	0	– –	Accidents may have potential significant negative impacts on the majority of environment components, human health and some other activities performed in the area such as fisheries, transport, tourism and infrastructure.

Table 16.3 Impact of the physical characteristics of the sea and atmosphere on the plan implementation and accidents

Operations	Assessment of the significance of impacts on the respective environment component																										Clarification
	Climate characteristics	Air	Seabed	Sea	Natural heritage		Cultural and historical heritage	Landscape features	Noise	Electromagnetic radiation	Physical features	Human health and life quality	Waste management	Ecological network	Socioeconomic characteristics	Geological and oil-geological characteristics	Hydrogeology	Economic characteristics						Infrastructure			
					Biodiversity	Geodiversity												Tourism	Forests and forestry	Agriculture	Fisheries	Transport	Game and hunting	Water Supply	Sewage	Telecommunications and energetics	
IMPACT OF THE PHYSICAL CHARACTERISTICS OF THE SEA AND ATMOSPHERE ON THE PLAN IMPLEMENTATION																											
Pollutant discharge contingent upon sea currents direction and speed	0	0	–	–	–	0	0	0	0	0		0	0	–	0	0	0	0	0	0	–	0	0	0	0	0	Exploratory well drilling and hydrocarbon production generate certain quantities of pollutants dispersed into the sea via sea currents.
Suspension of works due to earthquakes and tsunami	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	Earthquakes and seismic sea waves (tsunami) may suspend production, thus incurring economic damages to platforms.
IMPACT OF THE PHYSICAL CHARACTERISTICS OF THE SEA AND ATMOSPHERE ON ACCIDENTS																											
Increased risk of accidents caused by strong waves and wind gusts	0	0	–	– –	– –	0	–	–	0	0		– –	0	– –	0	0	0	– –	0	0	– –	–	0	0	0	0	Increased risk of accidents due to wind and waves is most evident during well drilling and installation of platforms.
Increased risk of accidents caused by earthquakes	0	0	–	– –	– –	0	–	–	0	0		– –	0	– –	0	0	0	– –	0	0	– –	–	0	0	0	0	Increased risk of accidents caused by earthquakes is evident on piled platforms.

Pollutant discharge contingent upon sea currents direction and speed	0	0	–	– –	– –	0	–	–	0	0		– –	0	– –	0	0	0	– –	0	0	– –	–	0	0	0	0	In case of accidents, oil spill dispersion will depend on wind force and direction, making the rehabilitation of the area more difficult.
Pollutant dispersion contingent upon wind and wave direction and force	0	0	–	– –	– –	0	–	–	0	0		– –	0	– –	0	0	0	– –	0	0	– –	–	0	0	0	0	The main direction and speed of oil dispersion in case of accidents is set by the flowing direction of sea currents.

16.4 Annex 4

Decision on the appointment of the Expert Advisory Committee

REPUBLIC OF CROATIA
MINISTRY OF ECONOMY

CLASS: 310-01/14-03/280
REG. NO: 526-04-02-01/1-14-22
Zagreb, 23 October 2014

Pursuant to Article 87, paragraph 1 of the Environmental Protection Act (Official Gazette, number 80/13 and 153/13), the Minister of Economy hereby adopts the following

DECISION

on the appointment of the Expert Advisory Committee for the strategic environmental impact assessment under the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic

I.

The following persons shall be appointed to the Expert Advisory Committee for the strategic environmental impact assessment under the Framework Plan and Programme of Exploration and Production of Hydrocarbons in the Adriatic:

- **Dragan Krasić, PhD**. Directorate for Energy and Mining. Ministry of Economy - Chair of the Committee
- **Mario Svrtan, BEng**. Directorate for Energy and Mining. Ministry of Economy - Secretary of the Committee
- **Anamarija Matak, BEng.** Sector for Environmental Assessment and Industrial Pollution. Directorate for Environmental Impact Assessment and Sustainable Waste Management. Ministry of Environmental and Nature Protection - Deputy Chair
- **Ana Kovačević, MSc**, Division for Strategic Environmental Impact Assessment. Directorate for Environmental Impact Assessment and Sustainable Waste Management. Ministry of Environmental and Nature Protection - Deputy Member
- **Marija Brajković, BEng (Geology).** Directorate for Nature Protection. Ministry of Environmental and Nature Protection - Member
- **Mara Kovačević, BEng (Geology)**. Directorate for Nature Protection. Ministry of Environmental and Nature Protection - Deputy Member
- **Ante Vujević, Prof.**, Directorate for Fisheries. Ministry of Agriculture - Member
- **Vesna Trbojević, BEng.**. Directorate for Water Management. Ministry of Agriculture - Deputy Member

