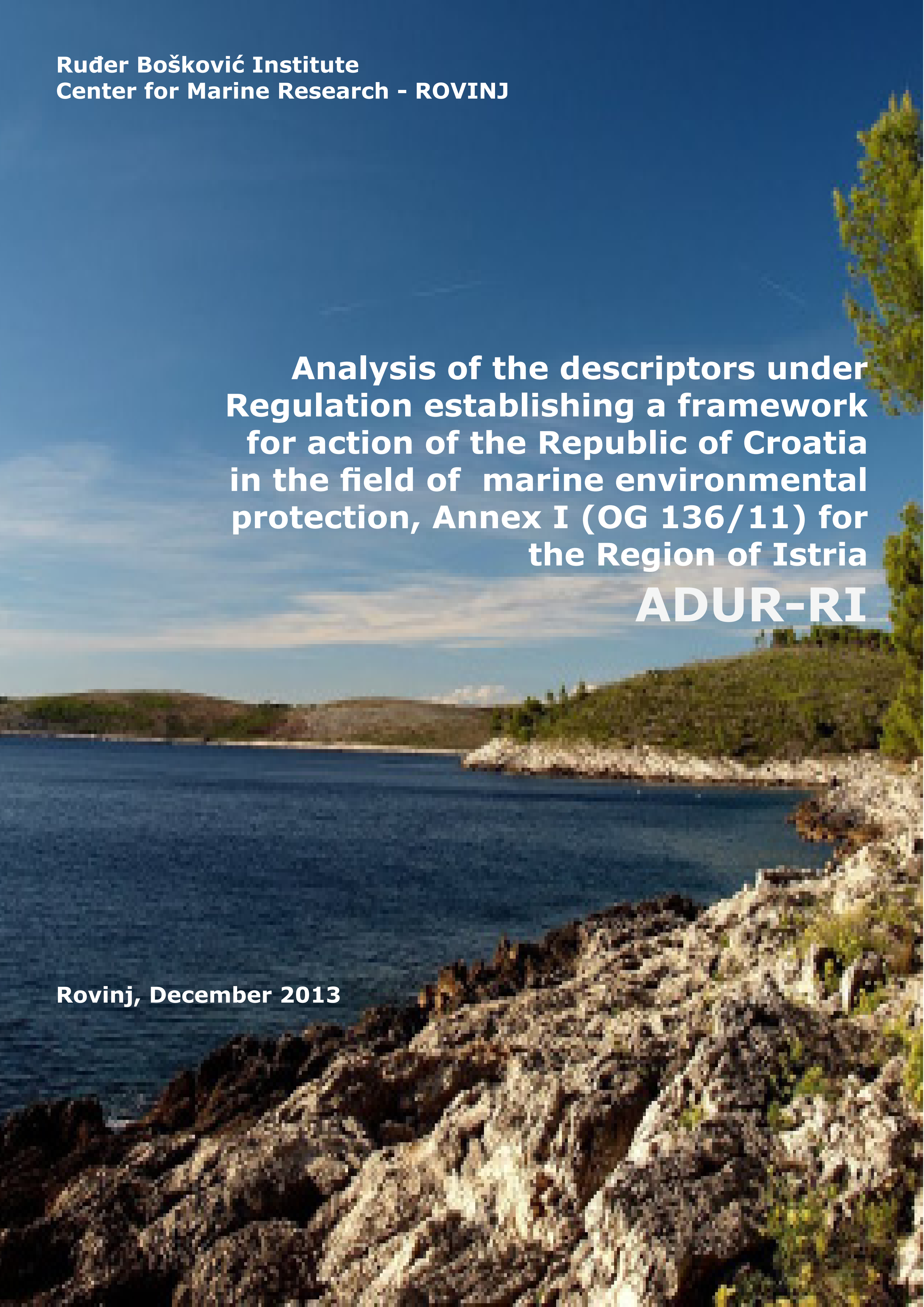

Ruđer Bošković Institute
Center for Marine Research - ROVINJ

Analysis of the descriptors under Regulation establishing a framework for action of the Republic of Croatia in the field of marine environmental protection, Annex I (OG 136/11) for the Region of Istria

ADUR-RI

Rovinj, December 2013

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RUĐER BOŠKOVIĆ INSTITUTE
CENTER FOR MARINE RESEARCH
ROVINJ

ANALYSIS OF THE DESCRIPTORS UNDER REGULATION ESTABLISHING A FRAMEWORK FOR ACTION OF THE REPUBLIC OF CROATIA IN THE FIELD OF MARINE ENVIRONMENTAL PROTECTION, ANNEX I (OG 136/11) FOR THE REGION OF ISTRIA

ADUR-RI

Project leader

dr. sc. Robert Precali

Director of the
Center for Marine Research

dr. sc. Renato Batel

Rovinj, December 2013

Natura non nisi parendo vincitur

Nature can only be conquered by being obeyed

Francis Bacon

Prepared by:

Center for Marine Research, Ruđer Bošković Institute, Rovinj

dr. sc. Robert Precali

Project leader
Physical and chemical oceanography, Nutrients, Eutrophication, GIS

dr. sc. Ljiljana Iveša

Macrophytobenthos

dr. sc. Ana Travizi

Macrozoobenthos

dr. sc. Nevenka Bihari

Ecotoxicology

Institute for Oceanography and Fishery, Split

dr. sc. Nedo Vrgoč

Demersal fishery

dr. sc. Igor Isajlović

Demersal fishery

dr. sc. Jakov Dulčić

Demersal resources

dr. sc. Branko Dragičević

Demersal resources

dr. sc. Melita Paharda Uljević

Shellfish

dr. sc. Daria Ezgeta Balić

Shellfish

dr. sc. Vanja Čikeš Keč

Small pelagic fish

dr. sc. Barbara Zorica

Small pelagic fish

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Content

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A. Term of reference

A.1. In general

To analyse descriptors under Regulation establishing a framework for action of the Republic of Croatia in the field of marine environmental protection, Annex I (OG 136/11) for the Region of Istria

A.2. A detailed description

A.2.1. Handle any changes that occurred under the influence of anthropogenic or climatic factors in the following areas: Limski kanal, Raša Bay, Plomin Bay, Budava Bay, Mirna estuary-Tar Bay, and designate trophic status of all of the above locations. In accordance with Regulation of establishing a framework for action of the Republic of Croatia in the field of marine environmental protection, Appendix I (OG136/11), give the conclusions for the following descriptors: *1-Biodiversity; 5-Eutrophication; 7-Permanently changing hydrographic and oceanographic conditions; 8-Concentrations of pollutants; 9-Pollutants in fish and other marine organisms.*

A.2.2. Provide a review of the impact of anthropogenic activities in the coastal sea of Istria County (pollutant loads from land-based sources (LBS), sanitary quality of shellfish culturing areas, the level and the influence of pollution in selected areas (hot spots) and the mutual impact of fish aquaculture and environment. Provide a review of unusual phenomena threatening human health, tourism, maritime transport and fisheries (natural phenomena of unusual intensity, harmful algal blooms and jellyfish "blooms", identification of toxic phytoplankton species and bio toxins analyses and introduction and excessive reproduction of allochthonous plankton species). In accordance with Regulation of establishing a framework for action of the Republic of Croatia in the field of marine environmental protection, Appendix I (OG 136/11), give the conclusions for the following descriptors: *5-Eutrophication; 9-Pollutants in fish and other marine organisms*

A.2.3. Provide a review of the status of the Istrian ichthyofauna and assessment of living resources, especially the commercially important species of coastal fish, as well as characteristic, important, or dominant species in the Istria County. Special focused have to be done on the dynamics of coastal fish populations and state and changes in coastal fish, crustacean and cephalopod populations due to their exploitation. Handle the impact of global climate change on the diversity of fish and other marine organisms in the Istria County. Provide a review of quantitative and qualitative changes in the composition of coastal fish communities in Istria County. Provide a review the introduction of new species (accidentally, by escaping from aquaculture or aquarium, through ballast water, or because of global climate change- tropicalization of Adriatic Sea). Mark areas of spawning, growth and feeding economically important fish and other marine organisms in Istria County. Make proposals for continuous monitoring. Establish measures to protect species and habitats. Provide an overview of fish from the Red Book of the Republic of Croatia for Istria County (if their existence). In accordance with Regulation of establishing a framework for action of the Republic of Croatia in the field of marine environmental protection, Appendix I (OG 136/11), give the conclusions for the following descriptors: *1-Biodiversity; 2-Alien species; 3 - State of stock; 4 – Marine elements of food network; 5-Eutrophication*

A.2.4. Provide a review of the benthic invertebrate communities, free-living marine nematodes, and make an assessment of the ecological status of coastal waters. In accordance with Regulation of establishing a framework for action of the Republic of Croatia in the field of marine environmental protection, Appendix I (OG 136/11), give the conclusions for the following descriptors: *1-Biodiversity; 2-Alien species*

B. Glossary of abbreviations and technical terms

Abbreviation or technical term	Description or meaning
Benthos	Organisms that live on or in the bottom of a body of water.
Benthic community	Community made up of organisms that live in and on the bottom of the sea floor.
BQE	Biological Quality Element.
Biocenosis (biotic community)	An ecosystem, originally defined by Tansley (1935), as a biotic community along with its physical environment (or biotope). In ecological studies, biocenosis is the emphasis on relationships between species in an area.
Chl *a*	Chlorophyll *a* is a photosynthetic pigment necessary for photosynthesis and is found in all phytoplankton cells. Determination of chlorophyll *a* concentration is the simplest method for estimating the biomass of phytoplankton.
Commission decision	COMMISSION DECISION of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters(notified under document C(2010) 5956; Text with EEA relevance; 2010/477/EU).
CTD probe	Conductivity, Temperature, Depth, a multi-parameter probe for measuring conductivity (salinity), temperature and depth in natural waters.
Diatoms	The most abundant phytoplankton group in the Adriatic (over 80%). They are characterized by silica shells, which are built from two parts.
Dinoflagellates	According to the significance and representation are the second phytoplankton group in the Adriatic. Unlike diatoms, which are stationary, most dinoflagellates has a very good ability to move using flagella. These organisms can cause intense blooms in a very short time.
Facies	The same biocenosis with appearance of an individual or a group of plants or animals.
Guidance Document	Implementation guide.
HD	The Habitats Directive (more formally known as Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora).

Abbreviation or technical term	Description or meaning
Indicator fish species	Selected fish species that are indicators of some kind of change in the environment, in this case, the tropical elements that represent either new or rare species for the Adriatic and indicators of climate change, and composition of the Adriatic ichthyofauna.
MSFD	The Marine Strategy Framework Directive.
Nutrients	Dissolved salts of nitrogen (nitrate, nitrite, ammonium salts), phosphorus (orthophosphate) and silicon (orthosilicate) involved in primary production of organic matter in natural waters, or are a necessary element for the construction of diatom shells.
O_2 (%)	Oxygen saturation of water calculated from the ratio of established and theoretical content of oxygen at an ambient temperature and salinity.
Phytoplankton	Unicellular and colonial algae whose cells are floating in the water.
S	Salinity; Weight (g) of salt dissolved in 1 kg of sea water when all the bromides and iodides are replaced by an equal amount of chloride, and the organic matter oxidized. (Knudsen, 1901). Derived from a polynomial of 5th order: $S = - 0,08996 + 28.29720\ R_{15} + 12.80823\ R_{15}^2 - 10.67869\ R_{15}^3 + 5.98624\ R_{15}^4 - 1.32311\ R_{15}^5$ where R_{15} is the ratio of the conductivity of a sample and a standard of seawater with salinity of 35 at 15 °C and 101 325 Pa. Expressed as PSU (UNESCO, 1985).
TRIX	Trophic index, which is calculated from the concentrations of total dissolved inorganic nitrogen, total phosphorus, chlorophyll a, and deviation of oxygen saturation from steady state.
Trophic status	A term that generally indicates the level of productivity, and specifically for the fish community indicates the diet, or position in the food chain. This status is a result of the level of productivity of habitat in which the organism resides.
WFD	The Water Framework Directive.

1. Introduction

1.1. Basics

The sea and the marine environment is of strategic importance for Croatia. Its protection, conservation and restoration of natural resources aimed at conserving biodiversity and marine ecosystems in order to facilitate and ensure the sustainable use of marine resources for the benefit of present and future generations.

1.2. Marine Strategy Framework Directive (MSFD)

The Marine Strategy Framework Directive (MSFD) of the European Parliament and of the Council of 17 June 2008 (2008/56/EC) establishes a framework for the Community action in the field of marine environmental policy within which Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment at the latest by 2020. MSFD is a legal framework that connects the various policy and encourages the inclusion of environmental issues in other policies (fishing, agriculture, tourism, shipping, etc.), and provides a general framework for the harmonization of the measures to be taken, to enable, to complement the existing measures on the basis of other laws and international agreements, applying the "Ecosystem approach" as a strategic approach to integrated management of the marine environment in a balanced manner that promotes the conservation and use of natural resources. MSFD takes into account existing regulations and policies related to the marine environment, such as the Water Framework Directive (2000/60/EC), the Habitats Directive (92/43/EC), the Birds Directive (79/409/EC), the Common Fisheries Policy and other relevant international regulations.

During the accession to the EU, Croatia among other obligations assumed the obligation to transpose the Marine Strategy Framework Directive (2008/56/EC) to Croatian legislation which was provided through the Regulation establishing a framework for action of the Republic of Croatia in the field of marine environment protection (OG 136/11). The Regulation defines the baseline and benchmarks for designing, development, implementation and monitoring strategy to protect the marine environment.

The main objectives MSFD has to achieve through protection of the marine environment in areas which are under the sovereignty of the Republic of Croatian, and in which the Republic of Croatia exercises sovereign rights and jurisdiction, are:

- **to protect, preserve and facilitate recovery and, where practicable, restore the structure and function of marine and coastal ecosystems, and its biodiversity protection and sustainable use;**
- **conservation of protected areas in the sea and ecologically important areas of the European Union's Natura 2000;**
- **reduce pollution, or load in the marine and coastal environment to ensure that no significant adverse impacts or risks to human health and/or health of ecosystems and/or use of the sea and coast;**
- **the preservation, enhancement and re-establishment of the balance between human activities and natural resources in the sea and on the coasts.**

1.3. Marine, transitional and coastal waters

Marine waters are internal waters, territorial sea of the Republic of Croatian and their seabed and subsoil, as well as marine areas, including their seabed and subsoil, to which the Republic of Croatia exercises sovereign rights.

Transitional and coastal waters are parts of the ecosystem where sea is in direct contact with land, i.e., where the impacts of land on the sea are the strongest. This part is the most vulnerable and requires a superior approach to management and protection.

The WFD defines the term **transitional waters** as "bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows", a term **coastal water**s means "surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters".

1.4. Objectives

The objectives of this study should be consistent with those provided in the main project: **Shaping a Holistic Approach to Protect the Adriatic Environment: between coast and sea** (SHAPE), Adriatic IPA, No. 167/2009.

The main objectives of this study will contribute to:

- **reasonable and sustainable management of coastal sea living resources of Istria County,**
- **find and recommend ways of implementation of the sustainable exploitation of edible marine organisms of Istria County for the purpose of their preservation,**
- **collect scientific data for the Plan of Integrated Coastal Zone Management and Physical Plan of the Region of Istria,**
- **obtain the new biological knowledge in order to enable the realisation of reasonable and sustainable fishery management, together with the protection of ichthyo-communities and populations.**

2.0. Methodology

2.1. Tools

Quality tools are a prerequisite for a successful work. On this track, just the establishment of quality tools and guidelines (Guidelines) for each descriptor is the first step.

2.1.1. Database

To create this study the oceanographic database of the Center for Marine Research in Rovinj was used. In the database are generally stored data for physical and chemical parameters, and phytoplankton biomass and composition. For this study, the database is complemented by GIS data needed for rendering the relevant charts.

Unfortunately, collection of data relating to the data on macrophytobenthos and macrozoobenthos communities is not organized in a database, but only in MS Excel tables. To create these tables a lot of working time was spent since the original data were mainly from historical data that are only in a paper form. Once a database for handle such entries will be organised their analysis will be much easier. Selection of such a storage format was also due because the inputs to the software that was used for the calculation of various indices use only MS Excel tables.

To create the fishery substrates the database of the Institute of Oceanography and Fisheries in Split was used.

2.1.2. Geographic Information System (GIS)

GIS was mainly used to produce maps presented in this study and the quality of the substrate is at least 1:25000 or better. Maps were created in ArcView 8.1.

2.1.3. Marine waters definition

Marine waters based on MSFD Art. 5 § 5 are:

(a) the internal waters, territorial sea of the Republic of Croatian and their seabed and subsoil, as well as marine areas, including their seabed and subsoil, to which the Republic of Croatia exercises sovereign rights or jurisdiction in accordance with the UN Convention on the Law of the Sea and special Croatian laws;

(b) coastal waters as defined by specific regulation of water management, their seabed and subsoil, the extent to which specific aspects of the ecological status of the marine environment are not already covered by these regulations or other laws of the Republic of Croatia;

The coastal waters are determined by: "The term coastal waters means surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters." Baseline for measuring the breadth of the territorial sea is defined in Article 18 of the Maritime Code of the Republic of Croatia (OG 181/04, OG 76/07, OG 146/08, OG 61/11, OG 56/13) and reads as follows:

Article 18

(1) Territorial waters of the Republic of Croatia are the sea belt 12 nautical miles wide, starting from the baseline in the direction of the economic belt.

(2) The baseline is:
1) low-water line along the coast of the mainland and islands,

2) straight lines which close entrances to harbours or bays,
3) straight lines connecting the following points on the mainland coast and the island coast:
   a) C Zarubača – SE C of Is. Mrkan – S C of Is. Sv. Andrija – C Gruj (Is. Mljet),
   b) C Korizmeni (Is. Mljet) – Is. Glavat – C Struga (Is. Lastovo) – C Veljeg mora (Is. Lastovo) – SW C of Is. Kopište – C Velo danče (Is. Korčula) – C Proizd – SW C of Is. Vodnjak – C Rat (Is. Drvenik mali) – Rk Mulo – Rk Blitvenica – Is. Purara – Is. Balun – Is. Mrtovac – Is. Garmenjak veli – point on Is. Dugi otok with coord. 43°53' 12" N, 15°10' 00" E,
   c) C Veli rat (Dugi otok) – Rk Masarine – C Margarina (Is. Susak) – Rksw Albanež – Is. Grunj – Rk Sv. Ivan na pučini – Rksw Mramori – Is. Altiež – C Kastanjija.

(3) The baseline is drawn on the nautical chart "Adriatic Sea", issued by the Croatian Hydrographic Institute

Moving the baseline 1 Nm closer to the border of the territorial sea of Croatia external borders of the coastal sea were obtained, the interior one is the low-water line along the coast of the mainland and islands. The boundary of the coastal sea of Croatia for the Istrian coastal basins is shown on Figure 2.1.

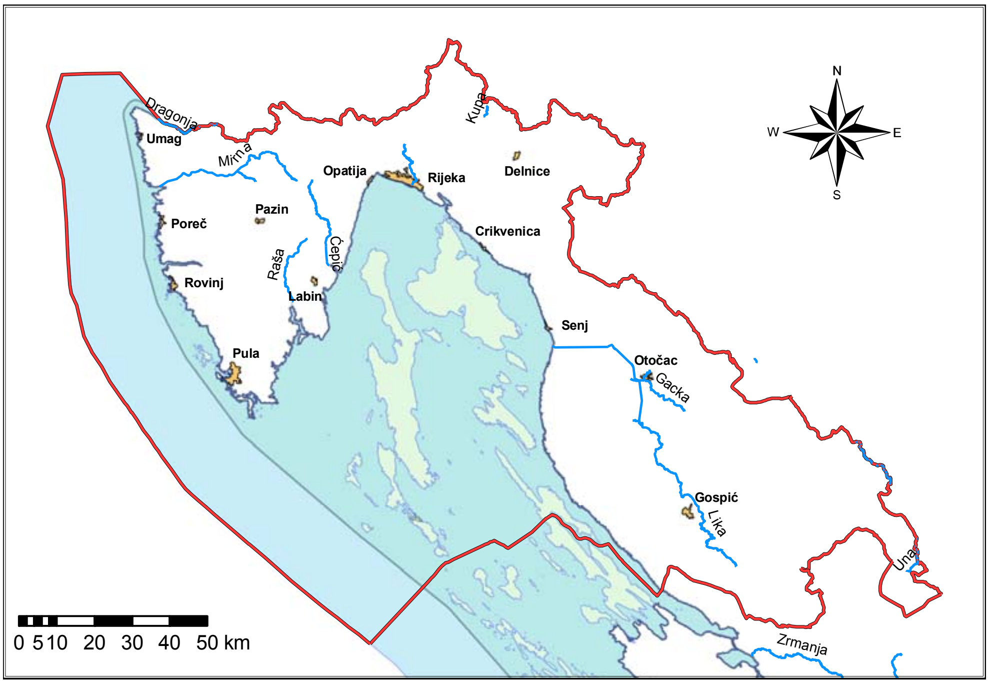

Figure 2.1. The Croatian marine and coastal waters as defined in the WFD and MSFD.

2.1.4. Indicators and DPSIR approach

The term indicator is meant to summarize and effectively present informations on the state of the environment, which is better suited to make decisions regarding its management.

According to the OECD definition from 1993 the indicator is: **"Indicator/parameter or a value derived from parameters, which points to, provides information about/ describes the state of the phenomenon/ environment/ area and has further implications for the environment. Indicator is not necessarily a parameter, but may be a term derived from the individual or from a set of parameters relating to the environment"**.

The indicator for the purpose of environmental management is mainly used for:

- collect information about problems in the environment in order to assess their severity,
- decision support and defining priorities, pointing out the key factors that cause pressures in the environment, and
- monitoring the effectiveness of applied responses.

Indicators are an effective way to monitor changes and achieving the objectives of sectorial policies and strategies. Indicators should be representative, relevant, credible and accurate. There are many criteria for the selection of indicators, but the most important are the following: how important is the problem from the standpoint of environmental damage, how policy looks at the problem and is it possible to collect and measure the indicators.

DPSIR (**D**rivers, **P**ressures, **S**tate, **I**mpacts, **R**esponses) is an approach to the system of indicators, which are widely used for the marine environment and coastal areas, as a way of organizing and reporting the systematic monitoring in communication with the control part of the society and the general public. DPSIR is also a tool for a better understanding of environmental problems. DPSIR model uses the approach by identifying the causes and causal sequence. In this approach, indicators are attributes that summarizes basic information or data relating to a setting or a problem. Such an approach has been applied to the problem of eutrophication of coastal sea water and is shown on Figure 2.2.

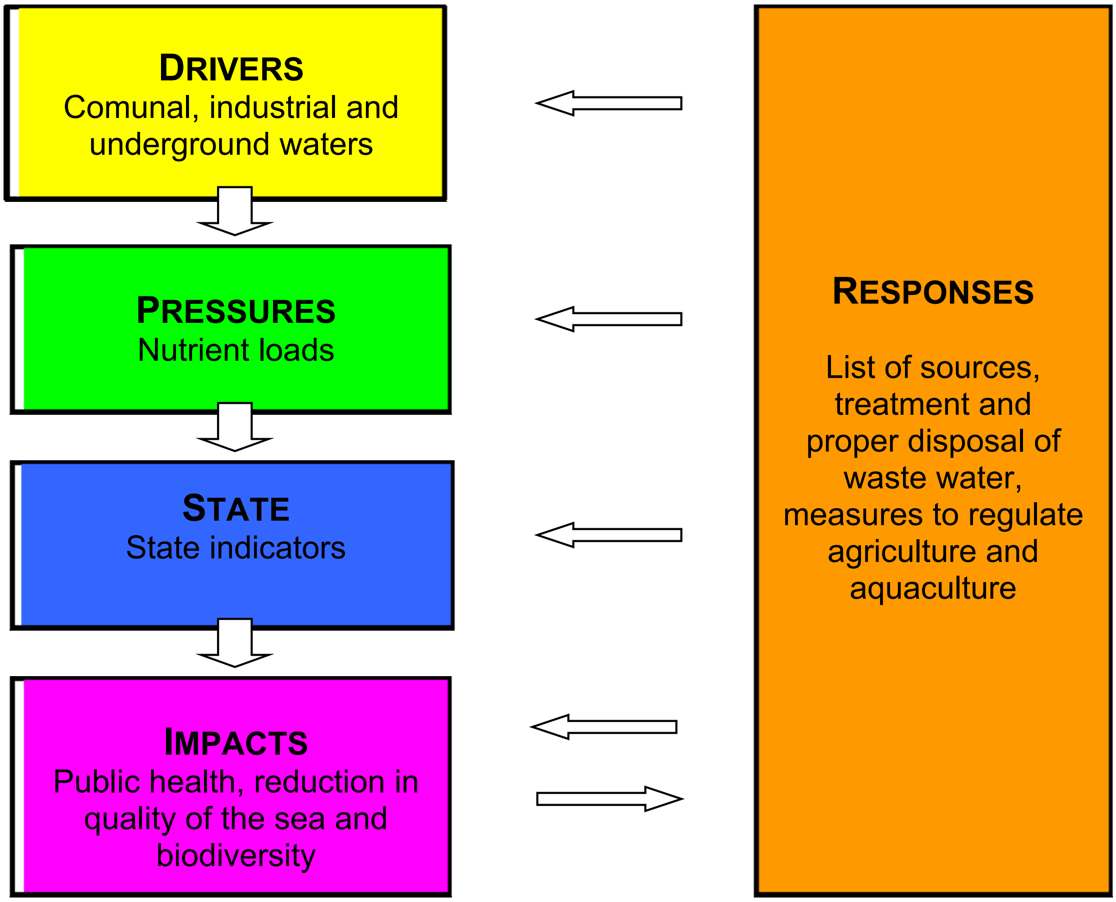

Figure 2.2. DIPSR approach applied to the eutrophication problem.

2.1.5. Eutrophication – classification of state

Since the MSFD classification system is still under development, we will certainly benefit from the experiences gained during the implementation of the WFD, and in this study we will use them for the initial evaluation.

Composition, richness and biomass of phytoplankton according to WFD are one of the major biological quality elements for transitional and coastal waters.

Primarily were selected because they represent a very sensitive part of the ecosystem to changes in the availability of nutrients. Load of nutrients as the main pressure in aquatic ecosystems resulting from human need for intensive agriculture, using in some industrial processes, and most importantly as a product of human physiology. The biological response to the load of nutrients into the aquatic ecosystem, in favourable abiotic conditions (sufficient light and favourable temperature), is the growth of phytoplankton (Bricker *et al.*, 1999). The consequences of excessive anthropogenic input are reflected in the process of eutrophication. It include an increase in the concentration of chlorophyll *a* (a measure of phytoplankton biomass), changes in the frequency of algal blooms, the rapid growth of opportunistic species and a significant accumulation of organic matter that can have negative effects on the ecosystem. Last manifested in closed ecosystems, such as most of the coastal waters, the appearance of hypoxia and anoxia, which results in mortality of benthic organisms, and a general decline in quality of the sea as a resource.

Assessment of state and impact of eutrophication in transitional and coastal waters is today one of the most important steps in environmental management (Painting *et al.*, 2005, 2007). Therefore, phytoplankton falls into one of the key biological quality elements. Although the WFD states that phytoplankton as a biological quality element consists of its composition, richness and biomass no multimetric index which would include all three components have been developed and at this point only classification based on biomass is considered. In the Mediterranean, all MS have elaborated national systems of classification based on the concentration of chlorophyll *a* (a measure of biomass). For now, the intercalibration of these methods is in progress.