- **Dantea Kničevic Šarac, BEng**. Directorate for Maritime and Inland Navigation, Shipping, Ports and Maritime Domain, Sector for Management of Maritime Domain, Port System and Concession System Ministry of Maritime Affairs, Transport and Infrastructure - Member
- **Dubravka Lulić Krivić, PhD**. Maritime Safety Directorate. Ministry of Maritime Affairs, Transport and Infrastructure - Deputy Member
- **Sonja Pelicarić, BEng (Architecture)**, Service for Valorisation of Tourist Potentials. Ministry of Tourism - Member
- **Antonija Drmić, MA (Geography)**, Department of Sustainable Development of Tourism, Ministry of Tourism - Deputy Member

II.

The Committee referred to in item I of this Decision, as well as deputy members and deputy chair, shall carry out their tasks in accordance with the Environmental Protection Act (Official Gazette, number 80/13 and 153/13) and, in their work, they shall apply the provisions of the Regulation on Strategic Environmental Assessment of Plans and Programmes (Official Gazette, number 64/08) and the Ordinance on the Committee for Strategic Assessment (Official Gazette, number 70/08), and the Committee Secretary shall draw their attention to that fact.

III.

This Decision shall enter into force on the date of its adoption and shall be published on the Ministry of Economy website (www.mingo.hr)

MINISTER
Ivan Vrdoljak
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16.5 Annex 5

Table 16.4 List of ecological network sites with possible risk of negative impact caused by accidents

<Translator’s note: The site names were intentionally left in Croatian because these are the names under which their details can be found in the European Nature Information System and on the Natura2000 website.>

Code	Ecological network site	Code	Ecological network site
Conservation of natural habitats and of wild fauna and flora			
HR3000431	Akvatorij J od uvale Pržina i S od uvale Bilin žal uz poluotok Ražnjić	HR3000121	Palagruža - podzemlje I
HR3000170	Akvatorij uz Konavoske stijene	HR3000430	Pantan
HR5000032	Akvatorij zapadne Istre	HR3000459	Pantan – Divulje
HR3000101	Arkanđel	HR5000038	Park prirode Lastovsko otočje
HR4000007	Badija i otoci oko Korčule	HR4000002	Park prirode Telašćica
HR3000098	Biševo more	HR3000041	Paška vrata
HR3000092	Blitvenica	HR3000115	Pelegrin – podzemlje
HR3000065	Bonaster – o. Molat	HR3000150	Pelješac – od uvale Rasoka do rta Osičac
HR3000127	Brač – podzemlje	HR3000058	Planik i Planičić
HR3000064	Brguljski zaljev – o. Molat	HR3000061	Plićine oko Maslinjaka; Vodenjaka; Kamenjaka
HR3000099	Brusnik i Svetac	HR3000062	Plićine oko Tramerke
HR2001388	Budava	HR3000002	Plomin – Mošćenička draga
HR3000466	Čiovo od uvale Orlice do rta Čiova	HR3000465	Podzemlje istočne obale otoka Krka
HR3000161	Cres – Lošinj	HR3000470	Podzemlje kod Rabca
HR3000004	Cres – rt Grota – Merag	HR3000467	Podzemlje Kostrene
HR3000005	Cres – rt Pernat – uvala Tiha	HR3000472	Podzemlje oko rta Ćuf na Krku
HR3000007	Cres – rt Suha – rt Meli	HR3000113	Podzemlje otočića Mrduja
HR3000133	Crni rat – o. Brač	HR3000022	Podzemlje otoka Grgur i Goli
HR5000031	Delta Neretve	HR3000021	Podzemlje otoka Prvić
HR3000026	Dolfin i otoci	HR3000017	Podzemlje otoka Suska
HR4000028	Elafiti	HR3000018	Podzemlje otoka Unije
HR3000108	Fumija I – podzemlje	HR3000016	Podzemlje Plavnika i Kormata
HR3000110	Fumija II - podzemlje	HR3000468	Podzemlje poluotoka Lopar – Rab
HR3000105	Hrid Muljica more	HR3000027	Podzemlje Trstenika
HR3000456	Hvar – od uvale Vitarna do uvale Maslinica	HR3000464	Područje oko rta Tatinja – Hvar
HR3000451	Hvar – otok Zečevo	HR2001334	Poluotok Ubaš
HR3000014	Ilovik i Sv. Petar	HR3000054	Premuda – vanjska strana
HR3000419	S. Molat – Dugi – Kornat – Murter – Pašman – Ugljan – Rivanj – Sestrunj – Molat	HR3000063	Prolaz između Zapuntela i Ista
HR3000423	Jabučka kotlina	HR3000051	Ražanac M. i V.
HR3000066	JI dio o. Molata	HR3000111	Recetinovac
HR3000096	JI strana o. Visa	HR3000074	Rivanjski kanal sa Sestricama
HR3000457	Južna obala Hvara – od rta Nedjelja do uvale Česminica	HR3000455	Rt Gomilica – Brač
HR4000024	Južna obala Šolte	HR3000437	Sedlo – podzemlje
HR3000093	JZ strana Šolte – I	HR3000053	Silba – podzemlje
HR3000094	JZ strana Šolte - II	HR4000025	Silbanski grebeni
HR3000116	Kabal – podzemlje	HR3000421	Solana Nin
HR3000442	Kakanski kanal	HR3000458	Šolta od uvale Šipkova do Grčkog rata
HR3000441	Kaprije	HR3000043	Stara Povljana
HR3000042	Košljunski zaljev	HR3000163	Stonski kanal