In Table 2.1 definitions for very good, good and moderate ecological status in transitional and coastal waters for phytoplankton under the WFD is presented. Based on these definitions, as well as the knowledge on ecosystems a classification system based on biomass (chlorophyll *a*) was developed. The known gradients of trophic states directly related to the process of eutrophication of an ecosystem were taken into account to obtain the class boundaries. As a measure of trophic state a trophic index developed by Vollenweider *et al*. (1998) for the area of Emilia Romagna in Italy was considered. Although the trophic index was developed for a limited area, it can be applied at least in most of the northern Adriatic, if not the entire Adriatic (Giovanardi and Vollenweider, 2004). Namely, the input of and the relationships between nutrients are similar for the entire Adriatic. Essentially, the Adriatic Sea is an oligotrophic sea limited by phosphorus, and just it load mainly regulate the trophy of the Adriatic (Gilmartin *et al.*, 1990; Giovanardi and Vollenweider, 2004)

Table 2.1. Definitions of very good, good and moderate ecological status in transitional and coastal waters (WFD, Annex V, 1.2.3 and 1.2.4) for phytoplankton as a biological quality element.

Element	High status	Good status	Moderate status
Phytoplankton	**Transitional waters**		
	The composition and abundance of the phytoplanktonic taxa are consistent with undisturbed conditions. The average phytoplankton biomass is consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type specific physico- chemical conditions.	There are slight changes in the composition and abundance of phytoplanktonic taxa. There are slight changes in biomass compared to the type-specific conditions. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbance to the balance of organisms present in the water body or to the physico-chemical quality of the water. A slight increase in the frequency and intensity of the type specific planktonic blooms may occur	The composition and abundance of phytoplanktonic taxa differ moderately from type-specific conditions. Biomass is moderately disturbed and may be such as to produce a significant undesirable disturbance in the condition of other biological quality elements. A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months.
	Coastal waters		
	The composition and abundance of phytoplanktonic taxa are consistent with undisturbed conditions. The average phytoplankton biomass is consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type specific physico- chemical conditions	The composition and abundance of phytoplanktonic taxa show slight signs of disturbance. There are slight changes in biomass compared to type-specific conditions. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbance to the balance of organisms present in the water body or to the quality of the water. A slight increase in the frequency and intensity of the type-specific planktonic blooms may occur	The composition and abundance of planktonic taxa show signs of moderate disturbance. Algal biomass is substantially outside the range associated with type-specific conditions, and is such as to impact upon other biological quality elements. A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months

It is generally accepted that the first boundary changes (very good-good) for trophic index scale is about 4 or chlorophyll *a* concentration around 1 mg L^{-1} (Yamada *et al.*, 1980; Chiaudani *et al.*, 1982, Italian law-D. LGS. 152/99). Accordingly boundaries are set equidistantly from trophic index 4-7, although the Italian law states the change from low to bad ecological status of about 8. Because the scale is linear in the used trophic index range value in our case we used 7. A similar scale was used from2003 to assess the degree of eutrophication within the Project "Adriatic" (Table 2.2). This scale is now incorporated into the Regulation on water quality standards (OG 73/13) and sometime should be used for the classification of waters. After the intercalibration of method for the Mediterranean, which is in the final phase, a new approach which will be in the spirit of all the assumptions that are built into both directives (WFD and MSFD) will be used. In this study the approach used in the Regulation was applied.

Table 2.2. The classification of the ecological status of the Adriatic Sea regarding the degree of eutrophication, which has been in use informally for the Project "Adriatic.

Ecological state Eutrophic degree Colour	z_{Sd}/m	$\gamma(O_2/O_2')$	*c*(TIN) µmol L^{-1}	*c*(TP) µmol L^{-1}	*c*(Chla) µg L^{-1}	Trix	Conditions
Very good Oligotrophic Blue	**>10**	**0,8-1,2**	**<2**	**<0,3**	**<1**	**2-4**	- low trophic level - good water transparency - absence of anomalous colours of water - absence of subsaturation of dissolved oxygen
Good Mezotrophic Green	**3-10**	**p.- 1,2-1,7 d.-0,3-0,8**	**2-10**	**0,3-0,6**	**1-5**	**4-5**	- average trophic level - occasional clouding of water - occasional anomalous colours of water - occasional hypoxi
Moderate Eutrophic Yelow	**<3**	**p.- >1,7 d.- 0,3-0,8**	**10-20**	**0,6-1,3**	**5-10**	**5-6**	- average trophic level - occasional clouding of water - occasional anomalous colours of water - hypoxia and occasional anoxia - problems in benthic communities
Poor Ekstremely eutro. Orange	**<3**	**p.- >1,7 d.- 0,0-0,3**	**>20**	**>1,3**	**>10**	**6-7**	- high trophic level - high turbidity of water - persistent colouring of water - persistent hypoxia and anoxia - dying of benthic organisms - alteration of benthic communities

z_{Sd} - Transparency, γ – Oxygen saturation ratio, *c* - concentration, TIN – Total Inorganic Nitrogen, TP – Total Phosphorous, Chla – Chlophyll *a*, Trix – Trophic index, p.- surface and d.- bottom layer.

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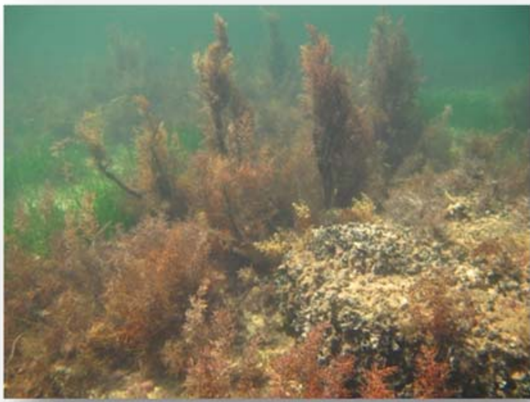
2.1.6. Classification of macroalgal assemblages



In the European Union Water Framework Directive, several methods were proposed for the classification of coastal and transitional waters using the biological quality elements (BQE) macroalgae and seagrass. To assess the coastal waters along the Istria coast, two methods for analysing BQE macroalgae were tested: the EEI (Ecological Evaluation Index; method developed in Greece) and the CARLIT (Littoral Cartography; method developed in Catania, Spain).

EEI method

EEI methodology is used to quantify the anthropogenic impact in the coastal waters of the Aegean coast (Orfanidis et al., 2001, 2003; Panayotidis et al., 2004). The method was based on the destructive sampling of macroalgal assemblages at depths from 0 to 1 m.

The concept of EEI is based on the macrophytobenthos functional-morphological model of Littler and Littler (1980, 1984) and includes two ecological status groups (ESG I and ESG II) according to Orfanidis and others (2003). These two groups represent two possible states of ecosystems, a pristine environment (ESG I) and a highly stressed or disturbed marine environment (ESG II). ESG I includes the following groups: the thick leathery group, the jointed calcareous group and the crustose-group; all species belonging to these 3 groups are growing slowly. ESG II includes opportunistic species with high growth rates and reproductive potential with thin, foliose or filamentose thalli. All seagrasses are included in ESG I (Orfanidis et al., 2003).

EEI is a categorical variable with 5 numerical levels (2, 4, 6, 8 and 10) that are calculated using cross comparison methodology on the two ESG categories. Each level of EEI corresponds to one ecological status class (ESC): Bad, Low, Moderate, Good and High.

EEI allows the comparison of marine ecosystems on the regional, national and international levels. Furthermore, EEI describes the function and potential of recovering the marine ecosystem and is an indicator for sustainable development (Orfanidis et al., 2003).

Sampling was carried out along 60 km of the western Istrian coast, from Limski canal at the north end to Barbariga point at the south end (Figure 2.3). Ten locations were randomly selected:

- four locations were randomly selected in putatively pristine areas: 1, 8, 9 and 10;
- three locations were randomly selected in the harbour areas of the town, which are mainly subjected to urban pollution: 2, 4 and 6;
- two locations were situated on a small island at a distance of approximately 1 km or less from the town of Rovinj: 3 and 5;
- location 7 was in a non-urban area where the main sewage outlet of the towns was located 1 km offshore at a 35 m depth.

The coordinates of the locations were determined with a global positioning system (GPS; Table 2.3). Macroalgal assemblages usually completely covered the rocky shore, which was at all locations characterised by a calcareous rocky bottom, usually composed of limestone, except for the locations U. Kuvi and Sv. Ivan, where the rocky shore was built up from dolomite. The macroalgal assemblages in this investigated area to a 5 m depth were composed from species of the genuses: *Cystoseira*, *Padina*, *Dictyota*, *Dictyopteris*, *Corallina*, *Ulva*, *Codium*, *Stypocaulon*, *Acetabularia* and *Amphiroa*.

In accordance with EEI methodology (Orfanidis et al., 2001, 2003), sampling was performed seasonally in August 2003, November 2003, February 2004, and May 2004. At each location, a permanent plot of approximately 10x10 m was marked at the depths 1, 3 and 5 m on the horizontal rocky shore. At location 4 at the depth of 5 m and at location 6 at the depths of 3 and 5 m, because of the lack of adequate rocky substratum, sampling was not performed. Three 20x20 cm quadrats were haphazardly scattered over each permanent plot. Then, the encrusting macroalgae delimited by the quadrats were detached together with the adhering substratum using hammer and chisel.

In the laboratory, each sample was carefully sorted. The macroalgae were identified at least to genus, the cover was determined, and the cover of macroalgae within ESG I and ESG II was calculated. The cross comparison methodology to assess the EEI, the ecological status class (ESC) and the spatial-scale weighted EEI and ESC were calculated according to Orfanidis et al. (2001, 2003) (Table 2.4). Spatial EEI represents the total of the EEI values at each location multiplied by the respective portion of the coast (Table 2.4)

The environmental variables were determined seasonally at the time of macroalgal sampling: oceanographic parameters (oxygen saturation, temperature, salinity, chlorophyll a and transmission), nutrients (ammonium, nitrite, nitrate and orthophosphate) and the sanitary seawater quality (faecal coliform, streptococcal coliform and total coliform bacteria).

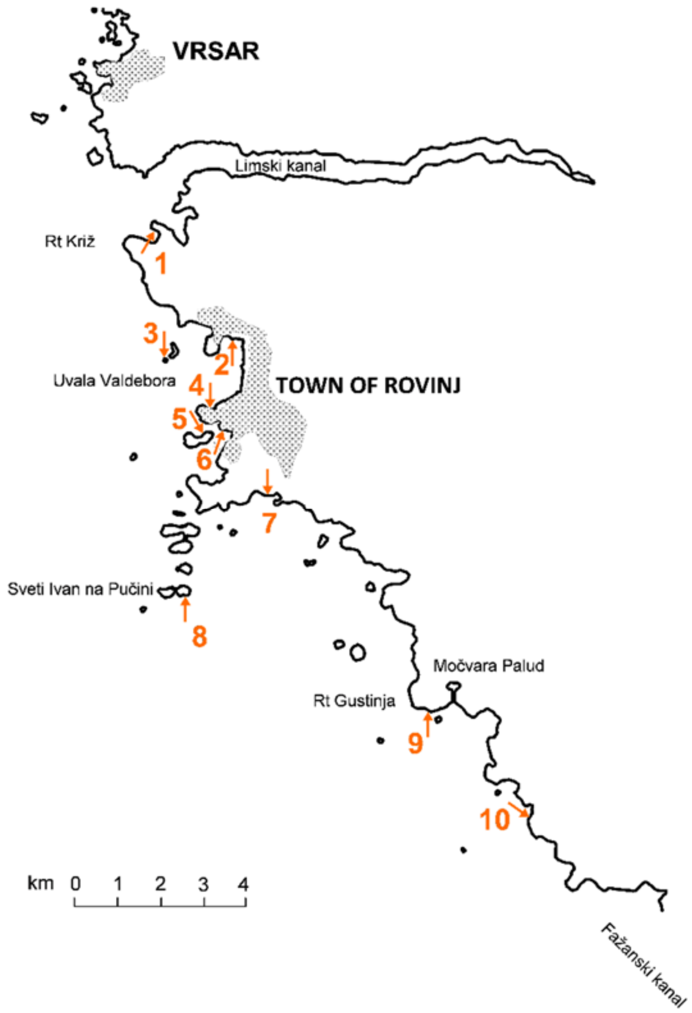


Figure 2.3. Map of the surveyed location along 60 km of the western Istrian coast.

Table 2.3. Coordinates of the investigated locations.

Locations	Name of location	Coordinate
1	Uvala Faborso	45˚07.12' N; 013˚36.87' E
2	Uvala Valdebora–Bolnica	45˚05.84' N; 013˚38.11' E
3	Hrid Mala Figarola	45˚05.61' N; 013˚37.07' E
4	Uvala Valdebora–Stari Grad	45˚05.06' N; 013˚37.96' E
5	Otok Sveta Katarina	45˚04.76' N; 013˚37.87' E
6	Luka Rovinj	45˚04.78' N; 013˚38.15' E
7	Uvala Kuvi	45˚03.90' N; 013˚38.86' E
8	Otok Sveti Ivan na Pučini	45˚02.79' N; 013˚38.59' E
9	Rt Gustinja	45˚01.28' N; 013˚41.62' E
10	Uvala Bus	45˚00.09' N; 013˚43.87' E

Table 2.4. Estimates of the ecological evaluation index (EEI) and the equivalent ecological status classes (ESC) using macroalgae grouped in two ecological status groups (ESG I and ESG II) according to Orfanidis et al. (2003).

Mean coverage of ESG I (%)	Mean coverage of ESG II (%)	ESC	EEI	Spatial scale
0-30	0-30	Moderate	6	<6 - >4 = Moderate
	>30-60	Low	4	<4 ->2 = Low
	>60	Bad	2	2 = Bad
>30-60	0-30	Good	8	<8 - >6 = Good
	>30-60	Moderate	6	<6 - >4 = Moderate
	>60	Low	4	<4 - >2 = Low
>60	0-30	High	10	<10 - >8 = High
	>30-60	Good	8	<8 - >6 = Good
	>60	Moderate	6	<6 - >4 = Moderate

CARLIT metoda

The second method used to categorise the coastal waters along the Istrian coast is the CARLIT (Littoral Cartography) method. This method is based on the sampling survey in a entire coast with a small boat kept as close as possible to the shoreline and on annotating the appearance and abundance of littoral and upper-sublittoral communities along the rocky shore (Ballesteros et al., 2007; Mangialajo et al., 2007; Asnaghi et al., 2009). Macroalgal communities (Table 2.5) and geomorphological factors of the coastline sectors, which are one of the most important ecological features that influence macroalgal assemblages (Table 2.6), are directly annotated in a graphic display – maps (nautical, aerials and satellite photographs). This graphic support must be of an appropriate scale and suitable for use in the field and for notation of macroalgal assemblages and geomorphological factors (map scale 1:10.000 or 1:5.000).

According to the literature and experimental work, it is established that the macroalgal assemblages in the upper infralittoral are sensitive to environmental changes. Thus, settlements of *Cystoseira* in pristine areas are well developed (with continuous settlements), while in slightly polluted and polluted areas, tolerant and opportunistic species dominate (e.g., the crustose algae *Corallina elongata* and genus *Ulva*). In preliminary research on the western Istria coast, this situation is noted regarding the shift of the macroalgal assemblages under anthropogenic impacts (Figure 2.4).

The CARLIT method has been successfully used in Catalonia (Spain) since 2001 and recently tested in Italy (since 2004), in France (since 2006) and in Croatia (since 2009; Nikolić *et al*., 2013). The first preliminary investigation using the CARLIT method along the Istrian coast was performed during spring 2011 (April, May and June), during the maximum algal vegetation along the western Istrian coast - along the coastline of Umag, Novigrad, Poreč, Limski canal, Rovinj, Barbariga, Fažana, National Park Brijuni and in Harbour Pula. During 2012 and 2013, the mapping of the macroalgal assemblages continued in more areas along the western and eastern Istrian coast.

The results of the CARLIT method are calculated as EQR (ecological quality ratio) values (Table 2.7.) according to the following formula:

$$EQR = \frac{\sum \frac{EQ_{ssi} x\, l_i}{EQ_{rsi}}}{\sum l_i}$$

where:
i – geomorphological relevant situations (GRS)
EQ_{ssi} – environmental quality (EQ) at the study site for the situation *i*
EQ_{rsi} – environmental quality (EQ) at the reference sites for the situation *i*
l_i – coastal length of the study coast for the situation *i*

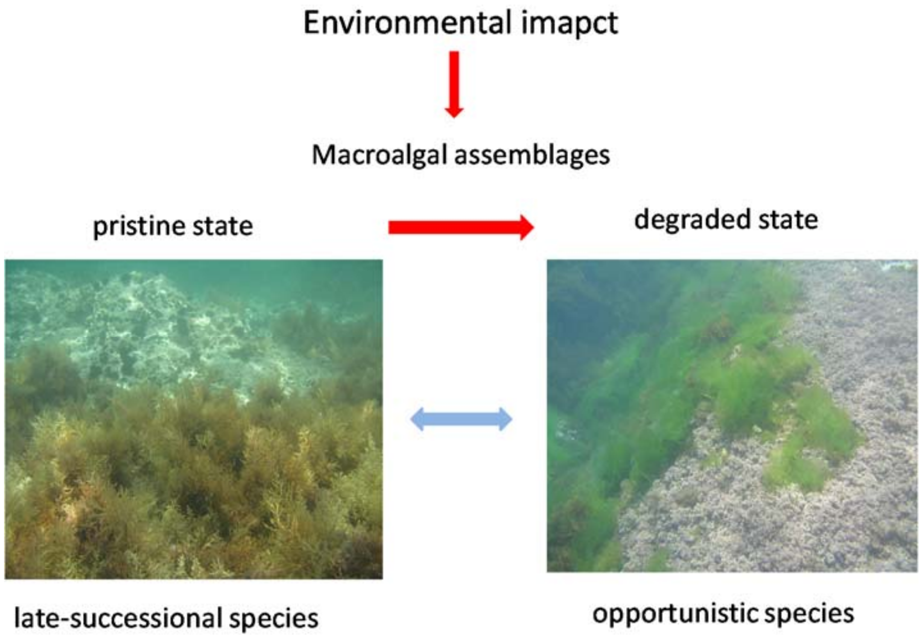


Figure 2.4. Shift of macroalgal assemblages along the coast from the stable pristine state, with the dominance of late-successional species, to the degraded state, with the dominance of opportunistic and tolerant species.

Table 2.5. The proposed list of macroalgal community types and their sensitivity levels (SL) in the eastern part of the Adriatic Sea.

Community type	Community description	Sensitivity level (SL)
Cystoseira spicata 3	Continuous belt of *Cystoseira amentacea* var. *spicata*	20
Cystoseira crinitophylla	Populations of *Cystoseira crinitophylla*	20
Cystoseira crinita	Populations of *Cystoseira crinita*	20
Cystoseira corniculata	Populations of *Cystoseira corniculata*	20
Cystoseira foeniculacea	Populations of *Cystoseira foeniculacea*	20
Trottoir	Organogenic build-ups of *Lithophyllum byssoides* and other coralline algae	20
Cystoseira barbata	Populations of *Cystoseira barbata* without other *Cystoseira* species	16
Cystoseira spicata 2	Abundant patches of *Cystoseira amentacea* var. *spicata*	15
Cystoseira compressa	Populations of *Cystoseira compressa* without other *Cystoseira* species	12
Cystoseira spicata 1	Rare scattered plants of *Cystoseira amentacea* var. *spicata*	10
Photophilic algae	Community dominated by *Padina/Dictyota/Dictyopteris/Taonia/Halopteris*	10
Corallina	Community dominated by *Corallina elongata* and/or *Haliptilon virgatum*	8
Mytilus	Community dominated by *Mytilus galloprovincialis*	6
Green algae	Community dominated by *Ulva/Enteromorpha/Cladophora*	3
Cyanobacteria	Cyanobacterial belt	1

Table 2.6. A list of geomorphological factors and their categories used to describe the coastline sector in the Eastern Adriatic Sea.

Geomorphological factor	Category
Coastal morphology	high coast low coast blocks
Substrate	calcareous (limestone), metamorphic, sandstone, conglomerate
Coastline slope	horizontal: 0-30° sub-vertical: 30-60° vertical: 60-90° overhanging
Coastline orientation	north, northeast, east, southeast, south, southwest, west, northwest
Natural or artificial	natural artificial
Substrate rugosity	smooth rugose
Wave exposure	sheltered moderately exposed very exposed

Table 2.7. Correspondence between ecological status (ES) classes by colour and ecological quality ratio (EQR), according to expert analysis of our data and the normative definitions of the classes in the WFD.

Ecological status	EQR	Colour
High	> 0.75 – 1	
Good	> 0.60 – 0.75	
Moderate	> 0.40 – 0.60	
Poor	> 0.25 – 0.40	
Bad	0 – 0.25	

2.1.7. Classification of macrozoobenthic comunities

Benthic communities are one of the best indicators of the environmental quality status in marine ecosystems. Changes in their taxonomic composition, biodiversity and functional structure are considered as reliable indication of negative changes caused by natural and anthropogenic factors. Advantages of benthic communities over their pelagic counterparts are associated with the much longer life cycles of benthic populations and intimate relationship between benthic organisms (infaunal, sessile, sedentary and even vagile epibenthic organisms) and their sedimentary habitats. Soft bottom benthic communities, largely consisted of benthic invertebrates, are very suitable **B**iological **Q**uality **E**lement (BQE) for assessment of ecological status due to: 1) predominance of soft bottom and associated communities in marine ecosystems (they are widespread over more than 90% of the sea bed), 2) spatial-temporal stability of benthic populations (territoriality, yearlong presence, moderate seasonal dynamics) and 3) ability of benthos to integrate physical-chemical perturbation in marine ecosystems.

Methodological approach for assessment of ecological status using BQE benthic invertebrates

Methodological approach for assessment of ecological status using **B**iological **Q**uality **E**lement benthic invertebrates (BQE) differs among EU member states, but it generally relies on different structural indicators such as density, biomass, species richness and several diversity indices e.g. Shannon-Wiener diversity index (H'), Margaleff's index (D), Simpson's and Hill's indices (N1-N21); graphical-distributional methods and statistical methods (Hurlbert's rarefaction method, W statistics, ABC method ...) and biotic indices based on the species abundances (BQI) or functional composition of benthic communities e.g. percentage share and ratios of specific functional groups (BI, AMBI, BENTIX).

Most of biotic indices are based on the Pearson Rosenberg paradigm (1978) according which developed benthic communities respond to increasing quality of ecological conditions through three successive steps: increasing abundance, increasing biodiversity and changes in composition of dominant species, i.e. shift from tolerant to pollution sensitive species. Based on integrated expert opinion, Grall and Grémalec (1997) classified individual benthic invertebrate species into one out of five ecological categories related to its specific sensitiveness to organic pollution and environmental disturbance: EG I – very sensitive species, EG II- indifferent species, EG III –tolerant species, EG IV- 2nd order opportunistic species and EG V -1st order opportunistic species. In our study aimed at ecological assessment of transitional and coastal waters during implementation of WFD, we have classified present invertebrate species into mentioned ecological groups in order to calculate index based on the average weighted changes in abundances, associated with species-specific sensitivity of macro invertebrates to environmental perturbations (AMBI). Ecological status and sea floor integrity were assessed applying factor analyses (FA) and discrimination analyses (DA) of selected indicators associated with communities structure (taxonomic and functional composition, species richness and Shannon-Wiener diversity index) integrated in **E**cological **Q**uality **R**atio (EQR) presented by multimetric biotic index M-AMBI (Borja *et al.*, 2000).

In the northern Adriatic, qualitative and quantitative composition of benthic invertebrates was studied at 24 sites located within five geographical areas. The study included transitional water of Mirna river estuary (western coast of Istria), and coastal waters in the central parts of the eastern (Raša bay) and western coast of Istria (Limski kanal and coastal area of Rovinj), as well as Kvarner area, i.e. area stretching over 150 km of coastline from Rijeka bay to Karinsko more mouth in the north-south direction (Precali *et al.*, 2008).

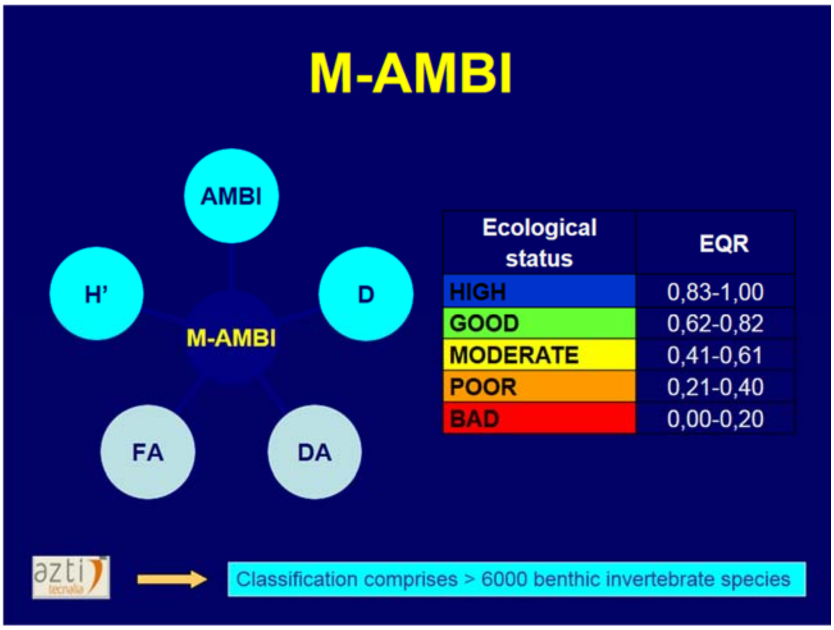


Figure 2.5. A concept scheme for multimetric biotic index M-AMBI with boundaries for ecological quality classes based on the Ecological Quality Ratio (EQR).

The main criteria for selection of study areas and study sites were: 1) spatial coverage of the entire littoral-istrian drainage basin, 2) selection of representative soft bottom habitats, and 3) availability of suitable and comparable qualitative/quantitative datasets (literature sources, field notes) related benthic invertebrate fauna, suitable for calculation of biotic indices – recommended by framework directives of EU, i.e. Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD).

Applied classification includes two complementary categorical indices (BI and AMBI) that rely on the sensitivity of benthic organisms to environmental perturbations. Both of them are based on the universal ecological principles - independent from geographical position of the study area and type of disturbance. According to species-specific sensitivity to increasing pollution, soft bottom macro invertebrates were classified into five ecological categories: EG I – very sensitive species, EG II-indifferent species, EG III –tolerant species, EG IV- 2nd order opportunistic species and EG V -1st order opportunistic species (Grall and Glémarec, 1977). Based on discrete values of Biotic index (BI; scale 0-8) and AMBI index (scale 0-6) results can be ranged into: 1) five categories associated with different pollution status (from pristine to extremely polluted) and 2) eight categories indicating „health conditions" of benthic communities (from normal to azoic) (Hily, 1984; Majeed, 1987; European commission, 2000).

To assess the environmental status of transitional and coastal waters of the littoral-istrian drainage basin we calculated multimetric biotic index M-AMBI (five categories of ecological quality status: poor, bad, moderate, good, very good), based on BQE benthic invertebrates and expressed as an Ecological Quality Ratio (EQR; Borja *et al.,* 2000). Boundaries between ecological quality classes (EQR scale 0-1) were adopted from the slovenian scale, related to the northern Adriatic (MED-GIG, 2007).

According to EQR/M-AMBI values, obtained results can be classified into five categories that indicate ecological status of studied areas: 0-0.20 (poor), 0.21-0.40 (bad), 0.41-0.61 (moderate), 0.62-0.82 (good) and 0.83-1.00 (very good). Due to regional/sub regional variability, national boundaries between quality classes will be revised at the end of the first 6th year monitoring cycle, if it will be necessary. In the meantime, we applied that classification scheme for setting up the reference conditions (Precali *et al.*, 2008) and monitoring of ecological status along the eastern coast of the Adriatic. The monitoring is still in progress, and recent results related to northern Adriatic are presented in this report.

APPENDIX

This supplement is based on several literature sources: 1) the list of the National Classification of Marine Habitats (Bakran - Petricioli, 2007), 2) the list of the Classification of Benthic Marine Habitat Types for the Mediterranean Region (UNEP, MAP, RAC/SPA, 2006), 3) the basic biocoenological literature related to the Mediterranean and Adriatic Sea (Pérès and Picard, 1964, Picard 1965, Pérès and Gamulin Brida, 1973) and 4) the list related to functional classification of benthic invertebrates, i.e. classification according species/genera sensitivity to anthropogenic disturbances (software: Azti, Marine Biotic Index v.5.0, 2007).

It provides information important for differentiation of infralittoral soft bottom benthic communities and identity of sensitive species characteristic for typical and/or relevant benthic habitats. Therefore, this review does not include all communities/habitats occurring in the Croatian part of the Adriatic Sea, but only those dominated by benthic invertebrates, i.e. communities relevant for assessment of ecological status of transitional and coastal waters associated with soft bottom benthic habitats. A review does not include the following habitats and/or communities:

- Hard beds and rocks with associated communities,
- Biocenoses associated with specific coastal habitats: Biocenoses of dark and semi-dark caves, Coralligenous biocoenosis, biocoenosis of marine lakes and biocoenoses associated with anthropogenic habitats in infralittoral and circalittoral zones,
- Biocenoses of gravel/pebble bottoms that occupy a very small area in the Croatian part of the Adriatic, i.e. G.3.3.1. Biocenosis of coarse sands and fine gravels mixed by the waves and G.3.4.1. Biocenosis of infralittoral pebbles,
- Biocenosis of shelf-edge detritic bottom (G.4.2.3) and Biocenosis of bathyal muds (G.5.1) that occur outside the territorial waters (up to a limit not exceeding 12 nautical miles from the mean low-water line along the coast), .i.e. boundaries covered by WFD.

BIOCENOSES OF INFRALITTORAL ZONE ON SOFT BOTTOMS

G.3.1.1. Euryhaline and eurythermal biocenosis

Infralittoral biocenosis that occurs in coastal lagoons and estuarine areas with muddy and silty sand bottoms. It is a very sensitive habitat with a small number of species and low species diversity. Characteristic species/taxa:

- seagrasses: *Ruppia* spp.*, Potamogeton pectinatus, Zostera noltii, Cymodocea nodosa*,
- bivalves and gastropods: *Cerastoderma glaucum, Abra alba, Scorbicularia plana, Loripes lacteus, Gastrana fragilis, Tapes* spp.*, Ostrea edulis; Rissoa* spp.*, Nassarius reticulatus, Cyclope neritea*,
- crabs: different species of Isopoda and Amphypoda, decapod crab *Carcinus maenas*.

G.3.2.1. Biocenosis of fine sands in very shallow waters

Infralittoral biocenosis of fine well-sorted sands –spread out from the lower mediolittoral to a depth of about 2.5 m. Community is common for the northern Adriatic, but it occupies small area of infralittoral seabed. Characteristic species/taxa:

- shellfish: *Donax trunculus, D. semistriatus, Tellina tenuis, Lentidium mediterraneum* (in areas with a strong influence of fresh water),
- polychaetes: *Glycera convoluta*.

G.3.2.2. Biocenosis of well-sorted fine sands

Infralittoral biocenosis, which continues to the previous one at depth 2.5-25 m. It encompasses a much smaller area on the east compared to the west coast of the Adriatic Sea, a common type is association with seagrass *Cymodocea nodosa*. Characteristic species/taxa:

- bivalves and gastropods: *Acanthocardia tuberculata, Mactra stultorum, Tellina fabula, T. nitida, T. pulchella, Donax venustus, Nassarius mutabilis*,
- polychaetes: *Sigalion mathildae, Onuphis eremita,*
- crabs: amphipods *Ampelisca brevicornis, Hippomedon massiliensis*,
- echinoderms: *Astropecten* spp.*, Echinocardium arcuatum*.

G.3.2.3. Biocenosis of superficial muddy sands in sheltered waters

This biocenosis is present in sheltered shallow bays that characterize by: little impact of waves, insignificant fluctuation of environmental factors, possible sedimentation and naturally eutrophic state. In relation to the biocenosis G.3.1.1 freshwater influence is significantly smaller, as well as variability of other abiotic factors. There are three common associations – two with seagrasses *C. nodosa* and *Z. noltii* and one with green alga *Caulerpa proliffera*. In the Adriatic Sea, three facies of Biocenosis of superficial muddy sands in sheltered waters are present:

- facies type with *Callianassa tyrrhena* and *Kellia* sp.,
- facies type with *Cerastoderma glaucum* and *Cyathura carinata* (impacted by freshwater),
- facies type with *Loripes lacteus, Tapes* spp.

Characteristic species/taxa:

- bivalves and gastropods: *Loripes lacteus, Paphia aurea, Tapes decussate, Cerithium vulgatum, C. rupestre*,
- polychaetes: *Paradoneis lyra, Heteromastus filiformis*,
- decapod crustaceans: *Upogebia pusilla, Clibanarius erythropus, Carcinus maenas*.

G.3.2.2. Biocenosis of coarse sands and fine gravels under the influence of bottom currents

This is benthic biocenosis independent on the vertical zonation, occurs in infra- and circalittoral-areas with strong bottom currents, on shelly sand and gravel bottom at depths of 3 - 25m, or even deeper. An inherent phenomenon of this community are calcified red algae unattached to sea bed, or association with rhodoliths (unattached biogenic nodules composed at least partly of calcified red algae from the family Corallinaceae) and facies Maërl.The Maërl facies is an association characterised by the presence of two small many-branched and unattached calcareous algae *Lithothamnion corallioides* and *Phymatolithon calcareum*, that occur on coarse sands and gravels with a high proportion of detritic elements. Given their many-branched shape, these Lithothamnia never constitute bioconstructions or rhodolithes. Small Rhodophyceae may be present as epiphytes on the Lithothamnia. This association/facies occur in other biocenosis. Characteristic species/taxa:

- unattached algae from the family Corallinaceae,
- shellfish: *Venus casinos, Dosinia exoleta, Capsella variegata, Glycymeris glycymeris, Laevicardium crassum*,
- polychaetes: *Sigalion squamosus, Euthalanessa oculata, Armandii polyophthalma*,
- crabs: *Anapagurus breviaculeatus, Thia scutellata*,
- echinoderms: *Ophiopsila annulosa, Spatangus purpureus*,
- cephalochordata: *Branchiostoma lanceolatum*.

G.3.5.1. Posidonia oceanica meadows (=association with Posidonia oceanica)

Infralittoral biocenosis that constitutes characteristic formations called ‘meadows’ between the lower mediolittoral and 30-40 m depths on coarse, but more or less muddy sands. It occurs rarely along the west coast of Istria. Characteristic species/ taxa:

- epibionthic algae: *Peyssonnelia* spp., *Flabellia petiolata*, *Hydrolithon* spp.,
- bivalves and gastropods: *Venus verrucosa, Pinna nobilis, Bittium reticulatum, Risoa* spp.,
- crabs: *Pisa nodipes*,
- hydrozoans: *Sertularia perpusilla*,
- bryozoans: *Electra posidoniae*,
- echinoderms: *Paracentrotus lividus, Echinaster sepositus, Holothuria tubulosa, Asterina pancerii*,
- ascidians: *Halocyntia papillosa.*

BIOCENOSES OF CIRCALITTORAL SOFT BOTTOMS

Circalittoral bottom extends from the lower limit of photophilic vegetation down to the edge of the continental shelf and lower limit of sciaphilic vegetation (avg. depth 30 m, max. depth about 200 m). Circalittoral zone comprises about 88 % of the seabed in the Croatian territorial sea. This zone is characterized by, reduced amount of light, low fluctuations in temperature and salinity, increase in animal *vs.* algal biomass with increasing depth, continuous sedimentation and reduced hydrodynamics. Circalittoral zone dominated by sedimentary bottoms (terrigenous, biogenic detritus or mixed sediment types), while coralligenous bottom (hard bottom of biogenic origin) is poorly represented. On soft bottoms, one can distinguish two types of benthic communities: Biocenoses of circalittoral mud (G.4.1.1) and Biocenoses of circalittoral sands (G.4.2).

G.4.1.1. Biocenosis of coastal terrigenous mud

Circalittoral biocenosis is widely distributed along the eastern coast of the Adriatic Sea where occur in areas with weak bottom currents and high sedimentation of mud particles. It appears in the form of three soft mud facies (facies dominated by species: *Turritella tricarinata* f. *communis*, *Oerstergrenia digitata* and *Owenia fusiformis*) and two facies of sticky mud - facies types with bottom rooted and sessile forms (more common in the Adriatic). Characteristic species of soft mud facies are *Pennatula phosphorea, Virgularia mirabilis* and *Veretillum cynomorium*, and locally Virgularia mirabilis. Characteristic species of sticky mud facies are: coral *Alcyonium palmatum adriaticum*, sea cucumber *Stichopus regalis*, sea squirt *Diazona violacea*, while a group of euryoecious sea squirt species (Phallusia *mammillata, Ascidia mentula, A. virginea*) are often present. From three facies belonging to this biocenose, facies of sessile form is most common in the Adriatic. In this facies we can find many empty shells of *Turitella profunda*, species that lives in a neighboring facies.

G.4.1.2. Biocenosis of muddy bottom of the open sea and canals of the northern Adriatic

This circalittoral biocenosis harbors rich population of Norway lobster (*Nephrops norvegicus*). It is developed in the central part of the central Adriatic Sea (Jabuka Pit depression) and channels of the northern Adriatic (Velebitski kanal). It is a transitional biocenosis dominated by *Nephrops norvegicus* enriched with typical elements of biocenosis of coastal terrigenous muds, e.g. gastropod *Turritella tricarinata* f. *communis*, sea cucumber *Labidoplax digitata*, cnidarians *Virgularia mirabilis* etc.) and bathyal muds (*Thenea muricata* sponge, coral *Funiculina quadrangularis*, decapod crustaceans *Parapenaeus longirostrus* and *Chlorotocus crassicornis*). Characteristic species is a shellfish *Nucula profunda* and pelophylic and eurybathic species, especially *Brissopsis lyrifera*.

G.4.2.1. Biocenosis of the muddy detritic bottom

Due to reduced sea water transparency, circalittoral biocenosis associated with more or less muddy detritic sand appears in the northern Adriatic from depths as low as 13 m. In other parts of the Adriatic and the Mediterranean Sea depths less than 30 m belong to infralittoral zone. Biocenosis of the muddy detritic bottom contains three distinct zones: coastal zone of muddy detritic bottom, central zone of sandy detritic bottom and "open sea" zone of detritic bottom. It is a complex and polymorphic community, which appears in a number of facies with mosaic distribution within relatively small area, and it is quite difficult to distinguish this biocenosis from the previous one. Several distinctive species e.g. *Raspallia viminalis, Alcyonium palmatum* and *Aphrodite aculeata* are indicators of seabed siltation. Due to the complex community composition, there are lot of species typical for different facies. For detailed information, see review of characteristic species in the book Biological Oceanography (Peres and Gamulin Brida, 1973).

G.4.2.2. Biocenosis of the coastal detritic bottom

Circalittoral biocenosis which continues to infralittoral biocoenosis of well sorted fine sands, infralittoral biocoenosis of photophylic algae and/or to coralligenous biocenosis at depth 30-100m. This community stretches along the coast, islands and submarine reefs and it characterized by high biodiversity. Sediment consists from sand with low content of mud (<20 %) and high content of biogenic detritus. For this community is typical presence of, unattached, calcified red algae. Community appears in the form of three associations (association with rhodolithes, association with *Peyssonnelia rosa-marina* and association with *Laminaria rodriguezi*) and four facies (facies Maërl, the type *Ophiura texturata* (=*O. ophiura*), with sinascidias and big bryozoans.

Characteristic species/taxa are: red calcified seaweeds from the Corallinaceae family (*Phymatholithon calcareum, Lithothamnion corallioides, Lithothamnion fruticulosum*) other red algae (*Cryptonemia tunaeformis, Peyssonnelia* spp., *Osmundaria volubilis*) sponges (*Bubaris vermiculata, Suberites* spp.), shellfish (*Chlaymys flexuosa, Laevicardium oblongum, Acanthocardia deshayesii, Tellina donacina*), polychaete worms (*Laetmonice hystrix, Petta pussilla*), crustaceans *(Paguristes eremita, Anapagurus laevis*), echinoderms (*Ophiura ophiura, Astropecten irregularis, Anseropoda placenta, Luidia ciliaris, Psammechinus microtuberculatus* and *Spatangus purpureus* – the last one at localities with strong bottom currents), ascidians (*Molgula oculata, Microcosmus vulgaris, Polycarpe pomaria*).

For detailed information see review of characteristic species in the book Biological Oceanography (Peres and Gamulin Brida, 1973).

G.4.2.4. Biocenosis of coarse sands and fine gravels under the influence of bottom currents

This biocenosis is independent of the vertical zonation, occurs in infralittoral as well as in circalittoral areas with strong bottom currents (see paragraph G.3.2.2).

G.4.2.5. Biocenosis of detritic bottoms of the open Adriatic Sea

Adriatic Sea is semi-enclosed marine ecosystem, largely associated to continental shelf, thus "open sea" is considerably affected by coastal waters, especially in the shallow northern Adriatic. Due to the specific configuration of the eastern Adriatic coast, the open sea is separated from the coastal area by clearly defined transitional zone, i.e. islands region, that is considered as separate area from geographical, ecological and biocenological standpoint. Circalittoral biocenosis of detritic bottoms of the open Adriatic Sea, appears in two facies: facies dominated by shellfish *Atrina pectinata* (on the coarse detritic sands) and facies with hydroid *Lytocarpia Myriophilum* (on the medium detritic sands). Both species are characteristic for both facies, but each of them is dominated by only one species. Other common species, characteristic for both facies are echinoderms *Ophiacantha setosa, Cidaris cidaris, Litocarpia Myriophyllum* and hydroids *Nemertesia* sp. Also, there is a number of accompanying species common to both facies (see Pérès and Gamulin Brida, 1973).

3.0. State assessment – Good Ecological State (GES)

State assessment or assessment of whether it is achieved good ecological status (GES) is the underlying assumption MSFD in respect to its main goal to achieve and maintain good status of the marine environment by 2020. MSFD is based on the ecosystem approach to management of human activities, as well as other principles of integrated coastal zone management. On that track, it is important to establish the protection and the preservation of the marine environment, preventing its degradation and/or, if feasible, restoration of marine ecosystems in areas affected by adverse impacts. Furthermore, it should prevent and reduce loads into the marine environment in order to gradually eliminate pollution and significant adverse effects and/or risks to marine biodiversity, marine ecosystems, human health or the legitimate use of the sea and to achieve sustainability of good status of the marine environment. Finally, we must establish a systematic monitoring and observation system of the marine environment.

In order to achieve the previous assumptions the state assessment is an important step for the realization of the same. It is a compromise of our current knowledge and continuous learning, primarily in the frame of available data. Unfortunately, so far, in Region Istria no systematic collection of data for the evaluation of its ecological status and to manage its marine resources was established.

The results obtained during this study are largely unpublished, and all are based on measurements of CMR and IOF conducted as part of their regular or special activities. In the results are incorporated the experience obtained during the implementation of the WFD and our participation in the work of various international bodies or activities.

The main drawbacks are the lack of data for a real assessment for all segments of MSFD approach based on descriptors. We hope that this will be resolved by establishing a systematic monitoring and observation of the marine environment as anticipated by MSFD for 2014. Regarding GES assessment Croatia have not yet adopted the criteria for it and it is assumed that this will be resolved within a few months. This fact has represented the most significant lack in writing this paper.

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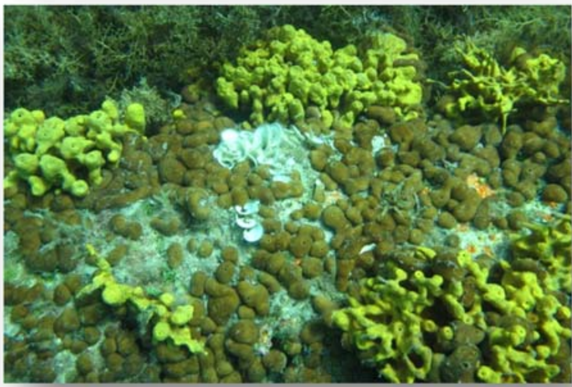
3.1. Descriptors: 1. Biological diversity, 2. Non-indigenous species and 6. Sea-floor integrity



Descriptor 1: Biological diversity

The **scope** of Descriptor 1, according to Annex III (Table 1) of the Directive, encompasses angiosperms, macro-algae, invertebrates, phytoplankton, zooplankton, fish, mammals, reptiles, birds, as well as microbes and pelagic cephalopods.

The Task group 1 (TG1 Report) coordinated the following definition as the basis for the explanation of Biological diversity, as descriptor within MSFD and in accordance with the Convention on Biological Diversity (CBD, 1992):

Biological diversity: the variability among living organism from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Recommendation for the quality of Descriptor 1: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

Good Environmental Status for Descriptor 1 will be achieved given no further loss of the diversity of genes, species and habitats/communities at ecologically relevant scales and when deteriorated components, where intrinsic environmental conditions allow, are restored to target levels.

Attributes of biological diversity. The recommended levels of ecological organisation for assessment are as follows: Species state (including intra-specific variation, where appropriate); Habitat/community state; Landscape state; Ecosystem state.

Biodiversity components are:

- The predominant seabed and water column types;
- Special habitat types;
- Habitats in particular areas (e.g. in pressured or protected areas);
- Biological communities associated with the predominant seabed and water column habitats;
- Fish, marine mammals, reptiles, birds;
- Other species;
- Non-indigenous, exotic species and genetically distinct forms of native species.

Criteria and Indicator classes for assessing the Good Environmental Status for the Species level are:

Criteria	Indicator classes
Species distribution	• Distributional range • Distributional pattern
Population size	• Population biomass • Population abundance (number)
Population condition	• Population demography (body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) • Population genetic structure

Criteria and Indicator classes for assessing the Good Environmental Status for Habitat/community state:

Criteria	Indicator classes
Habitat distribution	• Distributional range • Distributional pattern
Habitat extent	• Habitat area • Habitat volume
Habitat condition	• Condition of the typical species and communities • Relative abundance and/or biomass • Physical, hydrological and chemical conditions

Criteria and Indicator classes for assessing the Good Environmental Status for Ecosystem state:

Criteria	Indicator classes
Ecosystem structure	• Composition and relative proportions of the ecosystem components

Descriptor 2: Non-indigenous species

The identification and assessment of pathways and vectors of spreading of non-indigenous species as a result of human activities is a prerequisite to prevent that such species introduced as a result of human activities reach levels that adversely affect the ecosystems and to mitigate any impacts. The initial assessment has to take into account that some introductions due to human activities are already regulated at Union level to assess and minimise their possible impact on aquatic ecosystems and that some non-indigenous species have commonly been used in aquaculture for a long time and are already subject to specific permit treatment within the existing Regulations. There is still only limited knowledge about the effects of the non-indigenous species on the environment. Additional scientific and technical development is required for developing potentially useful indicators, especially of impacts of invasive non-indigenous species (such as bio- pollution indexes), which remain the main concern for achieving good environmental status. The priority in relation to assessment and monitoring relates to state characterisation, which is a prerequisite for assessment of the magnitude of impacts but does not determine in itself the achievement of good environmental status for this descriptor.

The Task group 2 (TG2 Report) coordinated the following definition for the explanation of Non-indigenous species, as the descriptor within MSFD:

Non-indigenous species (NIS; synonyms: alien, exotic, non-native, allochthonous) are species, subspecies or lower taxa introduced outside of their natural range (past or present) and outside of their natural dispersal potential. This includes any part, gamete or propagule of such species that might survive and subsequently reproduce. Their presence in the given region is due to intentional or unintentional introduction resulting from human activities. Natural shifts in distribution ranges (e.g. due to climate change or dispersal by ocean currents) do not qualify a species as a NIS. However, secondary introductions of NIS from the area(s) of their first arrival could occur without human involvement due to spread by natural means.

Invasive alien species (IAS) are a subset of established NIS which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions. Species of unknown origin which cannot be ascribed as being native or alien are termed cryptogenic species. They also may demonstrate invasive characteristics and should be included in IAS assessments.

Recommendation for the quality of Descriptor 2: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem.

Good Environmental Status for Descriptor 2 is explained: IAS cause adverse effects on environmental quality resulting from changes in biological, chemical and physical properties of aquatic ecosystems. These changes include, but are not limited to: elimination or extinction of sensitive and/or rare populations; alteration of native communities; algal blooms; modification of substrate conditions and the shore zones; alteration of oxygen and nutrient content, pH and transparency of water; accumulation of synthetic pollutants, etc. The magnitude of impacts may vary from low to massive and they can be sporadic, short-term or permanent.

It is suggested to observe following:

<u>Abundance and state characterisation of non-indigenous species, in particular invasive species</u>

- Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non-indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species.

<u>Environmental impact of invasive non-indigenous species</u>

- Ratio between invasive non-indigenous species and native species in some well-studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species).
- Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible.

Descriptor 6: Sea-floor integrity

Seafloor integrity includes chemical, physical and biological properties of the seafloor and implies spatial correlation of benthic habitats (absence of unnatural fragmentation) and natural processes that are not adversely affected. A term „not adversely affected“ means that some impacts may be present, but sustainable, such that natural levels of diversity, productivity, and ecosystem processes are not disturbed. Seafloor at high integrity level is more resistant to disturbances and although may be exposed to anthropogenic impacts, structural and/or functional changes in such systems e.g. variability in abundance, diversity, productivity etc.) are generally within the limits of sustainability. The activities related to the descriptor 6th aimed to ensure conditions that not hinder the ecosystem components to retain their natural diversity, productivity and dynamic ecological processes, taking into account natural variability of benthic components of the ecosystem. The Seafloor integrity is extremely complex descriptor, which integrates a diverse group of attributes (surface, bio-engineers, taxonomic composition of the benthos, size composition of the benthos, life history traits etc.) and biotic indicators. The assessment of this descriptor can be particularly problematic due to some disagreements related the nature of benthic ecosystems and the pressures caused by human activities. Assessment and monitoring of ecological status should be done after in-depth analysis of the effects and risks for biodiversity including types of anthropogenic pressure and after linking the results with different spatial scales (from small to a broader one) covering, if necessary, an appropriate subdivision, sub region or region.

Definition of the Seafloor integrity is provided by Task Group 6, responsible for all aspects of interpretation related MSFD Descriptor 6:

The integrity of the seafloor is at such level that allows maintenance of the natural structure of the benthic system and its normal functioning.

Good Ecological Status (GES) of the seafloor is such status that allows anthropogenic pressures affecting the benthos not endanger the ecosystem components in maintaining natural levels of biodiversity, productivity and ecological dynamics of the process - considering ecosystem plasticity.

Proposal for observing and monitoring of the Seafloor integrity includes:

Physical damage of the seafloor, taking into account substrate properties

- The type and area of distribution of relevant biogenic substrate.
- Extent of the seabed significantly affected by human activities for various types of substrates.

Condition of benthic communities

- The presence of particularly sensitive and/or opportunistic species.
- Structural and functional properties of benthic communities expressed by structural indices e.g. diversity, species richness, proportion of opportunistic and sensitive species and biotic indices for macrophytobentos (CARLIT and EEI), macrozoobenthos (AMBI and M-AMBI) and meiobenthos i.e. free-living nematodes (MI and trophic index).
- Proportion of biomass or number of macrobenthic constituents that exceed a certain length/size category.

Parameters that describe traits (shape, slope and starting point of the curve) related to size spectrum of benthic communities.

Assessment of the ecological status of the western Istrian coast using macroalgal assemblages

The data gathered for the western Istrian coast (Iveša, 2005) are suitable for assessing the ecological status of the coastal waters, and thus the rocky shore is analysed using EEI method.

Environmental variables

Locations are classified using principle component analysis (PCA) ordination of the environmental variables (Figure 3.1.1.). The first and second principal components accounted for 52% and 18% of the variability in the full matrix among the locations. The equation for PC1 was:

$$PC1 = -0{,}420 \cdot FS - 0{,}420 \cdot FS - 0{,}413 \cdot TC - 0{,}201 \cdot NH_4^+ - 0{,}250 \cdot NO_2^-$$
$$- 0{,}403 \cdot PO_4^{3-} - 0{,}307 \cdot Chla + 0{,}263 \cdot O_2\% \cdot 0{,}100 \cdot Tr$$

The coefficients of variables indicating urban pollution (faecal coliform = ***FC***, faecal streptococcal = ***FS***, total coliform bacteria = ***TC***, ammonium, nitrite, phosphate and chlorophyll *a* = ***Chla***) were all negative. The concentration of nitrate had no influence on the ordination of the locations. The coefficients of variables indicating pristine habitats (oxygen saturation = ***O_2%*** and transmission = ***Tr***) were positive. Thus, ***PC1*** represented an axis of decreasing urban pollution load. According to the PCA ordination, the inspected locations could be subdivided into three categories: polluted (locations 2, 4 and 6), slightly polluted (locations 5 and 7) and pristine (locations 1, 3, 8, 9, and 10).

The EEI at inspected locations

For the majority of locations, cross comparisons of ESG I and ESG II with the associated ESC are represented in Figure 3.1.2. Generally, ESC decreases with increasing depth. The ESC High was assessed only at 1 m depth at locations 3 and 9 and at the slightly polluted location 5. The ESC Good was assessed at the pristine locations 1 and 10, the slightly polluted locations 7 and the polluted location 4. The Moderate ESC values were found at the pristine location 8 and the polluted locations 2 and 6.

At 3 m depth, the categorisation of the location was much better. The ESC Low was found at the polluted locations 2 and 4 (at location 6, no rocky bottom was found at this depth). The ESC Moderate was assessed at the slightly polluted location 5, and at the pristine locations 9 and 19. The ESC Good was found at the slightly polluted location 7 and the pristine locations 1, 3 and 8.

At 5 m depth, the ESC was different for only two locations. At locations 4 and 6, sampling was not performed, as no rocky bottom was present at this depth. The slightly polluted location 7 was assessed as the ESC Moderate, while the polluted location 2 was assessed as the ESC Bad.

The values of the spatial EEI are shown in Table 3.1.1. The spatial EEI was 8.10 (ESC High), 6.72 (ESC Good) and 6.16 (ESC Good) at 1 m, 3 m and 5 m depth, respectively (Table 3). There is a question as to which depth best represents the ecological status of the western Istrian coast and is most suitable for assessment. Scientists from Spain have proved that the EEI method, which is mostly used between 0 and 1 m, does not give a clear picture for the categorisation of the coastal waters (Arévalo *et al.*, 2007; Ballesteros *et al.*, 2007). Also, along the western Istria coast, the EEI method is not suitable for categorising of the coastal waters at the depth of 1 m, because in the investigated area, there was high abundance of two macroalgal species of the ESG I in polluted locations: *Cystoseira compressa* and *Corallina elongata*. According to the classification of Orfanidis *et al.* (2001; 2003), these two species are indicators for pristine areas. However, from the literature, it is known that those species are also present in perturbed areas and in slightly polluted areas (Soltan *et al.*, 2001).