HR3000102	Kosmač M. i V.	HR3000024	Supetarska draga na Rabu
HR3000438	Kosmerka – Prokladnica – Vrtlac – Babuljak – podzemlje	HR3000031	Sv. Juraj – otočić Lisac
HR3000454	Krk – od Crikvenog rta do rta Sv. Nikola	HR3000164	Sveti Andrija – podzemlje
HR3000452	Krk – od rta Negrit do uvale Zaglav	HR3000124	Sveti Petar
HR3000453	Krk – od uvale Zaglav do Crikvenog rta	HR3000443	Tetovišnjak – podzemlje
HR3000109	Krknjaši	HR3000128	U. Ramova; u. Krvavica
HR3000444	Kukuljari	HR3000126	Ušće Cetine
HR3000426	Lastovski i Mljetski kanal	HR3000171	Ušće Krke
HR3000001	Limski kanal - more	HR3000433	Ušće Mirne
HR3000046	Ljubačka vrata	HR3000432	Ušće Raše
HR3000175	Ljubački zaljev	HR3000137	Uvala Bristova – Hvar
HR4000017	Lokrum	HR3000039	Uvala Caska – od Metajne do rta Hanzina
HR3000011	Lošinj – uvala Balvanida	HR3000045	Uvala Dinjiška
HR3000010	Lošinj – uvala Krivica	HR3000476	Uvala Divna – Pelješac
HR3000012	Lošinj – uvala Pijeska	HR3000088	Uvala Grebaštica
HR3000009	Lošinj – uvala Sunfarni	HR3000032	Uvala Ivanča
HR3000008	Lošinj – Vela i Mala draga	HR3000037	Uvala Jurišnica
HR2000522	Luka Budava – Istra	HR3000129	Uvala Klokun
HR3000067	Luka Soliščica; Dugi Otok	HR3000035	Uvala Krivača
HR3000030	M. Draga – Žrnovnica	HR3000140	Uvala M. Moševčica - Hvar
HR3000020	Mala i Vela luka na poluotoku Sokol; Krk	HR3000139	Uvala M. Pogorila - Hvar
HR4000015	Malostonski zaljev	HR3000086	Uvala Makirina
HR3000103	Merara	HR3000033	Uvala Malin; uvala Duboka
HR3000056	More oko otoka Grujica	HR3000463	Uvala Remac
HR3000060	More oko otoka Škarda	HR3000069	Uvala Sakarun
HR3000460	Morinjski zaljev	HR3000471	Uvala Škvaranska - Uvala Sv. Marina
HR3000112	Mrduja	HR3000165	Uvala Slano
HR3000104	Muljica V. more	HR3000180	uvala Stara Novalja
HR3000445	Murterski kanal	HR3000090	Stivančica cove
HR3000106	Murvica	HR3000091	Tijašnica cove
HR4000001	Nacionalni park Kornati	HR3000141	Uvala V. Moševčica - Hvar
HR5000037	Nacionalni park Mljet	HR3000138	Uvala V. Pogorila – Hvar
HR3000176	Ninski zaljev	HR3000044	Uvala Vlašići
HR4000030	Novigradsko i Karinsko more	HR3000136	Uvala Vlaška – Hvar
HR3000029	Obala između rta Šilo i Vodotoč	HR3000123	Uvala Vrulja kod Brela
HR3000172	Obalna linija od luke Gonoturska do rta Vratnički	HR3000036	Uvala Vrulja u Velebitskom kanalu
HR3000052	Olib – podzemlje	HR3000034	Uvala Zavratnica
HR3000125	Osejava	HR3000142	Uvale Divlja mala i Divlja vela - Hvar
HR3000114	Otoci Lukavci	HR3000415	Uvale Jaz; Soline i Sulinj na Krku
HR3000107	Otoci Orud i Mačaknar	HR3000143	Uvale Kruševa; Pokrvenik i Zaraće – Hvar
HR3000059	Otoci Škrda i Maun	HR3000089	Uvale oko rta Ploča
HR3000474	Otočić Drvenik	HR3000149	Uvale Prapratna i Makarac - Hvar
HR3000122	Otočić Galijula	HR3000038	Uvale Svetojanj V. i M.; uvala Lusk
HR3000135	Otok Hvar – od Uvale Dubovica do rta Nedjelja	HR3000439	Uvale Tratinska i Balun
HR3000100	Otok Jabuka – podzemlje	HR3000015	V. i M. Srakane
HR3000075	Otok Jidula do rt Ovčjak; prolaz V. Ždrelac	HR3000050	Vinjerac – Masleničko ždrilo
HR3000153	Otok Korčula – od uvale Poplat do Vrhovnjaka	HR3000469	Viški akvatorij
HR3000152	Otok Proizd i Privala na Korčuli	HR3000003	Vrsarski otoci
HR3000119	Otok Šćedro	HR3000070	Z. obala Dugog otoka