At 1 m depth, the brown alga *C. compressa* was abundant at all locations, except in the pristine location 8, where the coralline algae *Corallina officinalis* was present, and in the pristine locations 1 and 10 where two other *Cystoseira* species dominated: *Cystoseira barbata* and *Cystoseira crinita* (Figure 3.1.3.

A. i B.). Thus, *C. compressa* is not a good indicator for pristine areas in the northern Adriatic. According to this statement, in the CARLIT method, this species is in the lower position in relation to other *Cystoseira* species.

The calcareous alga *C. elongata* of ESG I (Orfanidis *et al.*, 2001; 2003) dominated at the polluted location 4, and thus this location was categorised with high EEI values (Figure 3.1.3.C.). The morphologically similar *Corallina officinalis* (Figure 3.1.3.D.) dominated at the pristine location 8, thus putting those two species in the same group ESG I, does not give a realistic assessment of the coastal zone at the depth 1 m.

At depths of 3 m and 5 m, *C. compressa* f. *compressa* and *C. elongata* were no longer abundant and were replaced in pristine locations with the brown macroalgae *Padina pavonica* and encrusting macroalgae (Figure 3.1.3.E. i F.). Because of these better results, in the future it is recommended to assess the coastal shore at the depths of 3 and 5 m. Figures 3.1.4. – 3.1.8. present underwater pictures of macroalgae assemblages in the investigated locations along the Rovinj area.

Conclusion

(1) Based on the investigation along the western Istrian coast, it is established that the EEI method is suitable for the assessment of the coastal waters at depths greater than 1 m.

(2) It is necessary to increase the number of locations in areas with the same ecological status as well as the number of replicates in these locations, which was done in our investigation, although the original methodology does not require this.

(3) The cross comparison results show that the ecological status of the western Istrian coast using macroalgae assemblages is in the category Good.

Table 3.1.1. Ecological evaluation index (EEI) assessed at each location for three depths (1, 3 and 5m) and spatial EEI for 60 km of the west Istrian coast.

Location	Proportion of the coast	EEI (1 m)	Spatial EEI (1 m)	EEI (3 m)	Spatial EEI (3 m)	EEI (5 m)	Spatial EEI (5 m)
1	0.17	8	1.36	8	1.36	8	1.36
2	0.05	6	0.30	4	0.20	2	0.10
3	0.05	10	0.50	8	0.40	8	0.40
4	0.04	8	0.32	4	0.16	(2)	0.08
5	0.04	10	0.40	6	0.24	6	0.24
6	0.04	6	0.24	(4)	0.16	(2)	0.08
7	0.15	8	1.20	8	1.20	6	0.90
8	0.12	6	0.72	8	0.96	8	0.96
9	0.17	10	1.70	6	1.02	6	1.02
10	0.17	8	1.36	6	1.02	6	1.02
Spatial scale weighted EEI for 60 km of the coast:			**8.10**		**6.72**		**6.16**
Spatial scale weighted ecological status class:			High		Good		Good

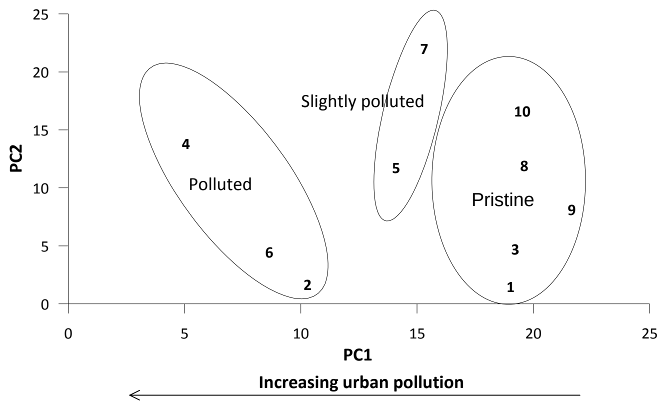


Figure 3.1.1. Two-dimensional PCA ordination of the nine environmental variables (4th-root transformed and normalised) for 10 locations along the western Istrian coast.

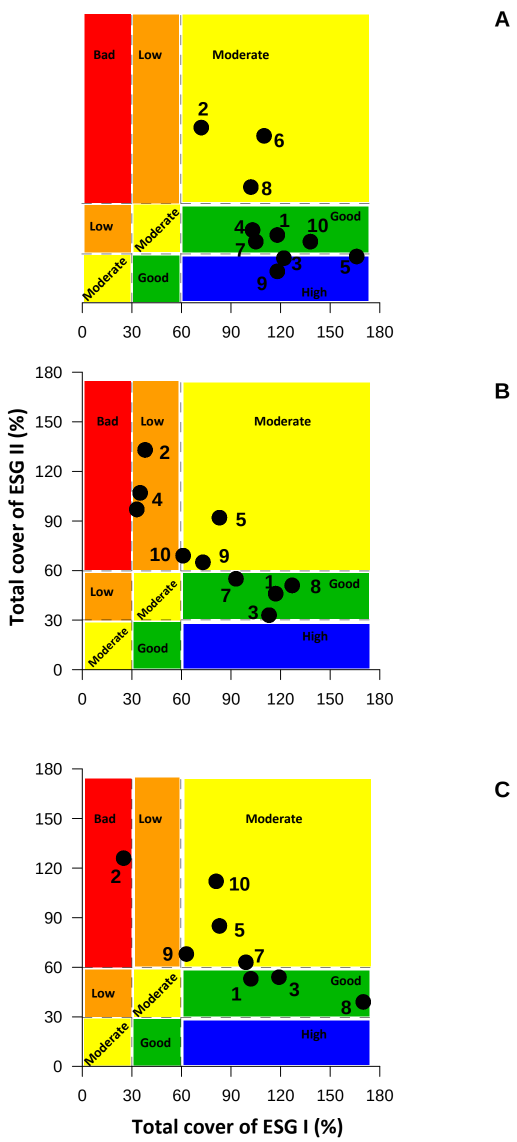


Figure 3.1.2. Categorised scatterplots of the total macroalgal cover (%) of the ecological status groups (ESG I and ESG II) for locations along the western Istrian coast at 1 m (A), 3 m (B) and 5 m depth (C). The vertical and horizontal lines divide the scatterplot into five ecological status classes.

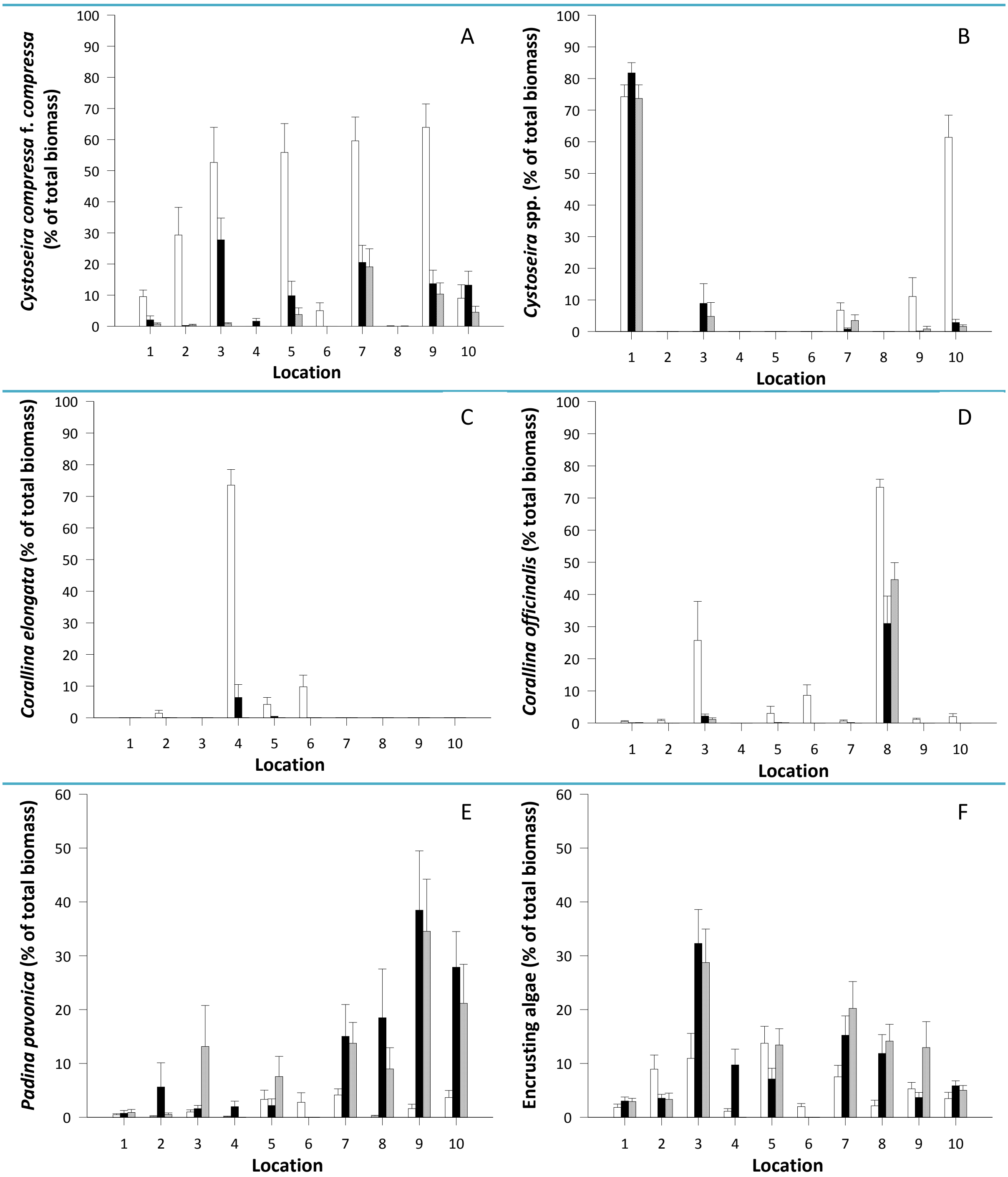


Figure 3.1.3. Abundance of dominant macroalgae in the investigated area. **A**: brown algae *Cystoseira compressa* f. *compressa*, **B**: other *Cystoseira* species pooled, **C**: crustose algae *Corallina elongata*, **D**: crustose algae *Corallina officinalis*, **E**: brown algae *Padina pavonica* and **F**: encrusting algae. Empty bars = 1 m, full bars = 3 m and dotted bars = 5 m depth. Data are yearly mean values and standard deviation of 12 replicates.

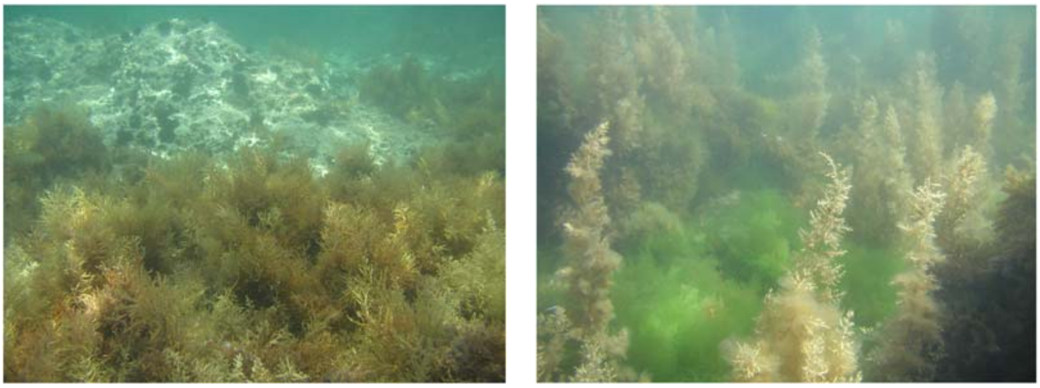


Figure 3.1.4. Macroalgal community at pristine location 1 at 1 m depth with dominance of brown algae *Cystoseira barbata* v. *barbata* (left); macroalgal community at polluted location 2 at 1 m depth with dominance of brown algae *Cystoseira compressa* f. *compressa* and green algae *Ulva lactuca* (right).

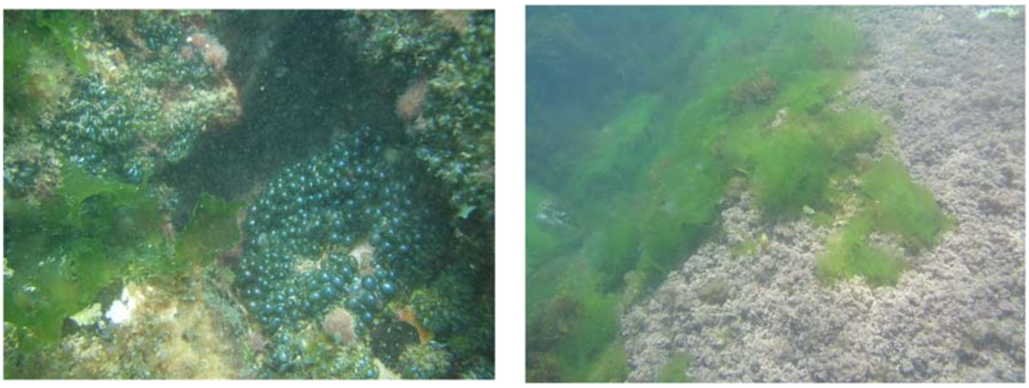


Figure 3.1.5. Macroalgal community at polluted location 2 at 3 m depth with dominance of green algae *Valonia utricularis* and *Ulva lactuca* (left); macroalgal community at polluted location 4 at 1 m depth with dominance of red calcareous algae *Corallina elongata* and green algae *Ulva lactuca* (right).

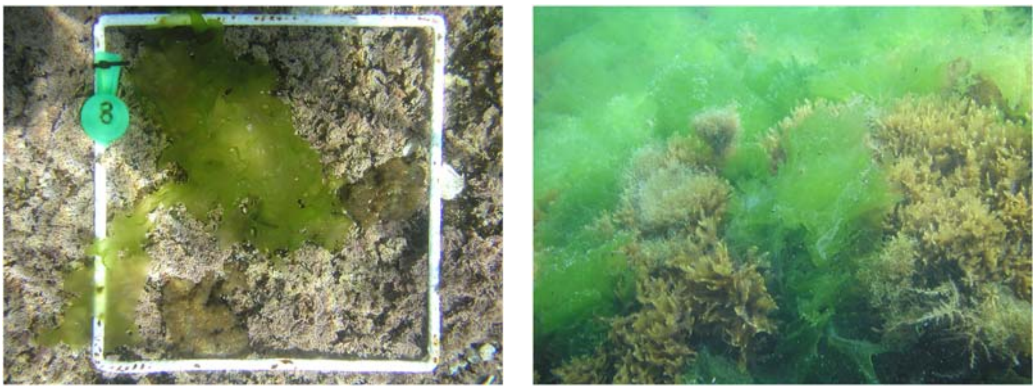


Figure 3.1.6. Macroalgal community at polluted location 4 at 1 m depth within the quadrat with dominance of the following species: *Corallina elongata*, *Ulva lactuca* and *Colpomenia sinuosa* (left); macroalgal community in polluted location at 3 m depth with dominance of brown algae *Dictyopteris polypodioides* and green algae *Ulva lactuca* (right).

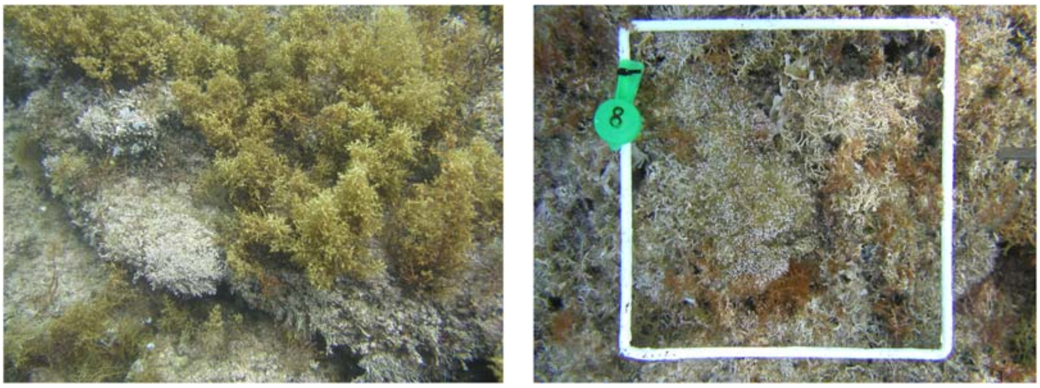


Figure 3.1.7. Macroalgal community at slightly polluted location 7 at 1 m depth with dominance of brown algae *Cystoseira compressa* f. *compressa* and red calcareous algae *Corallina officinalis* (left); macroalgal community at island location 8 at 1 m depth with dominance of crustose algae *Corallina officinalis* and *Laurencia obtusa*.

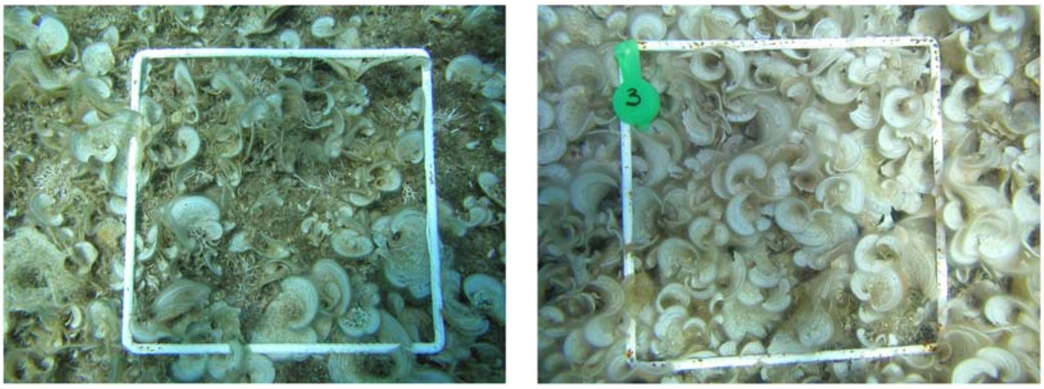


Figure 3.1.8. Macroalgal community at island location 8 at 3 m depth with dominance of brown algae *Padina pavonica* and red crustose algae *Amphiroa rigida* (left); high cover of brown algae *Padina pavonica* at location 9 at 3 m depth (right).

Assessment of water bodies using BQE macroalgae along Istrian coastline during 2011 and 2012

Results of the assessment of the water body Limski kanal (0413-LIK)

This water body (WB) is situated in Lim bay (a semiclosed canal) on the western Istrian coast near Vrsar and Rovinj. According to the surface, it is a small WB. The bay is 11 km long and originates as an estuary from the valley of the river Pazinčica (sunk-mouth river). A remarkable amount of salt water enters this WB.

Limski kanal 1
EQR value: 0.41
Ecological status: MODERATE

Limski kanal 2
EQR value: 0.56
Ecological status: MODERATE

Limski kanal 3
EQR value: 0.075
Ecological status: BAD

Figure 3.1.9. Ecological status and EQR values of WB Limski kanal.

The ecological status of Limski kanal is determined as Poor using the CARLIT method, which was performed in late spring 2011. (Figure 3.1.9.). The investigated coastline was dominated by degraded communities of photophilic algae with the dominant species being of the genus *Cladophora* and the genus *Ulva* (with and without *Mytilus*) (Figure 3.1.10.-3.1.12.). One of the reasons for the poor ecological status in this WB is intensive fish farming and the large input of organic matter. It is suggested that operative monitoring be established in this WB to identify the sources of impact on BQE macroalgae.

The EQR value of WB **O413-LIK** is **0.39**. According to this EQR value, we concluded that the ecological status of the whole investigated coastal area of this WB is POOR. In this WB, the seagrass *Posidonia oceanica* was not observed.

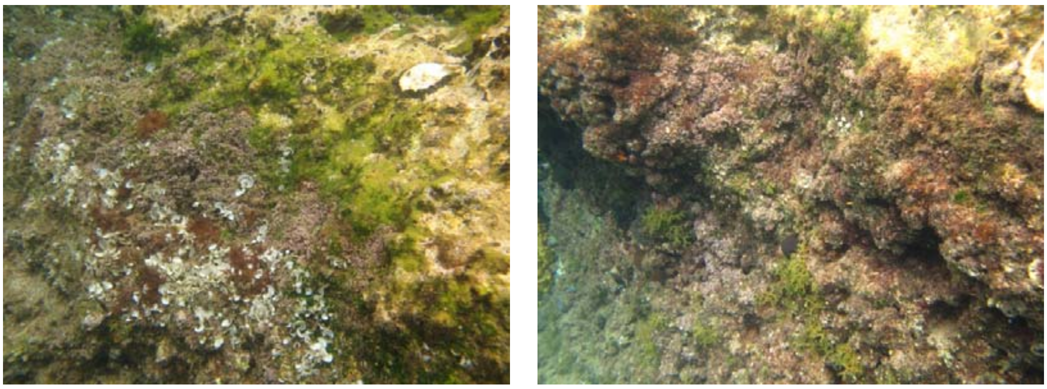


Figure 3.1.10. Macroalgal community in Limski kanal at 1 m depth with dominance of “turf” algae of the following composition: *Cladophora* spp., *Corallina officinalis*, *Laurencia obtusa* and *Dictyota dichotoma* (Transect 1).

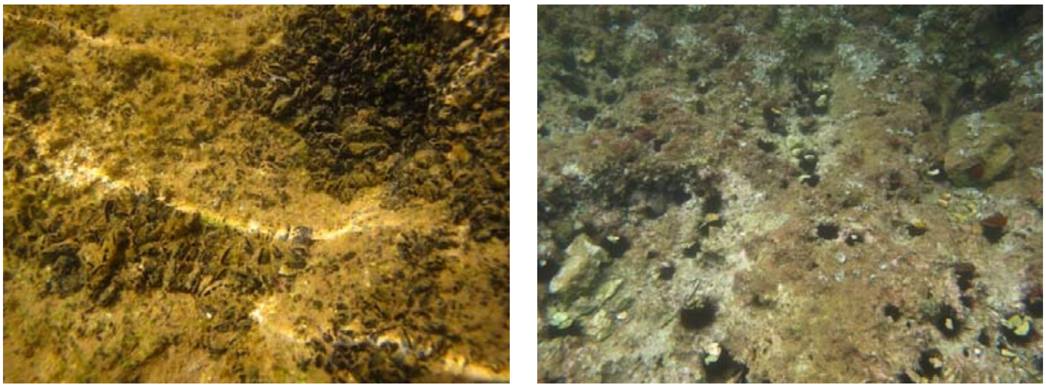


Figure 3.1.11. Dominance of green algae of genus *Cladophora*, mussel *Mytilus galloprovincialis* and sea urchins *Paracentrotus lividus* at 1 m depth off the coastline of Limski kanal (Transect 2).

Slika 3.1.12. Degraded macroalgal community off the coastline of Limski kanal with dominant green algae of the genus *Cladophora* at the 1 m depth. Macrofauna dominated by *Ostrea edulis*, *Anemonia sulcata* and *Chondrilla nucula* (Transect 3).

Results of the assessment of the water body Pula harbour (0412-PUL)

This WB is in the semienclosed bay where the most important harbour on the western Istrian coast (Pula harbour) is situated. According to its size, this WB is a small WB. The ecological status of this WB is under strong anthropogenic impact.

The ecological status of Pula harbour was assessed as Bad with the CARLIT method in the late spring 2011. (Figure 3.1.13.). The investigated coastline was dominated by degraded communities of photophilic algae with dominant species within the genus *Cladophora* and genus *Ulva* (with and without *Mytilus*) on both natural and artificial coastline (blocks and seawalls; Figures 3.1.14.-3.1.15.).

The EQR value of WB **O412-PUL** is **0.16**. According to this EQR value, we concluded that the ecological status of the whole investigated coastal area of this WB is BAD. In this WB, the seagrass *Posidonia oceanica* was not observed.

Rt Debeljuh - Rt Žunac
EQR value: 0.18
Ecological status: BAD

Uvala Mulimenti-Rt Guc
EQR value: 0.16
Ecological status: BAD

Uvala Lučica - Uvala Privlaka
EQR value: 0.16
Ecological status: BAD

Figure 3.1.13. Ecological status and EQR values of WB Pula harbour.

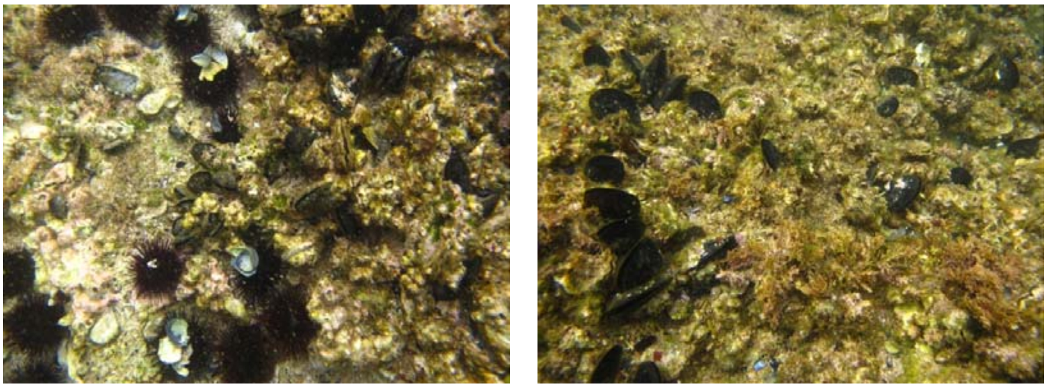


Figure 3.1.14. Dominance of green algae of the genus *Cladophora*, red calcareous algae *Corallina elongata*, mussel *Mytilus galloprovincialis* and sea urchins *Paracentrotus lividus* at 1 m depth along the coastline of the Pula harbour.

Slika 3.1.15. Photophilic algae of the genus *Dictyota* and green algae *Codium vermilara* on natural coast (left) and the dominance of green algae of the genus *Cladophora* and mussel *Mytilus galloprovincialis* on artificial coast (right) at 1 m depth along the coastline of Pula harbour.

Results of the assessment of the water body western Istrian coast (0412–ZOI)

This WB is situated along the coastline of the western Istria coast, from Savudrija to Medulin. According to its size, this WB is a mid-sized WB. The anthropogenic impacts along the whole Istria coast are localised, and their influences on different BQE in the last two decades are an object of scientific research.

To assess the ecological status of this WB, macroalgal assemblages were mapped along the coastline of the following areas: Umag, Novigrad, Poreč, Rovinj, Barbariga, Fažana and National Park Brijuni (Figures 3.1.16.-3.1.22.).

Umag 1: Uvala Užulari - Uvala Sv. Pelegrin
EQR value: 0.84
Ecological status: HIGH

Umag 2: Rt Lovrečica - Uvala Kocišće
EQR value: 0.84
Ecological status: HIGH

Figure 3.1.16. Ecological status and EQR values of the WB western Istrian coast (coastline of Umag).

Tar - Vabriga: Veliki Rt Kras
EQR value: 0.24
Ecological status: BAD

Figure 3.1.17. Ecological status and EQR values of WB western Istrian coast (coastline of Novigrad).

Poreč 1: Velika uvala - Plava Laguna
EQR value: 0.69
Ecological status: GOOD

Poreč 2: Debeli Rt - Plava laguna
EQR value: 0.63
Ecological status: GOOD

Figure 3.1.18. Ecological status and EQR values of WB western Istrian coast (coastline of Poreč).

Rovinj: Rt Kuvi _Rt Kurent
EQR value: 1.05
Ecological status: HIGH

Figure 3.1.19. Ecological status and EQR values of WB western Istrian coast (coastline of Rovinj).

Općina Bale: Uvala Marić – Uvala Sv. Benedikt
EQR value: 0.75
Ecological status: HIGH

Figure 3.1.20. Ecological status and EQR values of WB western Istrian coast (coastline of Barbariga).

Brijuni: Uvala jezero - Rt Draga
EQR value: 0.85
Ecological status: HIGH

Brijuni: Tisnac Turanj - Rt Turanj
EQR value: 0.83
Ecological status: HIGH

Brijuni: Uvala Verige - Mrtvi Rt
EQR value: 0.79
Ecological status: HIGH

Brijuni: Rt Ploče - Uvala kozlac
EQR value: 0.79
Ecological status: HIGH

Figure 3.1.21. Ecological status and EQR values of WB western Istrian coast (coastline of NP Brijuni).

Fažana: Uvala Muraci – Luka Fažana
EQR value: 0.53
Ecological status: MODERATE

Figure 3.1.22. Ecological status and EQR values of WB western Istrian coast (coastline of Fažana).

The ecological status of the western Istrian coast was assessed as High by the CARLIT method in late spring 2011. (Figures 3.1.16.-3.1.22.). Along the coastline of Umag, Poreč and Rovinj, macroalgal assemblages of the genus *Cystoseira* dominated, and the most abundant species were *C. compressa*, *C. barbata* and *C. crinita*. In monospecific and mixed settlements of those species, species of the genus *Sargassum* were also often present, and in intertidal zone the brown endemic algae *Fucus virsoides* was observed. The coastline of Tarska vala was dominated by degraded macroalgal communities with the species of the genus *Ulva* and genus *Cladophora*, and the macrofauna was dominated by mussels and patchy population of sea urchins. In the mapped areas of Barbariga, Fažana and NP Brijuni photophilic algae and a patchy distribution of sea urchins were observed, while species of the genus *Cystoseira*, genus *Sargassum* and genus *Fucus* were not observed (Figures 3.1.23.-3.1.25.).

The EQR value of WB **O412-ZOI** is **0.76**. According to this EQR value, we concluded that the ecological status of the overall investigated coastal area of this WB is HIGH. In this WB, the seagrass *Posidonia oceanica* was observed in the coastal areas of NP Brijuni, Banjole and Rt Kamenjak.

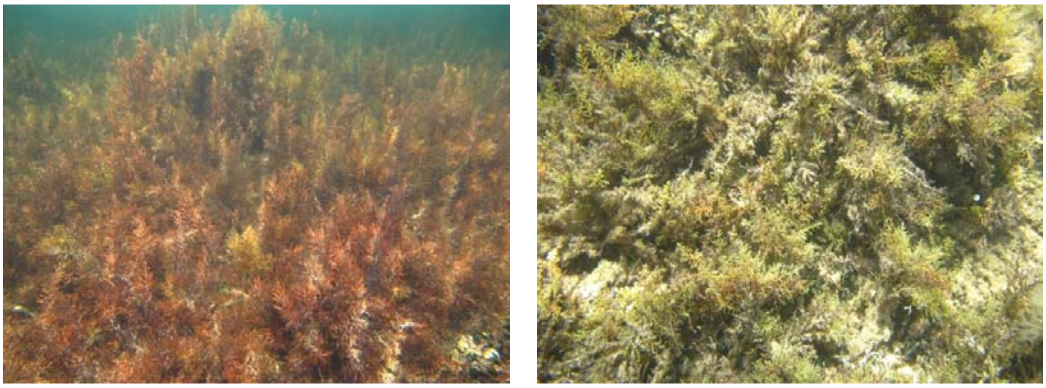


Figure 3.1.23. Settlements of the genus *Cystoseira* dominated in the coastal areas of Umag, Poreč and Rovinj at the 1 m depth.

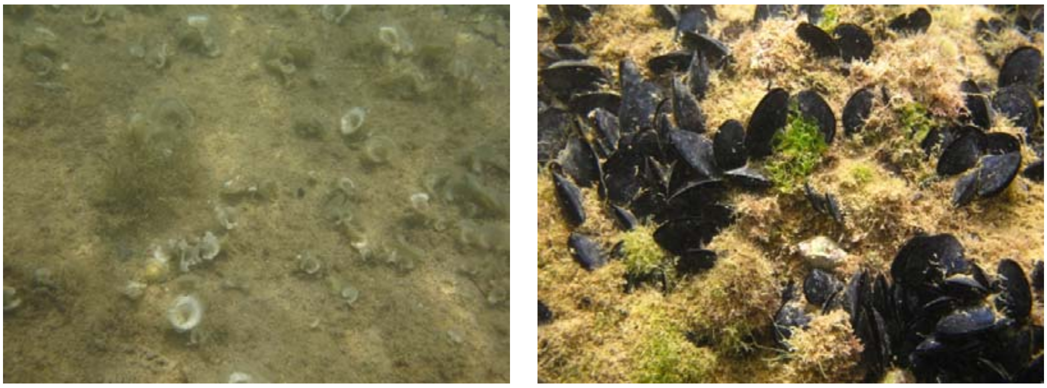


Figure 3.1.24. Degraded photophilic assemblages of algae dominated by the genus *Cladophora,* the genus *Ulva* and the mussel *Mytilus galloprovincialis* at the 1 m depth along the coastline of Tarska vala.

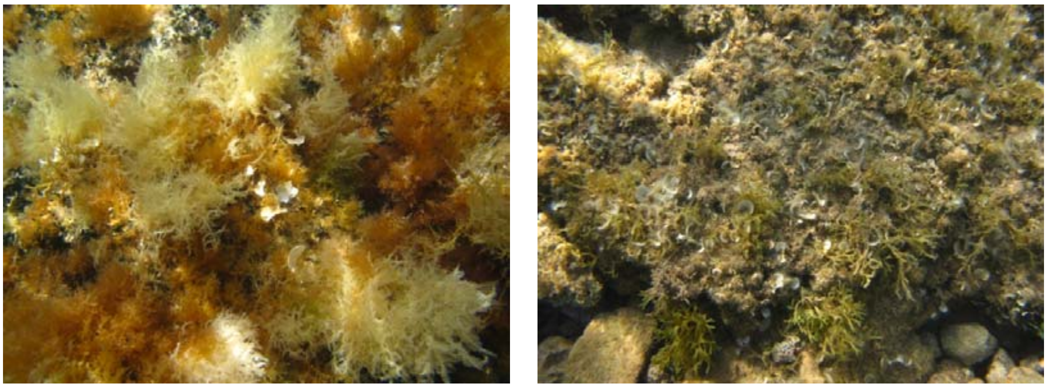


Figure 3.1.25. Photophilic assemblages dominated by the species *Laurencia obtusa* and *Wrangelia penicillata* (left) and species of the genus *Dictyota* and the brown algae *Padina pavonica* (right) along the coastlines of Barbariga, Fažana and NP Brijuni.

Results of the assessment of the water body Raša bay (0413 – RAZ)

During 2012, we mapped the macroalgal assemblages along the whole coastline of WB Raša bay using the CARLIT method. This WB (0413-RAZ) is situated in the eastern part of Raša bay, which has a semi-enclosed shape. In this WB there is a strong influence from rises of salt water, which increase the sedimentation and decrease the transparency of the seawater. All these specific environmental conditions influence the ecological status of its biological quality elements.

Legend

Ecological status	Colour
High	
Good	
Moderate	
Poor	
Bad	

Figure 3.1.26. Ecological status of WB Raša bay**.**

The ecological status of this WB was assessed as Moderate with the CARLIT method in the late spring 2012. (Figure 3.1.26.). Along the coastline the domination of *Mytilus galloprovincialis*, degraded photophylic assemblages (with the species domination of the genus *Cladophora*) and the presence of the brown algae *Fucus virsoides* were observed. In the inner part of Raša bay, under specific environmental conditions (lower seawater transparency and salt water), a patchy distribution of seagrass *Zostera noltii* was observed, and the rocky bottom was without vegetation and macrofauna (Figure 3.1.27.).

The EQR value for WB **O413-RAZ** is **0.44**. According to this EQR value, we concluded that the ecological status of the whole investigated coastal area of this WB was MODERATE.

In the summer 2013, sampling was performed of the seagrass *Zostera noltii* at the mouth of the Raša river to estimate the ecological status in transitional waters using BQE seagrass. In the mouth of Raša river, the seagrass *Cymodocea nodosa* was not observed. The analysis of the seagrass will be performed in the Institute of Oceanography and Fisheries in Split, and two methods for the assessment of the ecological status in transitional waters will be tested: CYMOX (Oliva *et al.*, 2012) and Cymoskew (Orfanidis *et al.*, 2009). Both methods have been developed for use with the seagrass *C. nodosa*.

Figure 3.1.27. Brown algae *Fucus virsoides* and the domination of the mussel *Mytilaster minimus* in the intertidal zone in Raša bay (left). Close to the mouth of the river, the seawater transparency during sampling was very bad at 1 m depth (right).

Within the "Jadranski project", macroalgae were mapped in intertidal and subtidal zones along 60 km of the coastline in three sectors (Umag, Rovinj and Rt Kamenjak) along the western Istrian coast, in both in pristine and urbanised areas (Figure 3.1.28.). The mapping and sampling of macroalgae were performed during late spring and early summer 2013.

Within each of three sectors, three transects were selected, and the coastline was inspected using the CARLIT method. In the Central sector, the Rovinj area, two sites were randomly selected within each transect; in each site, 6 replicate quadrats of 20x20 cm were randomly placed. The percent cover of the dominant macroalgae was measured within each quadrat, and the data will be used to calculate the Ecological Evaluation Index (EEI; Iveša *et al.*, 2009). The soundness of the CARLIT index in all three sectors, as well as of the EEI index in Rovinj, will be tested to use both indices as descriptors of environmental status for the inspected coastline along the western Istrian coast.

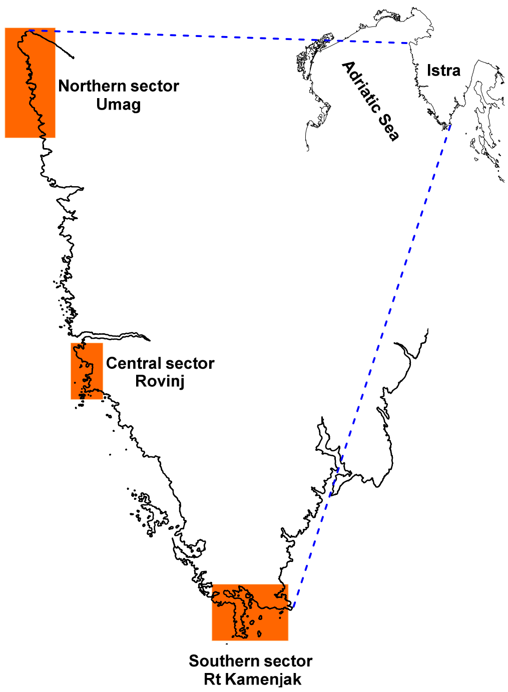


Figure 3.1.28. The investigated sectors along the western Istrian coast are marked in orange.

The Umag coastline (Northern sector) was visually inspected from Luka Savudrija to Marina Umag (Transect 1), from Sv Peligrin to Rt Sveti Ivan (Transect 2) and from Rt Lovrečica to Rt Malin (Transect 3). In Transect 1, several natural and artificial beaches were omitted from the mapping because they were fenced for swimmers. The natural coast was dominated by brown algae of the genus *Cystoseira,* which mostly presented with continuous settlements of *C. crinita* and *C. barbata* and patches of photophilic algae (e.g., *Laurencia obtusa*, *Wrangelia penicillata*; Figure 3.1.29.). In areas exposed to fresh water, the macroalgal community was dominated by green algae of the genus *Ulva*.

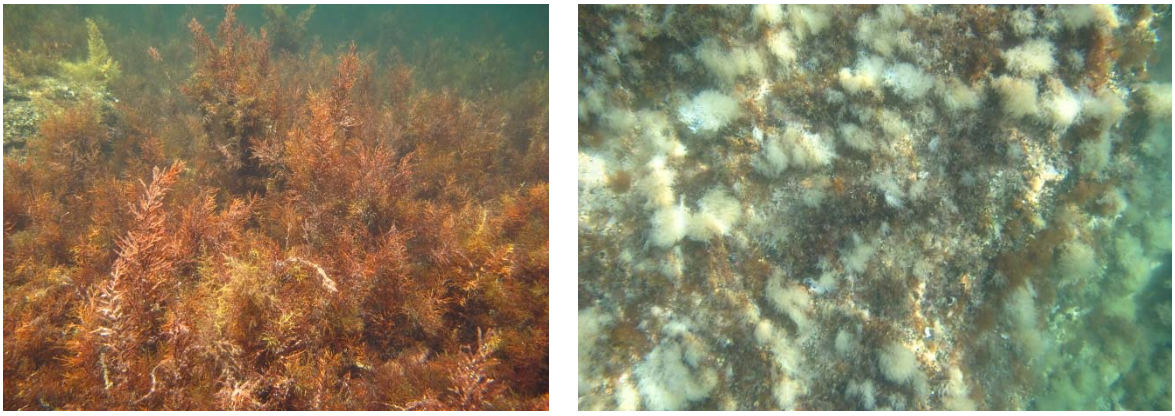


Figure 3.1.29. Main macroalgal communities detected using the CARLIT method in the Umag sector. On the natural coast, the macroalgal communities were dominated by *Cystoseira barbata* (left) and photophilic algae (right).

The Rovinj coastline (Central sector) was visually inspected from Rt Sv Fuma to Rt Mućа (Transect 1), from Rt Mućа to Luka Rovinj (Transect 2) and from Uvala Lone to Rt Kuvi (Transect 3). In Transect 1, the coastline was dominated by brown algae of the genus *Cystoseira*. Settlements were mostly composed of *C. crinita* and *C. barbata* with some patches of *C. amentacea.* In Transect 2, the urban area on the natural coast was dominated by dense settlements of *C. compressa*, with some individual thalli longer than 2 m (Valdebora bay), while on artificial structures, green algae with *Mytilus galloprovicialis* and limpets were dominant (Figures 3.1.30.- 3.1.31.). In Transect 3, the natural coast was mostly covered by photophilic algae and by the fucoid brown algae *Cystoseira compressa* subsp. *rosetta*.

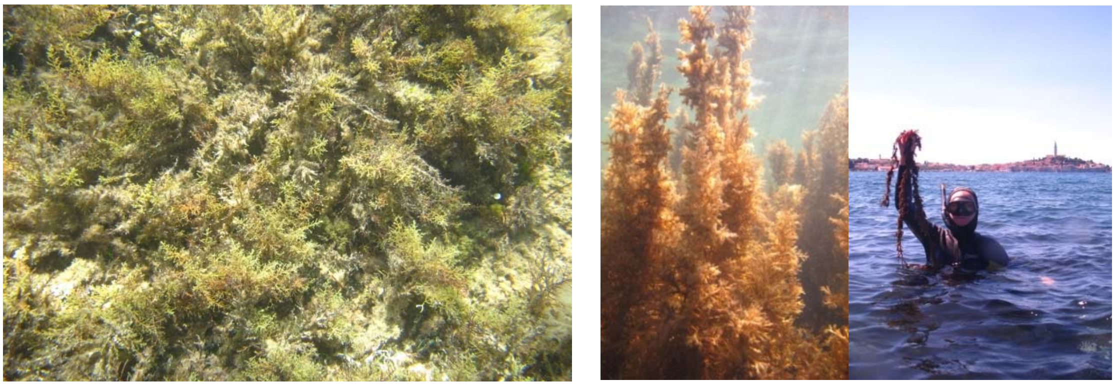


Figure 3.1.30. Main macroalgal communities detected using the CARLIT method in the Rovinj sector. Natural macroalgal communities dominated by the brown algae *Cystoseira crinita* in pristine area (left), and *Cystoseira compressa* in urban areas, with some thalli more than 2 m in length (right).

Figure 3.1.31. Dominant macroalgal species in the urban area of the Rovinj sector. The natural coast was covered by dense settlements of *Cystoseira compressa* with sparse patches of green algae of the genus *Ulva* (left); the seawalls were dominated by green algae of the genus *Ulva* and genus *Cladophora* (right).

The Rt Kamenjak coastline (Southern sector) was visually inspected from Rt Rakovica to Rt od Polja (Transect 1), Rt Kršine to Rt Munat Premanturski (Transect 2) and from Uvala Funtane to Kamp Kažela (Transect 3). Along 30 km of the coastline, the most dominant macroalgae on the natural coast were photophilic algae, with many areas of rocky bottom overgrazed by sea urchins (Figure 3.1.32.).

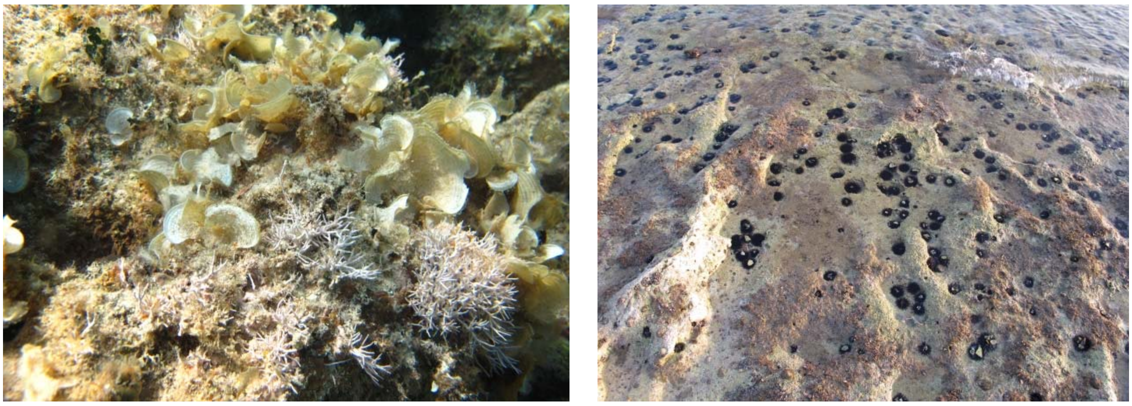


Figure 3.1.32. Dominant macroalgal species in the Rt Kamenjak sector. Natural coast dominated by photophilic algae (left) with large surfaces of rocky bottom overgrazed by sea urchins (right).

In Rt Kamenjak (Southern sector), the seagrass *Posidonia oceanica* meadow was mapped at 10 and 15 m depth along the coastline of the island Ceja (eastern part of Rt Kamenjak). At a depth of 10 m, the maximum number of shoots was 62, and at a depth of 15 m, the maximum number of shoots was 37 per 0.16 m^2. In this location, *P. oceanica* meadow continuously covered the seabed from 5 to 18 m depth with a lower % coverage of dead matte and unvegetated sandy patches (Figure 3.1.33.).

The data on the distribution and size of *P. oceanica* meadow along the Istria coastline are poor. Thus, to assess the ecological status of *P. oceanica* systems in accordance with Marine Strategy Framework Directive (MSFD), we suggest the continued mapping of *P. oceanica* along the Rt Kamenjak coastline, and the coastline of National Park Brijuni and of the eastern part of Istria.

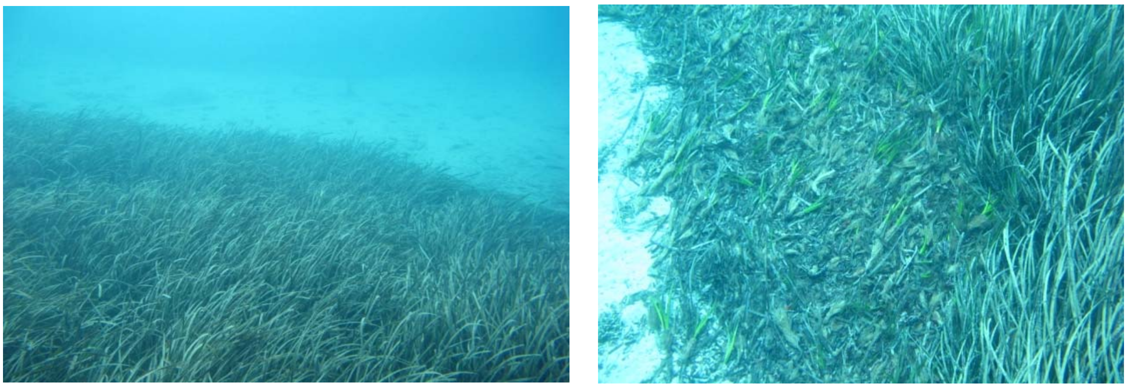


Figure 3.1.33. *Posidonia oceanica* meadow in Rt Kamenjak sector ending at 18 m depth (left) and dead matte at 9 m depth (right).

The cartographic data on the macroalgal assemblages and the quantitative sampling of macroalgal cover will be analysed during 2014. The CARLIT and EEI indices will be tested in pristine and urban area to determine the most accurate descriptor for the detection of Good Ecological Status (GES) according to the requirements of the **Marine Strategy Framework Directive (**MSFD) for the surveyed western Istrian coast.

Distribution of the invasive species *Caulerpa racemosa* along the Istrian coast

In the Vrsar area, the distribution and vegetative cycle of the invasive algae *Caulerpa racemosa* were investigated from the beginning of its appearance, from 2004 (Iveša and Devescovi, 2006). Research on its distribution in the same area on the rocky bottom outside the island of Sv. Juraj continued during 2008 (Figure 3.1.34.).

The results on the distribution of this invasive species indicate that this species is spreading along the coastal zone of the western Istrian coast. The bulk of information about its distribution comes from fishermen, divers, swimmers and our own observations. The species has been recorded in many areas along the Istrian coast: in the coastal zones of Umag, Poreč, Vrsar, Rovinj and Ližnjan.

Observing the seasonal variation of the algae *C. racemosa* on the rocky shore on the exposed site of the Island St. Juraj during the past few years will be useful for understanding the mechanism of its distribution. Sampling was performed during the maximum growth of this invasive species, in autumn 2008, and the following variables were measured: biomass of invasive species and of other dominant macroalgal species of the order Fucales. During autumn, a patchy distribution of the invasive species within the photophilic macroalgal assemblages was noted (Figure 3.1.35.). Regarding abiotic factors, the daily seawater temperature during 2008 was observed (with Data Logger).

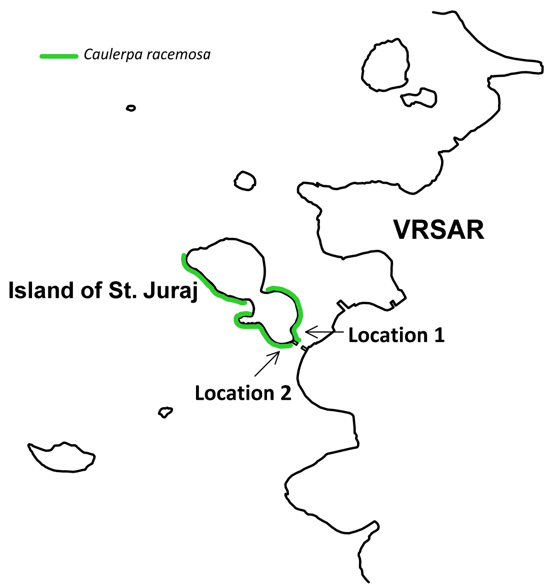


Figure 3.1.34. At location 1 and location 2, the distribution of the invasive algae *Caulerpa racemosa* in 2004 and in 2005 was investigated. In 2008, the mechanism of its distribution was investigated on the hard bottom at location 2 (along the exposed part of the Island Sv. Juraj).

The results of mapping the invasive algae during autumn 2008 demonstrate that this species spreads differently in association with the following infralittoral macroalgae: the species *Cystoseira compressa*, the species *Cystoseira crinita* and the species *Sargassum vulgare*. Those three habitats were randomly chosen. The biomass of the invasive algae was greater in the habitat of the brown algae *C. compressa* (43 g/400 cm^2) and *Sargassum vulgare* (41 g/400 cm^2), and lower biomass was noted in the habitat of the species *C. crinita* (23 g/400cm^2) (Figure 3.1.36.). In the quadrats, the qualitative composition of all other macroalgae, especially turf and incrusting algae, was sampled (Figure 3.1.37.).

Figure 3.1.35. Invasive algae *Caulerpa racemosa* within a settlement of brown algae of the genus *Sargassum* (left) and photophilic communities (right).

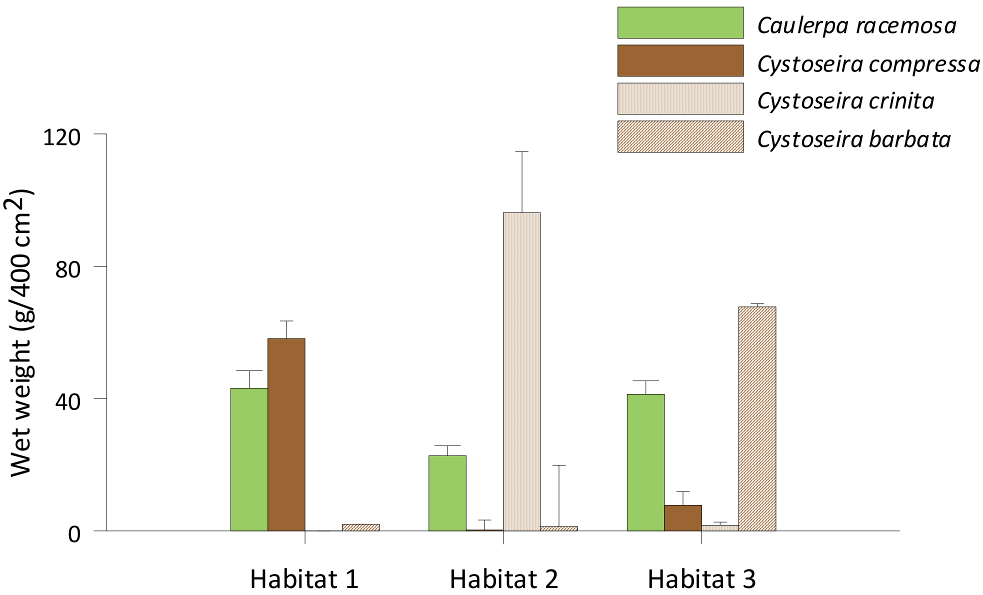
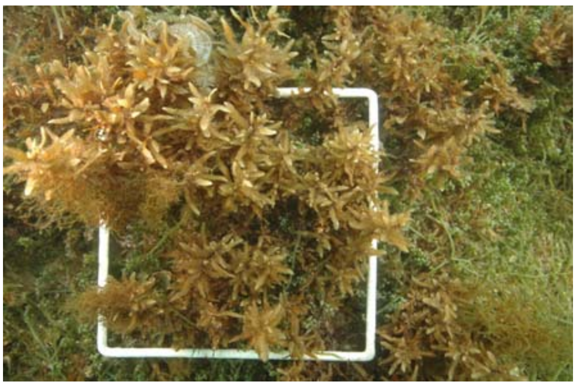


Figure 3.1.36. Biomass of the invasive algae *C. racemosa* and of settlements of brown algae of the order *Fucales*.