HR3000097	Otok Vis - podzemlje	HR3000025	Zaljev Kampor na Rabu
HR4000031	Otok Zeča	HR3000417	Zaljev Sv. Eufemije na Rabu
HR3000040	Pag – od uvale Luka V. do rta Krištofor	HR3000440	Žirje – Kabal
HR3000095	Pakleni otoci		
Code	**Ecological network site**	**Code**	**Ecological network site**
Important bird areas			
HR1000032	Akvatorij zapadne Istre	HR1000039	Pučinski otoci
HR1000031	Delta Neretve	HR1000034	S dio zadarskog arhipelaga
HR1000033	Kvarnerski otoci (Kvarner islands)	HR1000036	Srednjedalmatinski otoci i Pelješac
HR1000038	Lastovsko otočje	HR1000023	SZ Dalmacija i Pag
HR1000035	NP Kornati i PP Telašćica	HR1000037	SZ dio NP Mljet

16.6 Annex 6

Authorisations of IRES EKOLOGIJA d.o.o. company for performing professional environmental and nature protection activities

REPUBLIC OF CROATIA
MINISTRY OF ENVIRONMENTAL AND NATURE PROTECTION
10000 Zagreb, Republike Austrije 14
Tel: 01/3717 111 fax: 01/3717 122
Class: UP/I 351-02/13-08/33
Reg. No.: 517-06-2-1-1-13-3
Zagreb, 17 May 2013

The Ministry of Environmental and Nature Protection, pursuant to the provision of Article 39 paragraph 3 of the Environmental Protection Act (Official Gazette, 110/07) and the provision of Article 22 paragraph 5 of the Ordinance on requirements for issuing approvals to legal persons for performing professional environmental protection activities (Official Gazette, 57/10) at the request of company IRES EKOLOGIJA d.o.o., established in Zagreb, Prilaz baruna Filipovića 21, represented by the person authorised for representation in accordance with the law, for issuing the approval for performing professional activities in the area of environment protection, issued hereby this