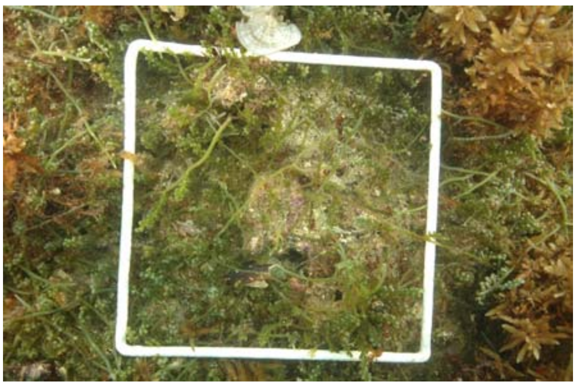


Figure 3.1.37. Quantitative sampling of brown algae of the genus *Sargassum* (left), invasive algae *C. racemosa,* understorey algal assemblage and encrusting algae (right).

Green algae *Codium fragile* ssp. *tomentosoides*

In the Rovinj area along the coastline, one new invasive species, green algae *Codium fragile* ssp. *tomentosoides,* was noted during 2009. This species is, according to its morphological features, very similar to the species *Codium vermilara*, which is common in the Rovinj area (Figure 3.1.38.). The species *C. fragile* ssp. *tomentosoides* was noted along the coast, mostly on artificial structures (limestone blocks; Figure 3.1.39.), while the species *C. vermilara* was mostly present on the natural rocky shore, and only a few individuals were found on artificial structures. Further investigation is planned for better understanding the biology and ecology of the invasive species *C. fragile* ssp. *tomentosoides* along the western Istrian coast.

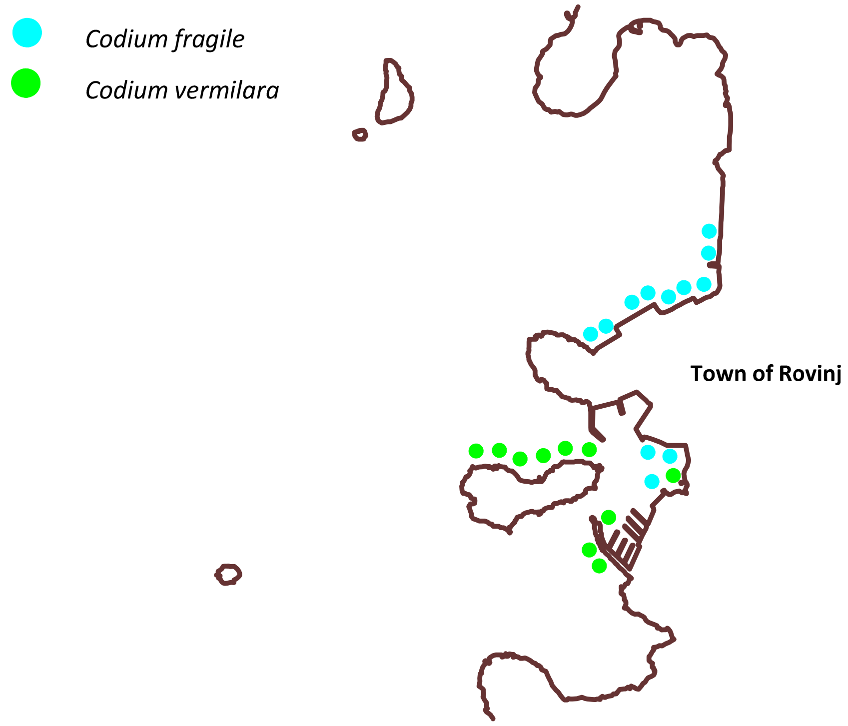


Figure 3.1.38. Mapping of the species *Codium fragile* ssp. *tomentosoides* and of the species *Codium vermilara* in the coastal area of Rovinj.

Figure 3.1.39. Settlement of the green algae *Codium fragile* ssp. *tomentosoides* on limestone blocks in the coastal Rovinj area.

Categorization of Istrian coastal waters based on BQE Benthic invertebrates

This contribution refers to data related to MSFD Descriptor 6 in order to meet the aims and objectives of this project: 1) to collect scientific data for the Plan of Integrated Coastal Zone Management of Region of Istria and the Physical Plan of Region of Istria, 2) to obtain new biological knowledge on the marine life on different levels of ecological organization, and 3) to provide a baseline for implementation of responsible and sustainable management of the coastal zone, including efficient protection of the coastal marine life.

MSFD Descriptor 6 is associated to the Seafloor integrity. It reflects the physical, chemical and biological characteristics of the sea bottom. Determination of GES should be at level that ensure that the pressures on the seabed caused by human activities do not prevent components of the ecosystem to maintain its natural diversity, productivity and dynamic ecological processes, taking into account the resilience of ecosystems.

In the ongoing, initial phase of the MSFD implementation in the Croatian part of the Adriatic Sea we focuses five principal attributes of D6 descriptor at different type of soft bottoms (biogenic/detritic sediment, sand and mud): substrate, bio-engineers, species composition of benthos, size composition of benthos and life-history traits. Criteria, Indicators and Biological Quality Elements proposed for determining GES associated with MSFD Descriptor 6 (Annex I of the Regulation establishing a framework for action of the Republic of Croatia in the field of marine environmental protection, OG 136/11) are summarized in Table 3.1.2.

Table 3.1.2. The Seafloor integrity assessment at selected sites in the northern Adriatic coastal waters will be focused to attributes, criteria and indicators recommended by MSFD.

ATTRIBUTE	CRITERIA TO ASSESS DESCRIPTOR	INDICATORS TO BE MEASURED	BIOLOGICAL QUALITY ELEMENTS
1- Substrate	Reduction in natural 3 dimensional structure	Benthic habitats on hard substrates	- Macroalgae - Seagrasses
2- Bio-engineers	Reduction in number and/or spatial extent of bio-engineers	Abundance of bio-engineer species	- Macroalgae - Seagrasses - Zoobenthos
3- Species composition of benthos	Increasing proportion of community comprised on few species in high abundance and/or permanent loss of species	- Diversity and richness - Shape of cumulative abundance curves - Position of samples in multivariate representations community composition	- Macroalgae - Macrozoobenthos (macrofauna) - Meiobenthos (meiofauna)
4- Size composition of benthos	Increasing/decreasing proportion of the community comprised of small/large individuals	- Proportion of number or biomass above some specified length - Shape of CA curves of numbers of individuals by size group	- Macrozoobenthos
5- Life-history traits	Increase/decrease in relative abundance of traits associated with sensitive/oportunistic species	- Opportunistic -sensitive species proportion (AMBI, M-AMBI, MI) - Integration of indicators already used	- Macrozoobenthos - Meiobenthos

In order to test the sensitivity/suitability of selected indicators for the Seafloor integrity assessment, study was conducted both in natural/undisturbed habitats and the same type of habitats under different anthropogenic and/or natural pressures. At present, taxonomical analyses still going on. The final assessment of the Seafloor integrity will be integration of indicators used in this study, related to physical and chemical indicators of the seafloor integrity and using experience and knowledge obtained in previous monitoring on the implementation Habitat Directive and Water framework Directive of EU. These results should be a baseline for preliminary assessment and determination of GES for three main types of soft bottoms in the northern Adriatic coastal area.

By 2010, when the initial phase of WFD implementation have started in the Croatian part of the Adriatic Sea, rather small number of datasets related benthic communities fulfilled the requirements necessary for assessment of ecological status of transitional and coastal waters. Two out of five principal attributes related to MSFD, i.e. species composition of benthos and life-history traits were analysed within the initial phase of WFD implementation for coastal areas where quantitative and qualitative historic data was available (Mirna River estuary, Limski kanal, coastal area of Rovinj, Raša bay and the Kvarner gulf (Fig. 3.1.40).

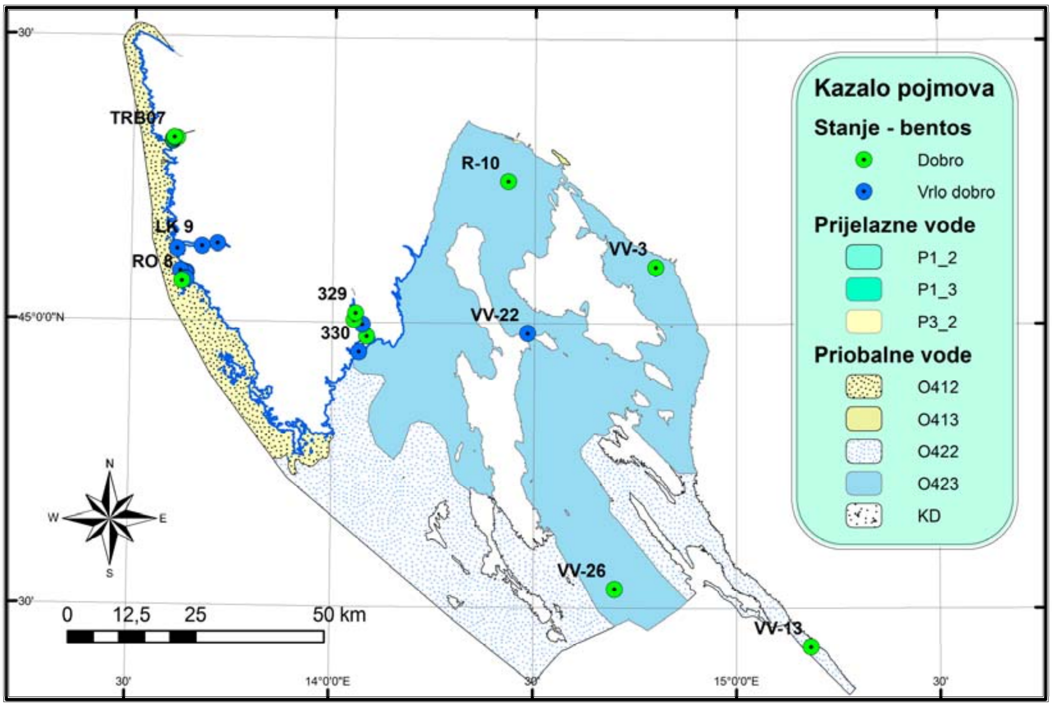


Figure 3.1.40. Benthic sites analysed for ecological status assessment based on BQE benthic invertebrates.

Historical data on the composition of marine invertebrates, obtained between 1973 and 1987 from five northern Adriatic coastal areas were a baseline for the analysis of functional structure of benthic communities, calculation of structural and biotic indices, assessment of ecological quality status and definition of reference conditions in the northern Adriatic coastal area.

Many of the biotic indices has been developed on the paradigm of Pearson and Rosenberg (1978), which stated that developed benthic communities respond to improvements in habitat quality in three progressive steps: the abundance increases; species diversity increases; and dominant species change from pollution-tolerant to pollution-sensitive species. Based on expert opinion, as summarized in Grall and Grémalec (1997), each macroinvertebrate species, are attributed to one of five ecological groups related sensitiveness to organic enrichment and disturbance (EG I - very sensitive species, EG II- indifferent species, EG III -tolerant species, EG IV- 2nd order opportunistic species and EG V-1st order opportunistic species). In our studies aimed at ecological quality assessment macrobenthic species was classified into upper mentioned functional groups in order to provide indices based on the abundance-weighted average disturbance sensitivity of macroinvertebrates (AMBI). Seafloor integrity is assessed through factorial (FA) and discrimination analysis (DA) of selected indicators associated with community structure (taxonomic and functional group composition, species richness and Shannon-Wiener diversity index) integrated in Ecological quality ratio (EQR) of multimetric biotic index M-AMBI (Borja *et al.*, 2000).

Structural and biotic indices obtained by analysis of soft bottom benthic communities using BQE macroinvertebrates for Mirna River estuary (sites TRB 2-7), Limski kanal (sites LK7-LK44), Rovinj area (sites RO2-RO8), Raša Bay (sites 326-329) and the Kvarner gulf. These data relied on analysis of 152 macrofauna samples collected between 1973 and 1987 from 24 northern Adriatic sites and provide a starting point for assessment of ecological quality and defining of reference conditions using BQE benthic invertebrates in the northern Adriatic. In general, reference conditions are associated with high or at least good ecological status of particular water type and/or benthic habitat within distinctive geographic areas, thus reference conditions are type specific and geographically specific. It refers to undisturbed (pristine) or slightly disturbed marine environment in which the diversity and abundance of invertebrate taxa is within the range normally associated with undisturbed conditions. Disturbance sensitive taxa associated with given community in undisturbed conditions should be present. Reference conditions should be derived to distinguish differences between very minor, slight and moderate disturbance (Table 3.1.3) and must incorporate natural spatial and temporal variability of macrobenthic communities to distinguish differences caused by environmental factors eg. changes in community composition and abundance, seasonal fluctuation in abundance of macrobenthic populations etc.) from changes caused by anthropogenic influence.

Table 3.1.3. Definition of high, good and moderate ecological state based on composition, abundance and percentage participation of benthic invertebrate species as one of the principal BQE in WFD and MSFD.

Very good ecological state	Good ecological state	Moderate ecological state
The level of macrobenthic abundance and diversity is within ranges that usually occur in natural (undisturbed/ pristine) conditions All species/taxa sensitive to stress conditions but immanent to particular community are present.	The level of macrobenthic abundance and diversity slightly deviate from the ranges defined by type specific conditions. The majority of sensitive species/taxa immanent to particular community is present	The level of macrobenthic abundance and diversity moderately deviate from the ranges defined by type specific conditions. All indicator of pollution are present. Many sensitive species/taxa are absent.

Unfortunately, due to methodological drawbacks (predominance of semi quantitative approach to study of benthic communities) and lack of quantitative results, there were no historical data suitable for assessment of marine ecological status and/or for description of reference conditions in all water types present along the eastern coast of the northern Adriatic. The results of ecological quality assessment relied on historical data and based on BQE benthic invertebrates is shown in Figure 3.1.41 and Table 3.1.4.

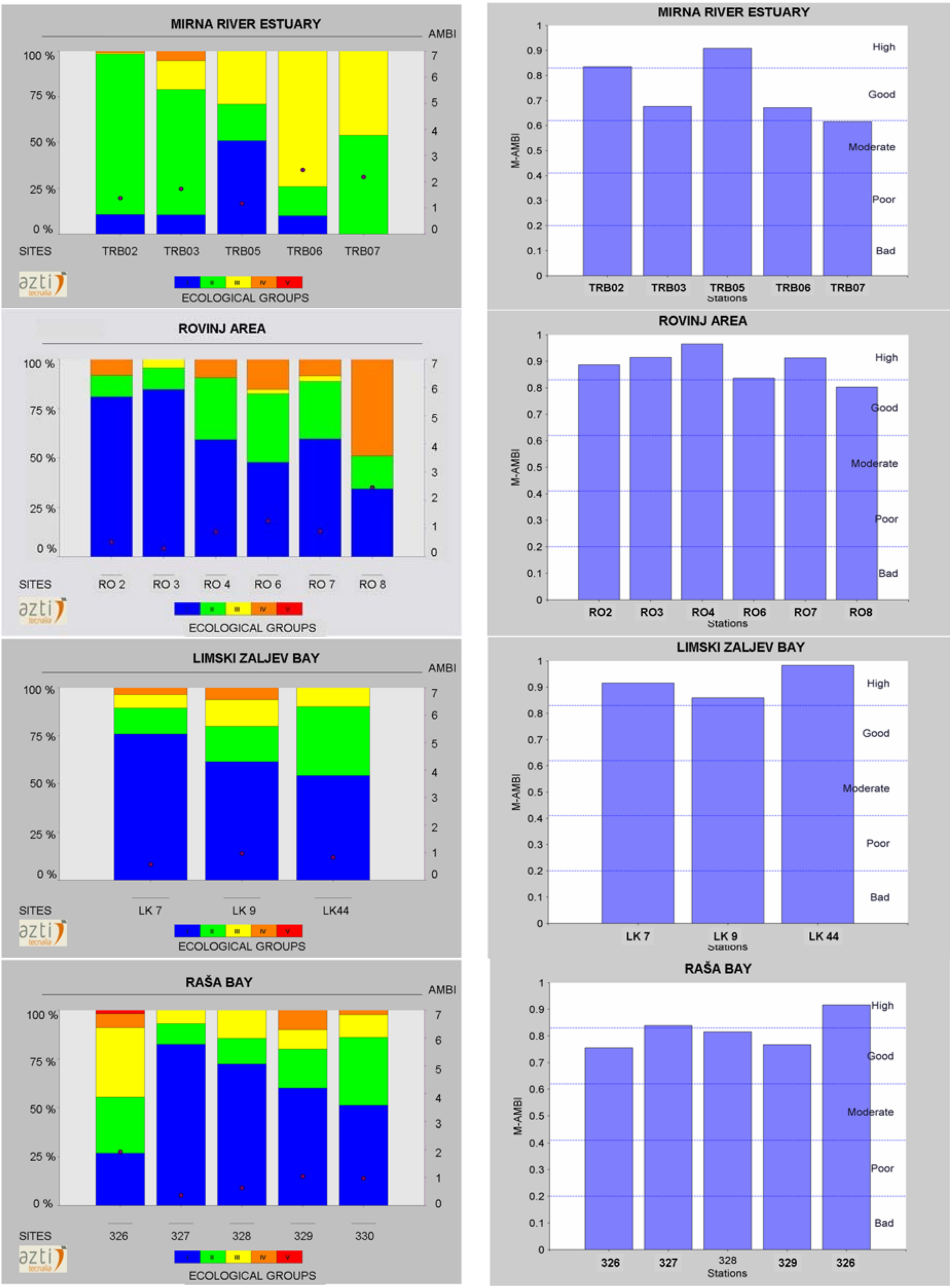


Figure 3.1.41. AMBI index (indicated by violet point) and distribution of ecological groups at study sites (on the left), and M/AMBI categorization based on EQR (on the right).

Table 3.1.4. An overview of structural and biotic indices used in the classification of transitional and coastal waters associated with soft bottoms and based on BQE benthic invertebrates. Type specific reference conditions of the first generation (*) are attributed to sites distinguish with very good ecological quality status.

Water type	Site	H'	S	BI	AMBI	Disturbance classification	M-AMBI	Ecological quality status
P 313	TRB05*	2,79	14	1	1,173	pristine	0,92	very good
	TRB06	2,38	8	2	2,460	slightly polluted	0,68	good
	TRB07	1,88	7	2	2,192	slightly polluted	0,62	good
P 312	TRB02*	1,53	19	2	1,378	slightly polluted	0,83	very good
	TRB03	1,98	8	2	1,737	slightly polluted	0,68	good
O 413	326	3,44	15	2	1,929	slightly polluted	0,75	good
	327	1,93	22	1	0,366	pristine	0,84	very good
	328	2,63	18	1	0,632	pristine	0,82	good
	329	3,13	14	1	1,050	pristine	0,77	good
	LK 7	4,14	44	1	0,575	pristine	0,92	very good
	LK 9*	4,15	39	1	0,973	pristine	0,86	very good
	LK 44	4,57	52	1	0,834	pristine	0,98	very good
O 412	RO 2	3,96	22	1	0,527	pristine	0,89	very good
	RO 3*	3,87	24	1	0,293	pristine	0,91	very good
	RO 4	4,02	30	1	0,890	pristine	0,97	very good
	RO 6	4,02	21	2	1,272	slightly polluted	0,84	very good
	RO 7	4,00	26	1	0,921	pristine	0,91	very good
	RO 8	3,35	29	2	2,453	slightly polluted	0,80	good
O 423	330*	3,96	19	1	0,797	pristine	0,92	very good
	R-10	4,21	29	2	1,326	slightly polluted	0,80	good
	VV-3	3,63	26	1	1,091	pristine	0,75	good
	VV-13	3,78	25	2	1,643	slightly polluted	0,72	good
	VV-26	4,06	24	2	1,352	slightly polluted	0,75	good
O 422	VV-22*	5,13	45	2	1,585	slightly polluted	0,97	very good

Ecological status of coastal waters along the west Istrian coast was monitored in 2011 at six sampling sites: the northernmost site (BB-O51) was situated in outer part of Tarska vala, two sites (BB-O49a, BB-O49) were located in Limski kanal – the first one in the close vicinity of mariculture facilities, and second one about 1 km seaward; two sites were situated in the coastal area of Rovinj (BB-O48, BB-O48a) and the last one (BB-O45) in the outer area of Pula harbour. Geographical position of sampling sites are indicated in Figure 3.1.42. The results related indicators of ecological quality are presented in Table 3.1.5. Rather high Shannon-Wiener diversity is measured at all sites, but somewhat lower values are reported from Limski kanal, due to lower species richness, especially at site in the vicinity of fish farms. AMBI values indicate pristine conditions at all site except BB-O48a – situated near the outlet of urban waste water. However, M-AMBI indices were rather high and indicated high ecological status for all sites except sites from Limski kanal and Pula harbour, where somewhat reduced values indicated good ecological status. Results related to biotic indices AMBI and M-AMBI are presented at Figures 3.1.43 and 44.

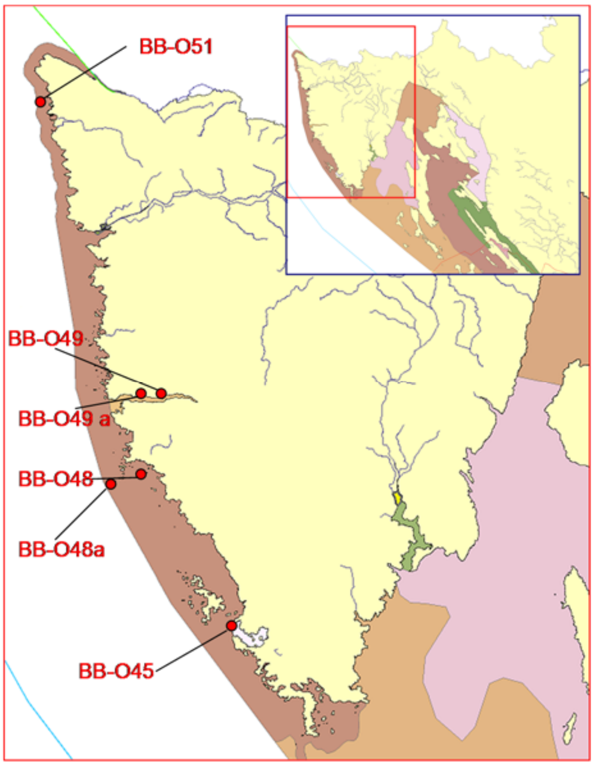


Figure 3.1.42. Sampling sites for assessment ecological state of coastal waters within WFD monitoring program in year 2011.

Table 3.1.5. Results of assessment the ecological state for coastal waters along the western coast of Istria.

Water type	Site	H'	S	BI	AMBI	Disturbance classification	M-AMBI	Ecological quality status
O 412	**BB-O48**	5,18	78	2	2,088	slightly polluted	0.94	good
	BB-O48a	4,68	66	2	1,863	slightly polluted	0,87	very good
	BB-O51	4,30	81	2	1,356	slightly polluted	0,90	very good
	BB-O45	4,59	54	2	1,538	slightly polluted	0,73	good
	BB-O49	3,61	31	2	1,434	slightly polluted	0,67	good
	BB-O49a	3,42	17	2	1,381	slightly polluted	0,61	very good

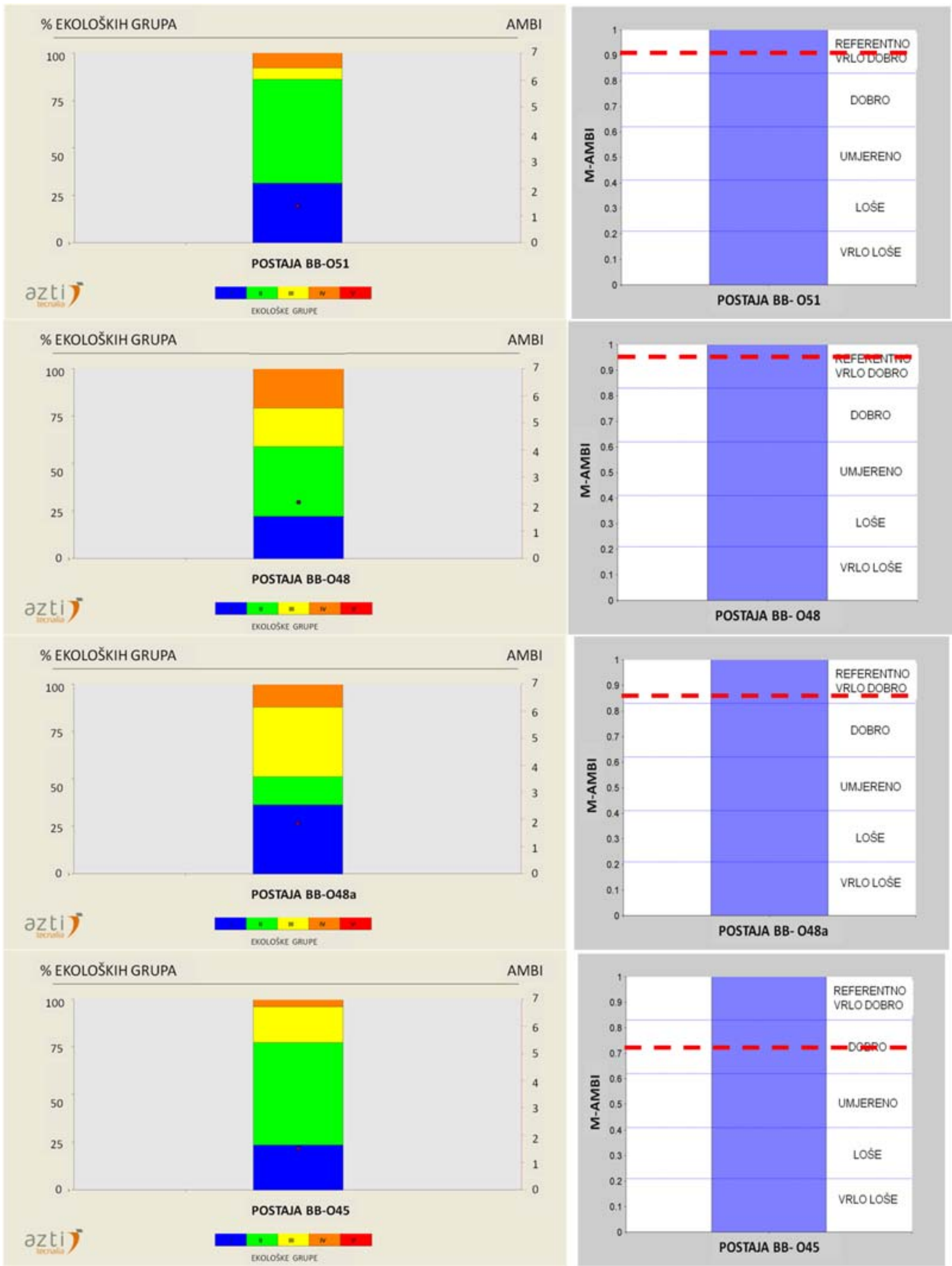


Figure 3.1.43. . Graphical presentation of results related to AMBI (left side) and M-AMBI (right side) analyses in Tarska Vala (BB-O51) and coastal area of Rovinj (BB-O48, BB-O48a).