DECISION

I. Company IRES EKOLOGIJA d.o.o., from Zagreb, Prilaz baruna Filipovića 21, has been issued the approval for performing professional activities in the field of the environment protection, referring to the following professional activities:

1) Drafting strategic studies on the main assessment of the of plan and programme acceptability for the ecological network.
2) Drafting a study on the previous assessment of the of plan and programme acceptability for the ecological network.
3) Drafting a study on the previous assessment of the acceptability of interventions in the ecological network.
4) Drafting a study on the main assessment of the acceptability of interventions for the ecological network.
5) Preparation and processing of documentation for the implementation of the procedure for determining a predominant public interest and compensation measures in line with special regulations in the area of nature protection.
6) Drafting a nature protection programme, management plans and action plans and a report on the condition of the nature protection.
7) Drafting studies on the risk assessment for the introduction, reintroduction and breeding of wild taxa.
8) Monitoring of the conditions in the area of nature protection in relation to professional activities of the Drafting of studies on the intervention impact on the environment, the Drafting of studies on the main assessment of the acceptability of interventions for the ecological network, Preparation and processing of documentation for the implementation of the procedure for determining the predominant public interest and compensation measures in line with special regulations in the area of nature protection.

II. The approval from item (I) of the Operative part of this Decision shall cease to have effect in the period of three years from the day of issue of this Decision.

III. This Decision shall be entered into the Register of issued approvals for the performance of professional environmental protection activities, kept by the Ministry of Environmental and Nature Protection.

IV. This Decision is accompanied by the employee list of the authorised legal person: the head of professional activities in the area of environmental protection and specialists who complied with the required conditions concerning employees.

Statement of reason

IRES EKOLOGIJA d.o.o. company from Zagreb (hereinafter: authorised legal person) on 27 March 2013 submitted to this Ministry a request for issuing approval for the performance of activities in the area of environmental protection pursuant to the Ordinance on requirements for issuing approvals to legal persons for performing professional environmental protection activities (hereinafter the Ordinance): Drafting of strategic studies on the main assessment of the of plan and programme acceptability for the ecological network; Drafting of elaborated report on the previous assessment of the of plan and programme acceptability for the ecological network; Drafting of elaborated report on the previous assessment of the acceptability of interventions in the ecological network; Drafting of studies on the main assessment of the acceptability of interventions in the ecological network; the Preparation and processing of documentation for the implementation of the procedure for determining the predominant public interest and compensation measures in line with special regulations in the area of nature protection; Drafting of a nature protection programme, management plans and action plans and of a report on the condition of the nature protection; Drafting of studies on the risk assessment for the introduction, reintroduction and breeding of wild taxa; Monitoring of the conditions in the area of nature protection in relation to professional activities of the Drafting of studies on the intervention impact on the environment, Drafting of studies on the main assessment of the acceptability of interventions for the ecological network, Preparations and processing of documentation for the implementation of the procedure for determining the predominant public interest and compensation measures in line with special regulations in the area of nature protection.
These types of professional activities belong to the group of activities pursuant to Article 4, items (A)(2) and (3), (B)(4)(5) and(6), (F)(4)and (5), (G)(2) of the Ordinance.

Considering the fact that the request refers to the issue of the approval for professional activities in the area of nature protection, the Environmental Assessment and Sustainable Development Directorate requested an expert opinion of the Nature Protection Directorate on the concerned request on 9 April 2013. The received opinion of the Nature Protection Directorate (Class: 612-07/13-69/08, of 29 April 2013) stated the following: *By inspection of the submitted documentation it was determined that the proposed employees of company Ires ekologija d.o.o. fulfil the conditions prescribed pursuant to Article 7, paragraphs 9, 11, 14, paragraph 2 , and Article 15 paragraph 2 of the Ordinance, for the performance of following groups/types of professional activities: group A – types A2 and A3, group B – types B4, B5 and B6, group F - types F4 and F5, group G - types G2 of the Ordinance.*

Respectively, the legal person enabled to perform professional activities in the area of nature protection for which the request for approval has been submitted must employ head of professional activities with the corresponding education in natural sciences or biotechnology, or being a working professional, with five years of work experience in professional activities of nature protection, one specialist in the area of natural sciences or biotechnology, or being a working professional, with at least three years of work experience in activities of nature protection, and one specialist in the area of natural sciences, technical sciences or biotechnology, or working in that field with at least three years of work experience in professional activities.

In view of the stated above, pursuant to the provision of Article 22 paragraph 5 of the Ordinance, it was decided as set out in the Operative part of this Decision.

The statements of items (I) and (IV) of this Decision have been based on the previously established facts.

The term of validity of this Decision laid down in item (II) of the Operative part of this Decision is set out in Article 22 paragraph 3 of the Ordinance.

Item (III) of the Operative part of this Decision is based on the provision of Article 39 paragraph 5 of the Environmental Protection Act and on the provision of Article 29 of the Ordinance.

INSTRUCTION ON LEGAL REMEDY:

This Decision is enforceable in the administrative procedure and no claim may be lodged against it, but an administrative dispute can be initiated. An administrative dispute can be initiated by raising a claim before the Administrative Court in Zagreb, Avenija Dubrovnik 6 and 8, in the period of 30 days from the day of delivery of this Decision. The claim shall be delivered to the aforementioned Administrative Court directly and in a written form, or orally to be entered in the minutes, or by mail or by electronic means.

An administrative fee for the application and this Decision has been duly charged by stamp duty in the amount of HRK 70.00 pursuant to Tariff No 1 and 2 of the Administrative Fee Tariff under the Administrative Fee Act (Official Gazette 8/96, 77/96, 95/97, 131/97, 68/98, 66/99, 145/99, 30/00, 116/00, 163/03, 17/04, 110/04, 141/04, 150/05, 153/05, 129/06, 117/07, 25/08, 60/08,20/10, 69/10, 126/11, 112/12 and 19/13).

Attachment: Employee list, as mentioned in item (IV) of the Operative part of this Decision.

SENIOR EXPERT ADVISER
<signature>
<stamp>
Zrinka Valetić

To be delivered to:
1) IRES EKOLOGIJA d.o.o., Prilaz baruna Filipovića 21, Zagreb, **with return receipt!**
2) The Ministry of Environmental and Nature Protection, Nature Protection Directorate, Savska 41, Zagreb
3) Directorate for Inspection Activities, here
4) Register, here
5) Case file, here

REPUBLIC OF CROATIA
MINISTRY OF ENVIRONMENTAL AND NATURE PROTECTION
10000 Zagreb, Ulica Republike Austrije 14
tel.; +385 1 3717 111.   Fax: +385 1 3717 149
Class: UP/ 351-02/12-08/91
Reg. No.: 517-06-2-1-1-13-2
Zagreb, 4 January 2013

The Ministry of Environmental and Nature Protection, pursuant to the provision of Article 39 paragraph 3 of the Environmental Protection Act (Official Gazette, 110/07) and the provisions of Article 22 paragraph 1 of the Ordinance on requirements for issuing approvals to legal persons for performing professional environmental protection activities (Official Gazette, 57/10) at the request of company IRES EKOLOGIJA d.o.o., established in Zagreb, Ivana Lučića 5, represented by the person authorised for representation in accordance with the law, for issuing the approval for performing professional activities of the environmental protection, issued hereby this

DECISION

I. The approval has been issued to company IRES EKOLOGIJA d.o.o, from Zagreb, Ivana Lučića 5, for performing professional activities of environment protection:

1) Drafting of strategic studies.

2) Drafting strategic studies on intervention impact on environment including activities of preparation and processing of documentation with a request for an assessment of the need for evaluation of the intervention impact on the environment and activities of preparation and processing of documentation with a request for the issuing of a guideline for the study content.

3) Drafting elaborated reports on environmental protection concerning interventions for which the obligation of environmental impact assessment including drafting of an elaborated report on environmental restoration has not been prescribed.

4) Drafting, verifying and analyzing condition monitoring for specifi activities and groups of activities in the area of environmental protection and for the purpose of the Environment Pollution Register.

5) Drafting environmental protection action plans or environmental components protection action plans (air, soil, sea and other) and safeguarding from pollution (waste management and other).

6) Drafting an environmental protection programme.