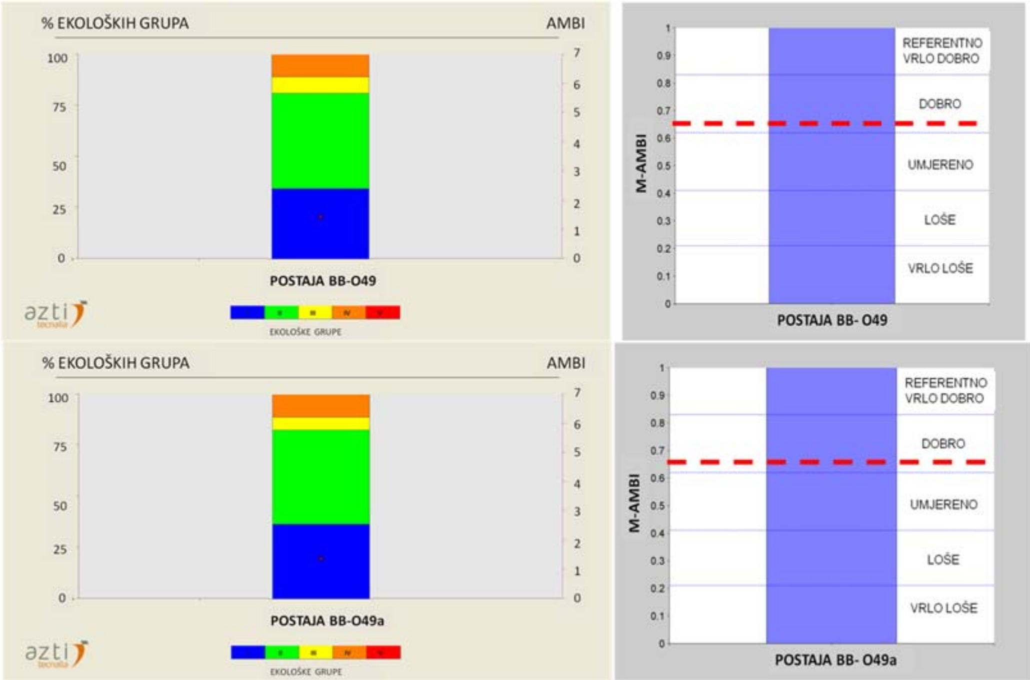


Figure 3.1.44. Graphical presentation of results related to AMBI (left side) and M-AMBI (right side) analyses in Limski kanal (BB-O49, BB-O49a) and Pula harbour (BB-O45).

CONCLUSIONS

Assessment of the Sea bottom integrity using BQE benthic invertebrates is carried out through implementation of the initial phase of the Marine Strategy Framework Directive and monitoring on implementation of Water Framework Directive. Recently we have involved assessment of ecological status in our projects research.

Preliminary assessment of ecological status of transitional and coastal waters in Istria County was carried out during the initial phase of WFD implementation. It relied on the analysis of faunistic data obtained from collected at 18 sites within 4 coastal areas: Mirna River estuary, coastal area of Rovinj, Limski kanal and Raša bay. Reference conditions were defined for two transitional and four coastal water types and reference sites were selected in accordance to WFD requirements. Boundaries between quality classes describing 5 categories of ecological status (from high to bed) were adopted from Slovenian classification.

Preliminary results related to historical data (temporal reference) pointed out good ecological status for 11 and good ecological status for 7 out of 18 sites. According AMBI results, three sites from Mirna river estuary (TRB 3, TRB6 and TRB7), three sites from Raša bay (326, 328, and 329) and two sites from Rovinj coastal area (RO6 and RO 8) were slightly polluted. Generally, results suggested favourable environmental conditions at all sampling sites covered by preliminary assessment of Seabed integrity.

Results on the assessment of ecological status related six coastal sites involved in the 1st cycle of WFD monitoring indicated good ecological status for site situated in Tarska Vala and two sites in the Rovinj coastal zone. Good ecological status was reported for site located near to the entrance to Pula harbour, and two sites in Limski kanal.

There were no quantitative data on the benthic communities from Plomin bay and Budava cove, so we cannot discuss available qualitative data in light of ecological quality assessment and Seabed integrity.

The results provided by biotic indices created for ecological quality assessment (AMBI, M-AMBI) indicated good applicability of both indices in coastal waters, but rather low resolution in transitional waters.

REMARKS AND RECOMMENDATIONS

Each water type contains several benthic communities which differ from each other in taxonomic composition and community structure

Categorisation of ecological status based on assessment of functional community structure (% share of EG I – EG V species) requires a knowledge about identity of benthic communities associated with particular site and knowledge about sensitive species immanent for particular community

In natural/pristine conditions faunistic composition and taxonomic structure are mainly defined by community type

There is a need for harmonization of knowledge obtained from results emerged during implementation of Water Framework Directive, Habitat Directive and Marine Strategy Framework directive in the northern Adriatic Sea. Better linking of WFD, HD and MSFD activities and continuous transfer of knowledge among single Directives is needed.

Assessment of ecological state using BQE benthic invertebrates should be done in all water types, all water bodies and all benthic communities that occur in the northern Adriatic Sea.

There is a need to define reference conditions/sites for all water types and all benthic communities that occur in the northern Adriatic Sea.

3.2. Descriptor 3: Commercially exploited fish and shellfish

This section applies to all stocks covered by national legislation in the field of fisheries (within the geographic scope of this Regulation) and similar obligations under the common fisheries policy. For these and other stocks in this part of the application depends on the available data (taking into account the provisions on the collection of data), based on which we can determine the most appropriate indicators to use.

The 2nd Working Group (TG2 Report) has agreed the following definition as a basis for interpreting commercially exploited fish and shellfish:

> Commercially exploited populations applies to all living marine resources targeted for economic profit. Fish and shellfish represent all marine vertebrate and invertebrate taxa including bone-fish, elasmobranchs, starfish, crayfish, bivalves, molluscs (including cuttlefish, squid) and extended to also include jellyfish.

Recommendations descriptor 3: Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

With regard to this descriptor, the three criteria for evaluating progress in achieving good ecological status with associated indicators are as follows:

1. Level of pressure of the fishing activity

Primary indicator. The primary indicator for the level of pressure of the fishing activity is:
- Fishing mortality (F).

Secondary indicators (if analytical assessments yielding values for F are not available):
- Ratio between catch and biomass index (catch/biomass ratio).

2. Reproductive capacity of the stock

Primary indicator. The primary indicator for the reproductive capacity of the stock is:
- Spawning Stock Biomass (SSB).

Secondary indicators (if analytical assessments yielding values for SSB are not available):
- Biomass indices.

3. Population age and size distribution

Primary indicators. Healthy stocks are characterised by high proportion of old, large individuals. Indicators based on the relative abundance of large fish include:
- Proportion of fish larger than the mean size of first sexual maturation,
- Mean maximum length across all species found in research vessel surveys,
- 95 % percentile of the fish length distribution observed in research vessel surveys.

Secondary indicator:
- Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation.

MARINE COASTAL RESOURCES OF ISTRA PENINSULA (ISTRIA COUNTY)

Fishery-biological research along the western coast of Istria (2002-2000 and 2010)

Demersal trawl-types of tartana

In the catches of “tartana” were recorded 65 species of fish, cephalopods, crustaceans and shellfish, of which 53 species of fish, 6 species of cephalopods, 3 species of crustaceans and 2 species of shellfish. Abundance of species, in the total catch, was as follows: musky octopus *Ozaena moschata* 39.9 %; cuttlefish *Sepia officinalis* 24.8 %; whiting *Merlangius merlangus* 11%; red mullet *Mullus barbatus barbatus* 6.9 %; hake *Merluccius mercluccius* 4.5 % etc., so mainly cephalopods with about 70 % by weight, which is one of the features of trawl catch for the area. The participation of the above and some other species (common sole *Solea solea*, squid *Loligo vulgaris*) shows the catch seasonal character, their mass fraction was higher in the catch from the colder part of the year. In contrast, species of the genus *Mullus* and common pandora *Pagellus erythrinus*, which were also common in the catch, were better represented in the mass catches from the warmer part of the year. The catch per unit of fishing effort (CPUE), i.e. the mass of the catch (kg) per hour trawling, calculated on the engine power of 100KS/74.57 kW, was relatively small, generally less than that which can be achieved in other trawl fields in the Adriatic, and was between 5.5 and 21.0 kg, generally more than 11 kg.

Dredging trawl- type rampon

In the catches of “rampon” were recorded 19 species, including 12 fish species, a substantially flatfishes (genus *Solea*, *Synapturichthys*, *Pegusa*, *Scophthalmus*, *Pleuronectes*, *Lepidorhombus*, *Arnoglossus*), by 3 species of cephalopods and molluscs and 1 species of crab (mantis shrimp *Squilla mantis*). In the total catch of rampon maximum mass was accounted to St. James scallop *Pecten jacobaeus* with a share of 58.5 %. In addition to the shellfish, regularly in the catch was represented queen scallop *Aequipecten opercularis*, often in greater quantities, and less but also regular Noah’s ark *Arca noae*. Among the other species in the catch by weight is best represented by a cuttlefish *Sepia officinalis* with 24.6 %, flatfishes with approximately 10%, mainly *Solea solea* 9.3 % and Klein’s sole *Synapturichthys kleinii* and squid with 4.8%. The catch per unit of fishing effort varied between 2.5 and 8.2 kg, and catch of St. James scallop between 2.73 and 3.69 kg, mainly 3 and above 3 kg, and cuttlefish between 0.06 and 4.02 kg, with which it was least during the warm part of the year.

Trammel net for catching Solea solea – “listarica”

In the catches of “listarica” were recorded 64 fish species, crustaceans and cephalopods, of which 56 species of fish, 5 species of crustaceans and 3 species of cephalopods. In the total realized catch, maximum mass accounted for common sole *Solea solea* with 80 %, and the cuttlefish *Sepia officinalis* with 5.5 %. In addition, some other flatfish species were recorded in the catches, from genus *Solea*, *Pegusa*, *Scophthalmus*, *Pleuronectes* and *Psetta*. Among the other fish, in the total catches mass was significantly represented by smooth-hound *Mustelus mustelus* with 2.3 %, and hake *Merluccius merluccius* with 1.3 %. *Squilla mantis*, which is particularly abundant in the northern Adriatic and more or less regularly in trawl catches and rampon, was here represented by 1 %. Total catch per unit of fishing effort, i.e., the mass of the catch per net (length of 18 m) was small. It hesitated by years, months and territories, ranging from 0.04 to 0.54 kg, and for *Solea solea* from 0.014 to 0.53 kg. Better catch per unit of fishing effort was achieved during the colder part of the year, from October to January inclusive, when the catches were the best and economically satisfactory.

There is the fact that in late winter (February) a decline in the catch of common sole occur most likely due to the gradual cessation of spawning (hence its migration into the sea and aggregation), and re-bury the substrate and thus becomes unavailable to trammel nets. Otherwise, common sole comes out, during the spawning, from substrate and is very active, migrate and gather to spawning area thus becoming available to trammel nets (as a percentage of the catch seems to be the most accessible in January, which could be linked to its highest activity during spawning). So catch of common sole, in the study area, are just done during its spawning cycle, which further indicates the level of vulnerability of the species in this area. If possible, it would be necessary to limit the fishing area, possibly the amount of trammel nets and determine the annual quota (harmonized regulatory measures, with the Italian side - the problem of overfishing of common sole), and in any case not increase fishing effort. It is also necessary to pursue further studies in order to determine the permissible level of utilization of the common sole, and to include additional studies of the biology and ecology of species in order to accurately determine its migration (possible introduction of labelling, the cooperation with the Italian side). Regarding control status of other fish populations it is necessary to pursue further studies as well as monitoring and collecting data on the catch according to DCR (Data Collection Framework)

Trammel net - prostica

The total catches recorded 56 species of fish, of which 13 species were sparids, then 3 species of crustaceans and 3 species of cephalopods. Cephalopods and crustaceans were recorded in the catches only sporadically. In the total catches mass was significantly represented by a sea bass Dicentrarchus labrax with 27.7 %, followed by common pandora Pagellus erythrinus with 26.14 %, gilthead seabream Sparus aurata from 7.92 %, Liza ramada with 7.73 % and bonito Sarda sarda with 4.2 %, which are characterized as „prostica“ catches in the study area as well as high quality and valuable commercial sense. Moreover, the quality sparid species were represented with a mass of up to 40.3 %.

Trammel net – „salpara“

The total catches recorded 7 fish species, with a maximum mass presented by common dentex *Dentex dentex* with 34.8 %, followed by sea bass *Dicentrarchus labrax* with 22.5 %, common two-banded seabream *Diplodus vulgaris* with 20.1 % and common pandora *Pagellus erythrinus* with 16.5 %. The catch per unit of fishing effort, i.e., the mass of the catch per net (100 m long) was in average of 2.7 kg.

Changes in the Adriatic ichthyofauna

New species for ichthyofauna of Istria County (biodiversity)

Caranx crysos (Mitchill, 1815) – Blue runner
Family: Carangidae

Lobotes surinamensis (Bloch, 1790) - Tripletail
Family: Lobotidae

Didogobius splechtnai Ahnelt and Patzner, 1995 – Istrian goby
Family: Gobiidae

Lebetus guilleti (Le Danois, 1913) - Guillet's goby
Family: Gobiidae

Gobius couchi Miller & El-Tawil, 1974 - Couch's goby
Family: Gobiidae

Gobius kolombatovici Kovacic & Miller, 2000 - Kolombatovic's goby
Family: Gobiidae

Sphyraena viridensis Cuvier, 1829 - Yellowmouth barracuda
Family: Sphyraenidae

Apletodon incognitus Hofrichter & Patzner, 1997
***Family:** Gobiesocidae*

Pomatomus saltatrix (Linnaues, 1766) – Bluefish
Family: Pomatomidae

Findings of non-native fish species in the North Adriatic Sea (close to the waters of Istria County)

Siganus luridus (Rüppell, 1829) – Dusky spinefoot
Family: Siganidae

Epinephelus coioides (Hamilton, 1822) - Orange-spotted grouper
Family: Serranidae

Terapon theraps Cuvier, 1829 – Largescaled terapon
Family: Teraponidae

Plectorhinchus mediterraneus (Guichenot, 1850) – Rubber-lip grunt
Family: Haemulidae

Review of fish species from the Red Book of the Republic of Croatia for Istria County

In Istria County is, based on the views and insights into the Red Book of marine fish of Croatia, found that there are: 1 regionally extinct species, 2 critically endangered species, 7 endangered species, 9 vulnerable and 24 near threatened species.

RE
Regionally extinct species

Acipenser sturio Linnaeus, 1758 - Sturgeon

CR
Critically Endangered Species
Dipturus batis (Linnaeus, 1758) – Blue skate
Isurus oxyrinchus Rafinesque, 1810 – Shortfin mako

EN
Endangered Species

Alosa fallax (Lacepède, 1803) – Twaite shad
Aphanius fasciatus (Valenciennes, 1821)
Carcharodon carcharias (Linnaeus, 1758) – Great white shark
Cetorhinus maximus (Gunnerus, 1765)
Epinephelus marginatus (Lowe, 1834) – Dusky grouper
Galeorhinus galeus (Linnaeus, 1758) – Tope shark
Oxynotus centrina (Linnaeus, 1758) – Angular roughshark

VU
Vulnerable species

Hippocampus guttulatus Cuvier, 1829 - Loung-snouted seahorse
Labrus viridis Linnaeus, 1758
Mugil cephalus Linnaeus, 1758 – Flathead grey mullet
Pagrus pagrus (Linnaeus, 1758) – Red porgy
Alopias vulpinus (Bonnaterre, 1788) – Thersher
Prionace glauca (Linnaeus, 1758) – Blue shark
Dipturus oxyrinchus (Linnaeus, 1758) - Longnose skate

Dasyatis pastinaca Linnaeus, 1758 – Common stingray
Acipenser naccarii Bonaparte, 1836 – Adriatic sturgeon

NT
Near Threatened Species

Chelon labrosus (Risso, 1827) – Thicklip grey mullet
Diplodus puntazzo (Cetti, 1777) – Sharpsnout seabream
Diplodus sargus sargus (Linnaeus, 1758) – White seabream
Gobius cobitis Pallas, 1814 – Giant goby
Labrus merula Linnaeus, 1758 – Brown wrasse
Liza saliens (Risso, 1810) – Leaping mullet
Lophius piscatorius Linnaeus, 1758 – Angler
Muraena helena Linnaeus, 1758 – Mediterranean moray
Pegusa impar (Bonnett, 1831) – Adriatic sole
Platichthys flesus (Linnaeus, 1758) – European flounder
Psetta maxima (Linnaeus, 1758) – Turbot
Raja asterias Delaroche, 1809 – Starry skate
Raja clavata Linnaeus, 1758 – Thornback ray
Sciaena umbra Linnaeus, 1758 – Brown meagre
Scophthalmus rhombus (Linnaeus, 1758) – Brill
Scorpaena scrofa Linnaeus, 1758 – Red scorpionfish
Scyliorhinus stellaris (Linnaeus, 1758) - Nursehound
Spondyliosoma cantharus (Linnaeus, 1758) – Black seabream
Squalus blainvillei (Risso, 1826) – Longnose spurdog
Squalus acanthias Linnaeus, 1758 – Piked dogfish
Umbrina cirrosa (Linnaeus, 1758) – Shi drum
Zeus faber Linnaeus, 1758 – John Dory
Myliobatis aquila (Linnaeus, 1758) – Common eagle ray
Mustelus mustelus (Linnaeus, 1758) - Smooth-hound

Ichthyofauna of NP „Brijuni“

In the wider waters of the National Park "Brijuni" (using visual census) were recorded 51 species of coastal fish species distributed in 20 families. Recorded total species richness was 17.9 % higher in the protected area of NP "Brijuni" in relation to nearby unprotected area. Numericaly extremely prevalent species of NP "Brijuni" were common two-banded sea bream *Diplodus vulgaris*, with a share of 40.6 %, and mediterranean rainbow wrasse *Coris julis* with share of 19.7 %. Among the 20 families recorded in protected area abundance of individuals prevailed to Sparidae with a share of 54.7 %, and Labridae, with a share of 34.8 %.

Areas of spawning, growth and feeding of commercially important species of fish and other marine organisms in the County of Istria

Herein can be also specify all the coves on the peninsula Kamenjak.

Tar cove, Marić cove, Mirna estuary

During the study of spatio-temporal diversity in the composition of juvenile fish communities, along the west coast of Istria, it was found 13 families and 38 species of fish at 3 sampling sites (Tar cove, river Mirna estuary and Marić cove). Five species (sand smelt *Atherina hepsetus* - 47.47 %, big-scale sand smelt *Atherina boyeri* - 27.73 %, annular sea bream *Diplodus annularis* - 9.96 %, marbled goby *Pomatoschistus marmoratus* - 1.62 % and golden grey mullet *Liza aurata* (1.54%) made up 88.32 % of the total catch. Population structure was determined by an Index of abundance (D), Diversity index (H), Uniformity index (J) and Jaccard's similarity coefficient (k). The annual value of the index D was 4.287, varied from 0.838 (Mirna estuary, in May) to 3.191 (Tar cove, in September), H index varied from 0.170 (Tar cove, in May) to 2.453 (Marić cove, in May), with an annual value of 1.661.The annual value of the index J was 0.46, varied from 0.01 (Tar cove, in May) to 0.25 (Marić cove, in November). The coefficient k was the largest among Tar cove and Mirna estuary in May (0.52). According to the same coefficient, the closest were Tar cove and Marić cove (0.68). All this leads to the fact that these areas represent significant areas of spawning, growth and feeding of commercially important species of fish and other marine organisms in Istria County.

Tar cove (Novigrad, Istria)

The Tar cove is located near the mouth of the Mirna River, and as an extremely specific and production quality habitat for numerous species of fish, in which it advocates for nutrition and reproduction of fishes, it was strictly forbidden to hunt and disturbing species that live in them by the Institute for the Protection of Nature in nature reserves. Preliminary fishery-ichthyological researches in Tar cove started in 1989. During the previous all years of investigation it was determined the presence of 12 to 16 economically important fish species (smooth-hound *Mustelus mustelus*, golden grey mullet *Liza aurata*, flathead grey mullet *Mugil cephalus*, thicklip grey mullet *Chelon labrosus*, thin lip grey mullet *Liza ramada*, striped sea bream *Lithognathus mormyrus*, salema porgy *Sarpa salpa*, gilthead sea bream *Sparus aurata*, seabass *Dicentrarchus labrax*, spotted seabass *Dicentrarchus punctatus*, leerfish *Lichia amia*, bluefish *Pomatomus saltatrix*, shi drum *Umbrina cirrosa* and 2 species of cephalopods (*Loligo vulgaris*, *Sepia officinalis*).

Demersal resources

The state of demersal resources is described on the basis of MEDITS survey in the period from 1996 till 2012. In the analysis are included the stations in Croatian territorial waters and the stations in the Fisheries Ecological Protected Zone („ZERP“). Sampling has been done using scientific sampling bottom trawl net GOC 73, which is different from the commercial nets used in Istrian area: GOC 73 has bigger horizontal and vertical opening, weak contact with bottom, and smaller mesh size in the cod-end (10 mm). It is important to underline that all data are collected in the spring-summer period (period according MEDITS protocol). Namely, it is well known that catch composition along Istrian coast is different in different seasons of the year and are mainly related to migration of some species as well as to the recruitment period (primarily in the case of different cephalopods which make bulk of demersal catch in Istria).

During MEDITS surveys 126 different species of demersal species were recorded (excluding commercially non important invertebrates in the discard as Holoturia, Spongia, Bivalvia …). The most abundant group are Osteichthyes with 86 different species, Chondrichthyes wit 12 species, Cephalopods with 18 species and Crustaceans with 10 species (Table 3.2.1).

Table 3.2.1. List of the demersal species caught during MEDITS surveys in the Istrian area.

CHONDRICHTHYES (12)
Dasyatis pastinaca
Mustelus asterias
Mustelus mediterraneus
Mustelus mustelus
Myliobatis aquila
Raja asterias
Raja clavata
Raja miraletus
Scyliorhinus canicula
Scyliorhinus stellaris
Squalus acanthias
Torpedo marmorata

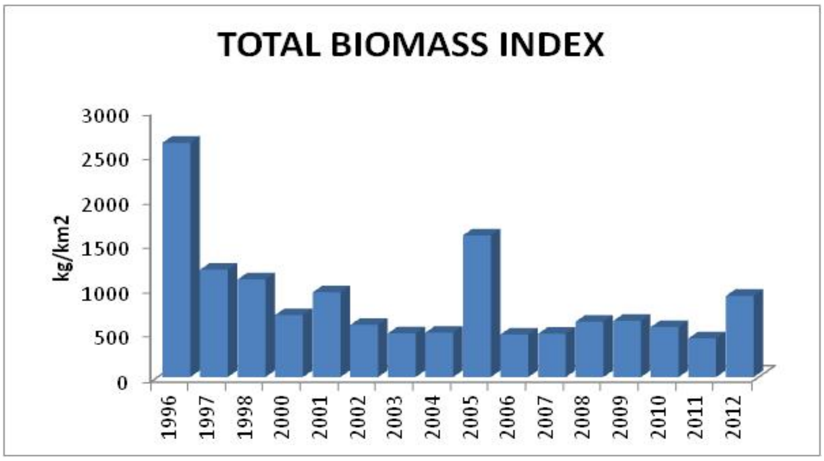
OSTEICHTHYES (86)
Acantholabrus palloni
Alosa fallax
Antonogadus megalokynodon
Aphia minuta
Arnoglossus laterna
Arnoglossus rueppelli
Arnoglossus thori
Aspitrigla cuculus
Blennius ocellaris
Boops boops
Buglossidium luteum
Callionymus maculatus
Callionymus risso
Cepola rubescens (macrophthalma)
Citharus linguatula (macrolepidotus)
Conger conger
Deltentosteus(Gobius)quadrimaculatus
Dicentrarchus labrax
Diplodus annularis
Diplodus sargus
Diplodus vulgaris
Engraulis encrasicholus
Eutrigla gurnardus
Gaidropsarus mediterraneus
Gobius niger
Lepidorhombus whiffiagonis
Lepidotrigla cavillone
Lepidotrigla dieuzeidei
Lesueurigobius suerii
Leusueurigobius (Gobius) friesii
Liza aurata
Lophius budegassa
Lophius piscatorius
Merlangius merlangus
Merluccius merluccius
Microchirus ocellatus
Microchirus variegatus
Micromesistius poutassou
Monochirus hispidus
Mullus barbatus
Mullus surmuletus
Ophidion barbatum
Pagellus acarne
Pagellus bogaraveo
Pagellus erythrinus
Pagrus (Sparus) pagrus
Parablennius (Blennius) gattorugine
Parablennius (Blennius) tentaculari
Phrynorhombus regius
Phycis blennoides
Pomatoschistus minutus
Psetta maxima
Sardina pilchardus

Sardinella aurita
Scomber (Pneumatophorus) japonicus
Scomber scombrus
Scophthalmus rhombus
Scorpaena elongata
Scorpaena notata
Scorpaena porcus
Scorpaena scrofa
Serranus cabrilla
Serranus hepatus
Solea impar
Solea kleini
Solea lascaris
Solea vulgaris
Spicara flexuosa
Spicara maena
Spicara smaris
Spondyliosoma cantharus
Sprattus sprattus
Symphodus cinereus
Symphodus mediterraneus
Syngnathus acus
Syngnathus phlegon
Trachinus araneus
Trachinus draco
Trachurus mediterraneus
Trachurus picturatus
Trachurus trachurus
Trigla lucerna
Trigloporus lastoviza
Trisopterus minutus capelanus
Uranoscopus scaber
Zeus faber

CEPHALOPODS (18)
Alloteuthis media
Eledone moschata
Illex coindetii
Loligo vulgaris
Octopus salutii
Octopus vulgaris
Rossia macrosoma
Sepia elegans
Sepia officinalis
Sepia orbignyana
Sepietta obscura
Sepietta oweniana
Sepiola affinis
Sepiola intermedia
Sepiola robusta
Sepiola rondeleti
Todarodes sagittatus
Todaropsis eblanae

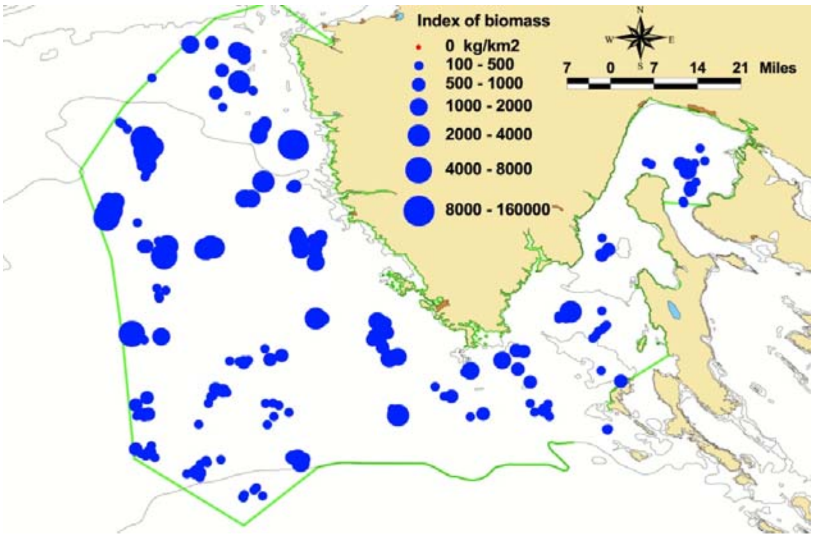
CRUSTACEANS (10)
Calappa granulata
Homarus vulgaris (gammarus)
Liocarcinus (Macropipus) depurator
Maja squinado
Nephrops norvegicus
Palinurus elephas
Pisa armata
Pontophilus spinosus
Solenocera membranacea

Total biomass index shows very high fluctuation over investigation period (Fig. 3.2.1) with general negative trend. This trend is more significant when small pelagic species (sardine and anchovy) are excluded. Majority of the catch in the Istrian area are short living cephalopods (*Eledone moschata, Loligo vulgaris, Sepia officinalis*) and high interannual fluctuation is the result of different level of recruitment in different years. In the case of *Solea solea* and *Merlangius merlangius*, biomass index is related to migration of the species from the Italian coast (nursery area) to the Croatian coast (spawning and feeding area).