7) Drafting a report on the condition of the environment.

8) Monitoring of the condition in the field of environmental protection – sampling, testing, measuring and similar for the purpose of certain environmental components protection or protection against environmental burdening, except for the air quality and emission into the air monitoring activities.

II. The approval from item (I) of the Operative part of this Decision shall cease to have effect in the period of three years from the day of issuing this Decision.

III. This Decision shall be entered into the Register of issued approvals for the performance of professional environmental protection activities, kept by the Ministry of Environment Protection, Construction and Spatial Planning.

IV. This Decision is accompanied by the employee list of the authorised legal person: head of environmental protection professional activities and specialists who complied with the required conditions concerning employed specialists for the issue of approval referred to in item (I) of the Operative part of the Decision.

Statement of reason

IRES EKOLOGIJA d.o.o. company from Zagreb (hereinafter: authorised legal person) on 18 December 2012 submitted to this Ministry a request for issuing approval for the performance of environmental protection professional activities pursuant to the Ordinance on requirements for issuing approvals to legal persons for performing professional environmental protection activities (hereinafter: the Ordinance): Drafting strategic studies: Drafting of strategic studies on intervention impact on environment including activities of preparation and processing of documentation with a request for an assessment of the need for evaluation of the intervention impact on the environment and activities of preparation and processing of documentation with a request for the issue of a guideline for the study content; Drafting of elaborated reports on environmental protection concerning interventions for which the obligation of environmental impact assessment, including also drafting of an elaborated report on the environmental restoration, has not been prescribed; Drafting, verifying and analyzing condition monitoring for certain activities and groups of activities in the field of environmental protection and for the purpose of the Environment Pollution Register; Drafting environmental protection action plans or environmental components protection action plans (air, soil, sea and other) and safeguarding from pollution (waste management and other); Drafting environmental protection programme; Drafting a report on the condition of the environment; Monitoring of the condition in the field of environmental protection – sampling, testing, measuring and similar for the purpose of certain environmental components protection or protection against environmental burdening, except for the air quality and emission into the air monitoring activities.

In the request for issuing the approval the authorised legal person has enclosed the following evidence on fulfillment of the required conditions: excerpt from court registry with registred activity: professional activities of nature protection; university degree and workbook copy for the head of professional activities: a list of works in the study of which he/she participated and where one can clearly see his/her capacity in the concerned activities with the copies of the work fragments in confirmation thereof; university degree and workbook copies for each specialist of the adequate profession and with required work experience in environmental protection activities in line with the professional activity that the authorised person applied for being granted the approval; a list of works in whose development he/she participated and where one can clearly see his/her capacity in the concerned activities with the copies of his work fragments in confirmation thereof;
Furthermore, the authorised legal person enclosed a statement verified by notary that he has adequate facilities at his disposal.

In the concerned procedure, pursuant to Article 4 paragraph 1 of the Environmental Protection Act and Article 21 paragraph 4 of the Ordinance, and conducted in line with Article 50, item 1, and Article 58 paragraph 2 of the General Administrative Procedure Act (Official Gazette, 47/09), it has been established that the authorised legal person provided the facts and submitted evidence in his/her application on the basis of which the real state of affairs can be determined, and it has also been identified that this body is familiar with the facts on the conditions available to the authorised legal person since the body disposes of official information in compliance with its records.

After the application examination and review of submitted evidence, it has been confirmed that the authorised legal person:

- employs the head of professional activities with five years of work experience in professional activities of environmental protection and who managed the drafting of studies on the intervention impact on the environment, of expert groundworks and elaborated reports on environmental protection, and who fulfills requirements pursuant to Article 7 of the Ordinance;

- employs specialists with the corresponding specialist profile and with the required years of work experience in the environmental protection activities, who participated in drawing up of respective expert groundworks and elaborated reports on the environmental protection, and who fulfils the requirements pursuant to Articles 8, 10, 13, 14 and 15 of the Ordinance;

- has adequate business premises at disposal.

The statements of items (I) and (IV) of this Decision have been based on the previously set forth and established facts.

The term of validity of this Decision laid down in item (II) of the Operative part of this Decision is set out in Article 22 paragraph 3 of the Ordinance.

Item (III) of the Operative part of this Decision is based on the provision of Article 39 paragraph 5 of the Environmental Protection Act and on the provision of Article 29 of the Ordinance.

Based on the specified above, it has been decided as stated in the Operative part of this Decision.

INSTRUCTION ON LEGAL REMEDY:
This Decision is enforceable in the administrative procedure and no claim may be lodged against it, but an administrative dispute can be initiated. An administrative dispute can be initiated by raising a claim before the Administrative Court in Zagreb, Avenija Dubrovnik 6 and 8, in the period of 30 days from the day of delivery of this Decision. The claim shall be delivered to the aforementioned Administrative Court directly and in a written form, or orally to be entered in the minutes, or by mail or by electronic means.

An administrative fee for the application and this Decision has been duly charged by stamp duty in the amount of HRK 70.00 pursuant to Tariff No 1 and 2 of the Administrative Fees Tariff under the Administrative Fees Act (Official Gazette 8/96, 77/96, 95/97, 131/97, 68/98, 66/99, 145/99, 30/00, 116/00, 163/03, 17/04, 110/04, 141/04, 150/05, 153/05, 129/06, 117/07, 25/08. 60/08, 20/10, 69/10, 49/11 and 126/11).

Attachment: Employee list, as mentioned in item (IV) of the Operative part of this Decision

ASSISTANT MINISTER
<signature>
<stamp>
Mario Obrdalj, B.Sc.C.E.

To be delivered to:
1) IRES EKOLOGIJA d.o.o., Prilaz baruna Filipovića 21, Zagreb – **with return receipt!**
2) Directorate for inspection activities, here
3) Register, here
4) Case file, here

16.7 Annex 7

<Translator's note: The site names were intentionally left in Croatian because these are the names under which their details can be found in the European Nature Information System and on the Natura2000 website.>

Site name	Protection category	Site name	Protection category
Badija	significant landscape	Malostonski zaljev	special nature reserve
Bijele i Samarske stijene	strict nature reserve	Mljet	national park
Brela	significant landscape	Mrkan, Bobara i Supetar	special nature reserve
Brijuni	national park	Mura	significant landscape
Brusnik	nature monument	Mura – Drava	regional park
Čambina	significant landscape	Ošljak (Preko)	significant landscape
Datule Barbariga	special nature reserve	Pakleni otoci	significant landscape
Delta Neretve - jugoistočni dio	special nature reserve	Palud	special nature reserve
Dolina Blaca	significant landscape	Pantan	special nature reserve
Donji Kamenjak i Medulinski arhipelag	significant landscape	Petrova gora	significant landscape
Dubrava Hanzina	significant landscape	Prud	special nature reserve
Fojiška – Podpredošćica	special nature reserve	Prvić i Grgurov kanal	special nature reserve
Gajna	significant landscape	Ravnik	significant landscape
Glavine – Mala luka	special nature reserve	Rijeka Dubrovačka	significant landscape
Gornji Kamenjak	significant landscape	Rovinjski otoci i priobalno područje	significant landscape
Jabuka	nature monument	Saplunara	significant landscape
Jelas polje	significant landscape	Šćedro	significant landscape
Jelkuš	significant landscape	Sitsko-žutska otočna skupina	significant landscape
Kalnik	significant landscape	Sjeverozapadni dio Dugog otoka	significant landscape
Kanal – Luka	significant landscape	Telašćica	nature park
Kanjon Zrmanje	significant landscape	Turopoljski lug	significant landscape
Kornati	national park	Učka - južni dio	significant landscape
Križnica	significant landscape	Uvala Prapratno	significant landscape
Krka – donji tok	significant landscape	Uvala Stiniva	significant landscape
Labin, Rabac i uvala Prklog	significant landscape	Uvala Vučina	significant landscape
Lastovsko otočje	nature park	Veliki Pažut	special nature reserve
Limski zaljev	significant landscape	Zavratnica	significant landscape
Limski zaljev - rezervat	special nature reserve	Zečevo	significant landscape
Lipa na Medvednici	significant landscape	Zelenjak – Risvička i Cesarska gora	significant landscape
Lisina	significant landscape	Zelinska glava	significant landscape
Lopar	significant landscape	Zlatni rat	significant landscape

Mali bok – Koromačna	special nature reserve	Zrće	significant landscape