Fugure 3.2.1. Index of total biomass in the period 1996-2012.

Majority of the biomass is located in theCroatian territorial waters (inside 12 Nm) along the western Istrian coast, while in Kvarner and Gulf of Rijeka biomass is lower. In the northern part of ZERP biomass is bigger than in southern parts (Fig.3.2.2). Very high biomass in those areas is the result of high catches of small pelagic fish (wich are by-catch in the bottom trawl net).



Fugure 3.2.2. Distribution of the total biomass index.

More realistic picture of status of resurces along the Istrian coast is when small pelagic species are excluded from analysis (Fig. 3.2.3). Again, majority of the biomass is located in the Croatian territorial water along western Istrian coast and in the northern part of ZERP. It is the result dominantly of biomass of *Eledone moschatta* (in territorial waters) and *Merlangius merlangus* (ZERP) in some years.

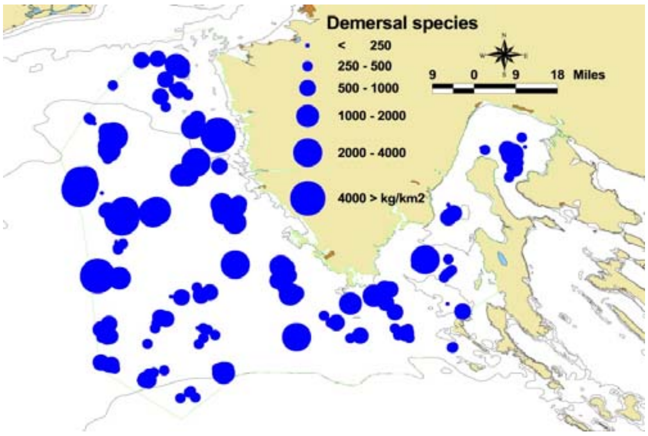


Figure 3.2.3. Distribution of the demersal species biomass index.

Biomass index of *Merlangius merlangus* showing high fluctuation over investigation period with increasing trend till 2005/2006 and decrease after that period. Biomass index in the last two years is again high in comparison with previous years (Figure 3.2.4).

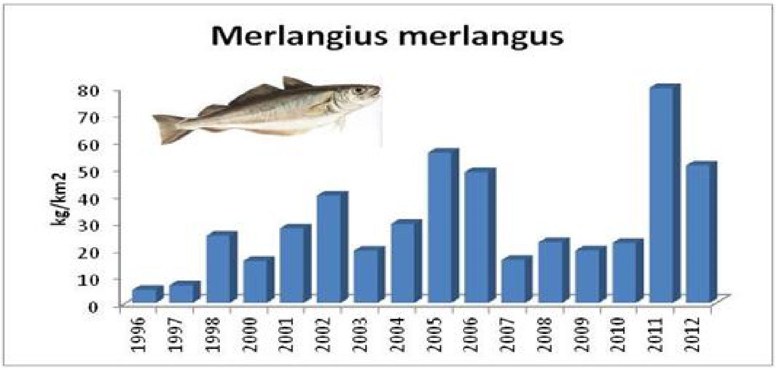


Figure 3.2.4. Biomass index of Merlangius merlangus.

The biggest part of the population is located in the extraterritorial waters near to the middle line (Fig. 3.2.5), and in the Italian territorial and extraterritorial waters. In Croatian territorial waters only adults' specimens are registered.

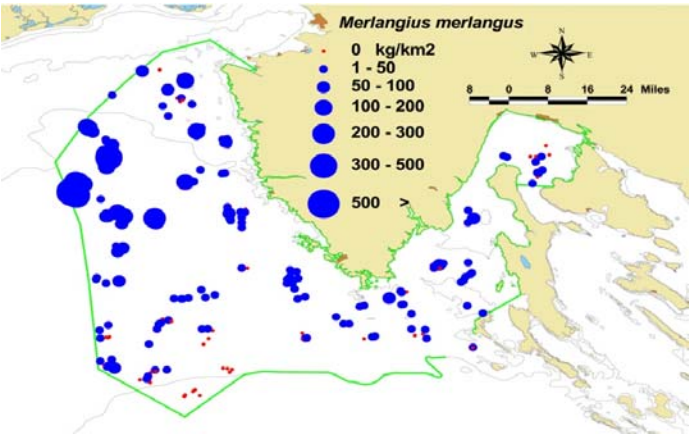


Figure 3.2.5. Distribution of Merlangius merlangus.

Pagellus erythrinus is a common species along the Istrian coast and in the demersal catches. Biomass index showing increasing trend till 2008, and after this decreasing trend. This decrease is mainly the result of very low level of recruitment in the last few years (Figure 3.2.6).

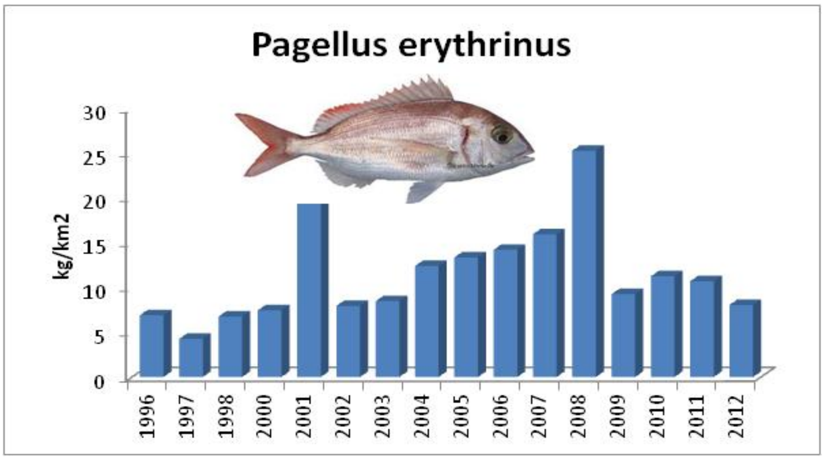


Figure 3.2.6. Biomass index of Pagellus erythrinus.

Majority of the biomass of this species is located in the Croatian territorial waters and mainly on the hard bottom in the southern part of ZERP (Fig. 3.2.7). It is typical circalitoral species. From this picture is clear that Istrian coast (especially part near to the coast) is a spawning and nursery area for *Pagellus erythrinus*. Biomass of this species along the eastern Istrian coast is lower.

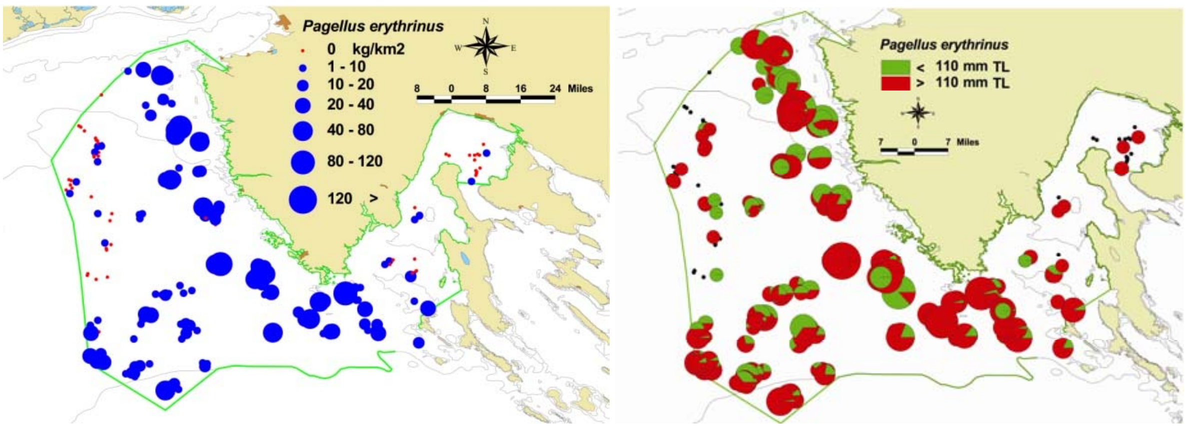


Figure 3.2.7. Distribution of the total biomass of *Pagellus erythrinus* (left) and distribution of spawners and juveniles (right).

Catch of *Solea vulgaris* is relatively low in Istrian area, and showing high fluctuation with negative trend (Fig. 3.2.8). But, here we should keep in mind that bottom trawl net is not proper gear for catching of this species (especially GOC 73 net), and also, *Solea vulgaris* is mainly caught in the winter period using trammel nets (and beam trawl).

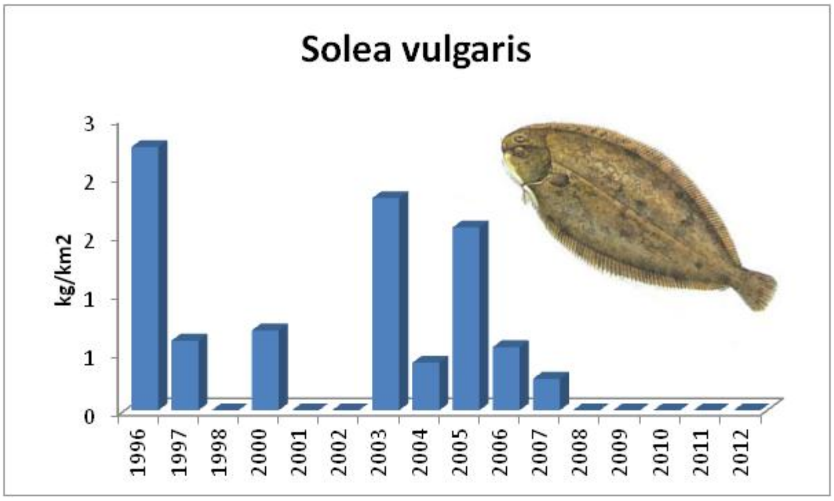


Figure 3.2.8. Biomass index of Solea vulgaris.

Species were caught in the territorial water and southern (hard bottom) part of ZERP. All caught specimens are adult (Fig.3.2.9). Namely, Croatian territorial waters are spawning and feeding area for this species, while juveniles inhabit mainly shallow part of western Adriatic (Fig. 3.2.9).

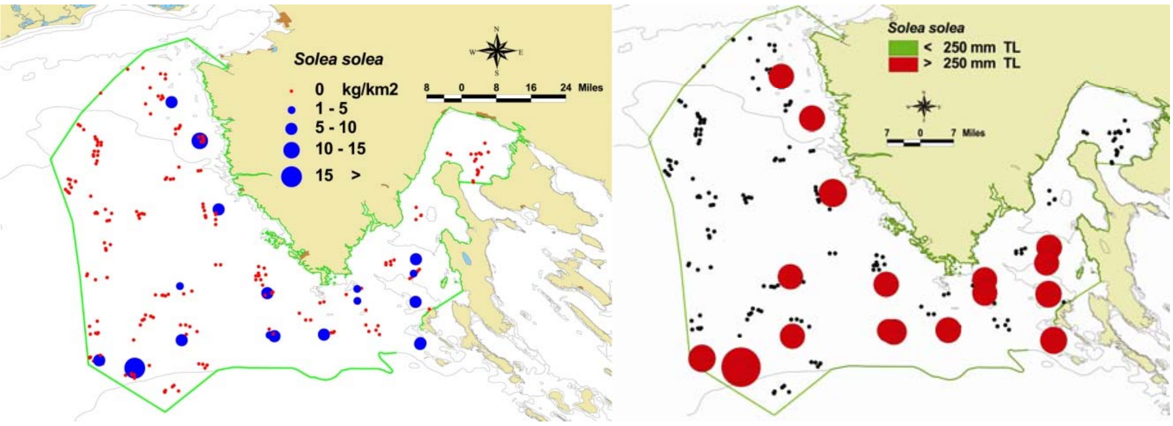


Figure 3.2.9. Distribution of the total biomass of *Solea vulgaris* (left) and distribution of spawners and juveniles (right).

Eledone moschata is the most important species in this area, and it is widely distributed along the whole Istrian coast. Biomass index shows high fluctuation with very low values in last three years (Fig. 3.2.10). Similar situation is registered in the whole Adriatic Sea.

Istrian area is known as the most important fishing area for this species in the Adriatic Sea. The catch is mainly using bottom trawl net. In past it was net with small mesh size of the cod-end (28 mm), and in the recent time this net is changed with net with 40 mm mesh size of the cod-end.

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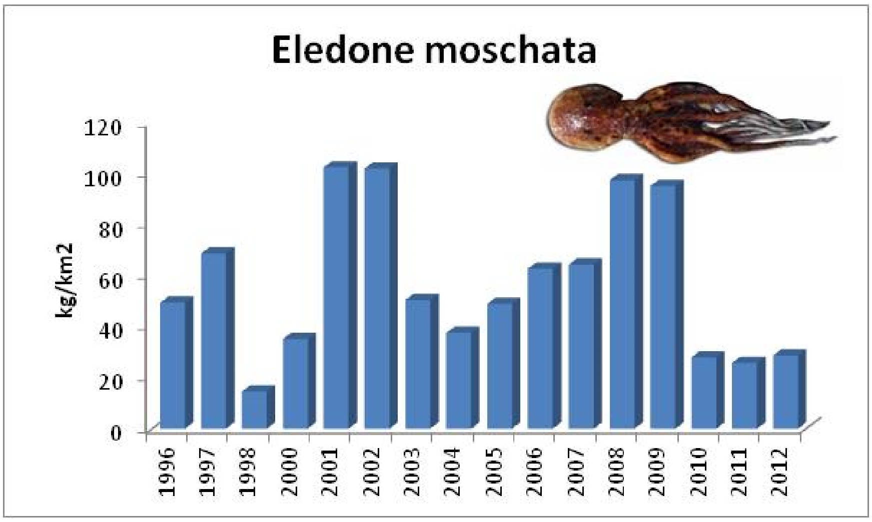

Figure 3.2.10. Biomass index of *Eledone moschata*.

The biggest biomass of species is in the Croatian territorial waters along the western Istrian coast. The biomass decreases from eastern to western coast (Fig. 3.2.11). From the figure is clear that the Istrian area is typical nursery and spawning area for this species, and juveniles are distributed widely in the whole area.

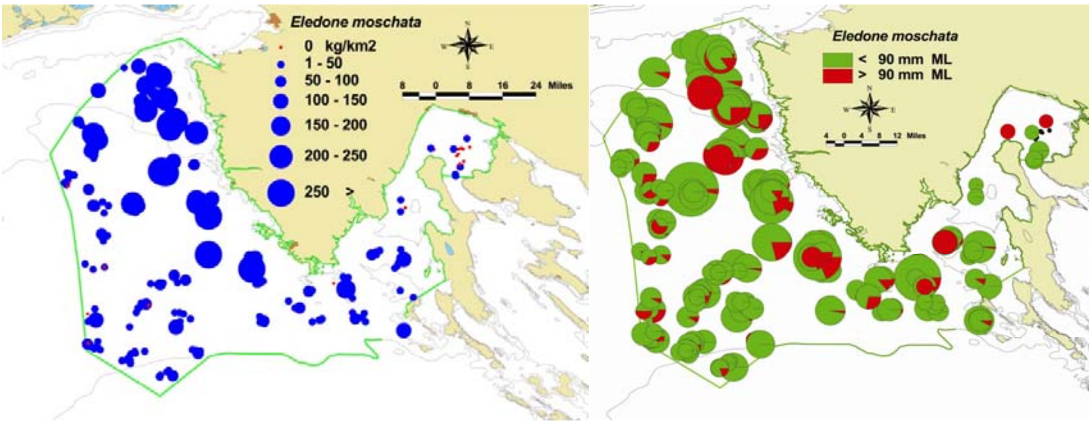

Figure 3.2.11. Distribution of the total biomass of *Eledone moschata* (left) and distribution of spawners and juveniles (right).

Loligo vulgaris shows fluctuation in the catches with the biggest value in 2005 (Fig 3.2.12). Those fluctuations are mainly result of different level of recruitment. We should keep in mind that spring-summer period is not proper period for catching *Loligo vulgaris* using bottom trawl net. The biomass in the bottom trawl catch is bigger in the autumn and winter period.

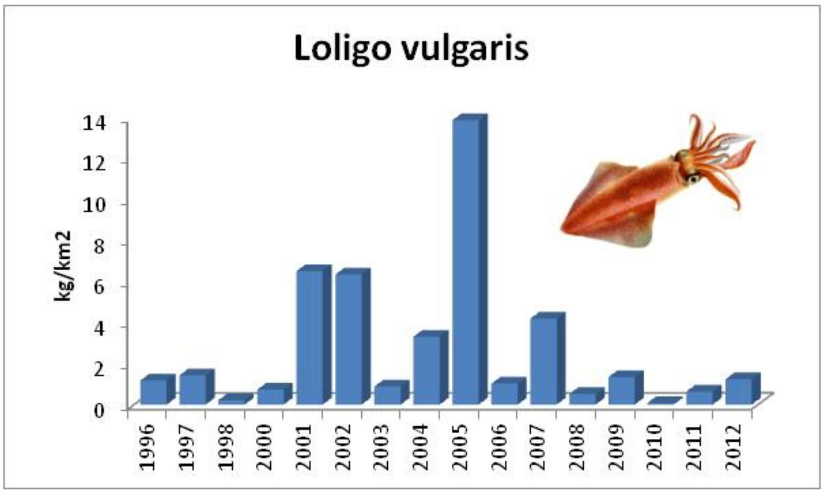

Figure 3.2.12. Biomass index of *Loligo vulgaris*.

This species is distributed in the whole Istrian area, but biomass is bigger in the territorial water along the western Istrian coast than in the rest of area (Fig. 3.2.13). Catch is composed from juveniles and adult individuals, but juveniles dominate in the whole area (spawning and nursery area).

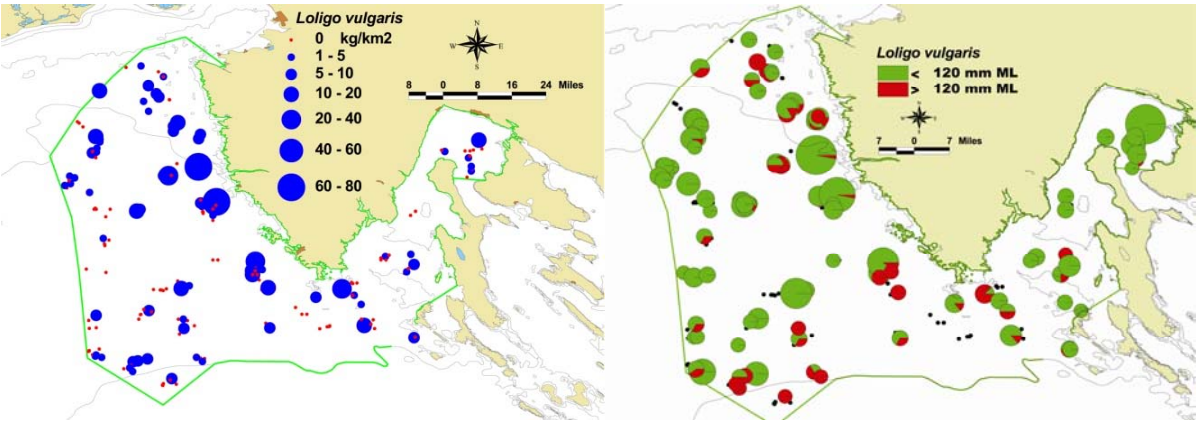

Figure 3.2.13. Distribution of the total biomass of *Loligo vulgaris* (left) and distribution of spawners and juveniles (right).

Catch of *Sepia officinalis* is relatively low, and shows fluctuation with maximal values during 2001 and 2008. In the last two years there is a very negative trend in the biomass index in the whole investigation area (Fig. 3.2.14).

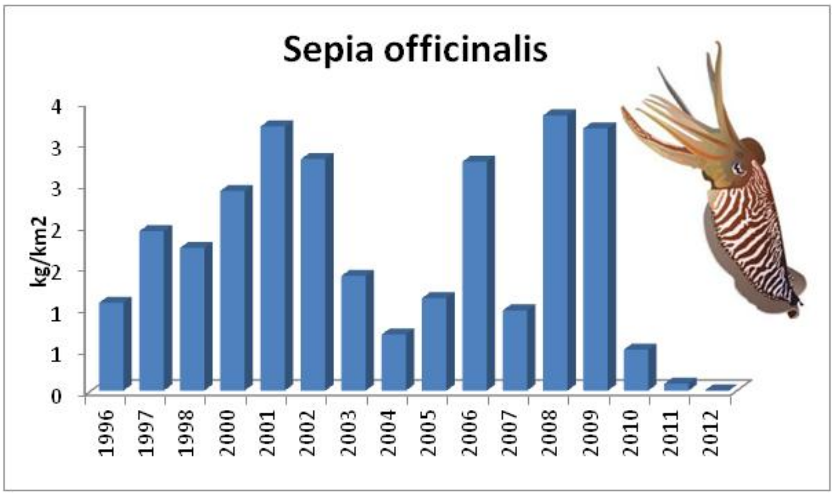

Figure 3.2.14. Figure 11. Biomass index of *Sepia officinalis*.

Population is distributed mainly in the territorial waters near to the coast along the whole western Istrian coast, while in the rest of area catches are very low (Fig. 3.2.15) or species is absent from catches (Rijeka Bay). Juveniles dominate in the catches, but there are also adult specimens (mainly in the Kvarner area).

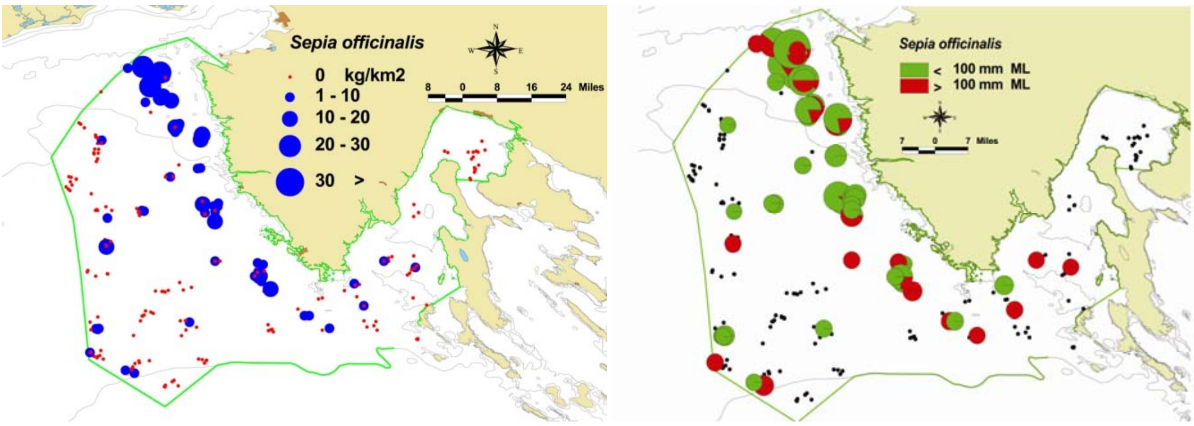

Figure 3.2.15. Distribution of the total biomass of *Sepia officinalis* (left) and distribution of spawners and juveniles (right)

Generally, the Istrian area is a very important area for bottom trawl fisheries, which is multispecies type of exploitation. Short living cephalopods dominate in the catches and because of that there is big interannual and intraanual fluctuation in the catches due to the difference in recruitment and migration of the species. Concentration of juveniles in the catches is very high, so this area can be characterized as nursery area for numerous species. Biomass index of the most important species shows big fluctuation, but general trend is negative, especially in the last few years. It is the result of very low intensity of recruitment, but also there is the negative impact of very high level of fishing pressures of different fishing gears used in this area.

Small pelagic fish

Croatian fishing fleet is in general as well as in the Istria County, mainly consisted of purse seiners. Catches of these type of fishery made around 77.3 % (period from 2000 to 2009) of Republic of Croatia total catches. This is the reason why small pelagic fish specially sardine and anchovy represent commercially important Croatian resources. In the fishing zone A, as main part of the Istria county fishing area, purse seiners land from 10.7 % up to 13.1 % of Croatian small pelagic total landings. In these catches, sardines are represented with 95 % and anchovy with 5 %. Monthly distribution of catches of sardine and anchovy varied, showing maximal values from August to November and from June to August, respectively (Fig. 3.2.16).

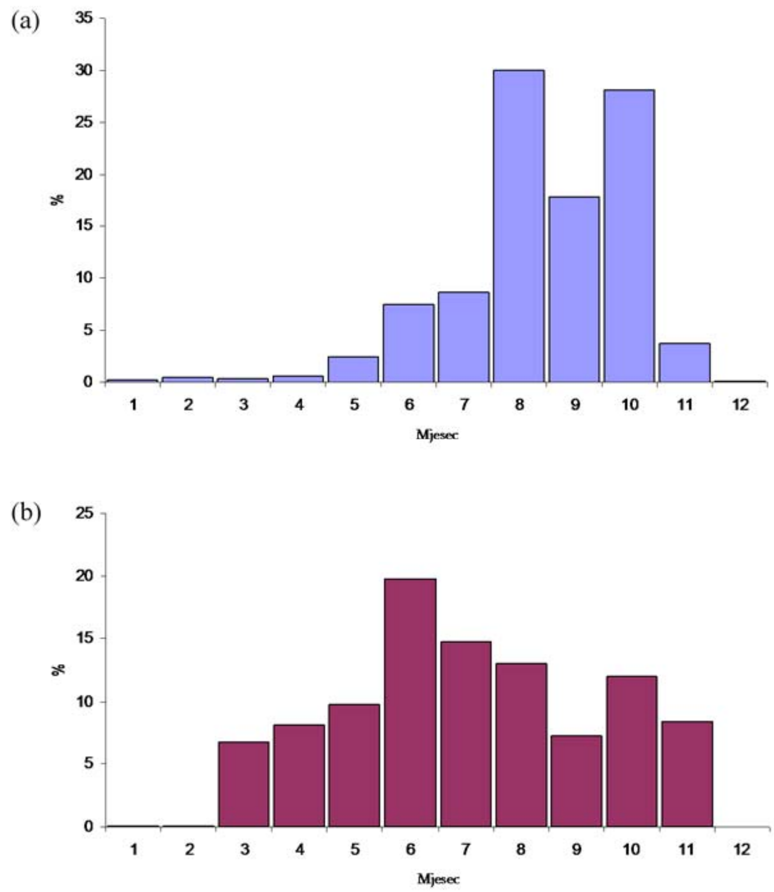

Figure 3.2.16. Monthly distribution of sardine (a) and anchovy (b) catches in the purse seine nets in Istria county area (fishing zone A).

Sardine and anchovy length distribution

Mean total lengths of sardines and anchovy varied during the period from 2004 to 2012 (Fig. 3.2.17). Namely, in this period systematic monitoring on the commercial purse seine vessels was conducted. From this monitoring it is obvious that sardines had mean minimum length in the 2012 (LT=13.5±0.508 cm), and anchovy in 2005 (LT=12.2±0.605 cm). Maximum mean length, on the other hand, was noted in 2005 (sardine: LT=15.3±0.470 cm) and 2007 (anchovy: LT=13.7±0.443 cm). Strong oscillations observed in the length distribution over the years, are probably due to the stronger recruitment – greater number of younger individuals entering the population. Besides recruitment, increasing fishing effort targeting smaller and smaller individuals or the changes in the ecological characteristics of the environment (mainly drop of the temperature, which could induce slower growth rate) could also trigger decrease in the mean lengths of this two species over the time.

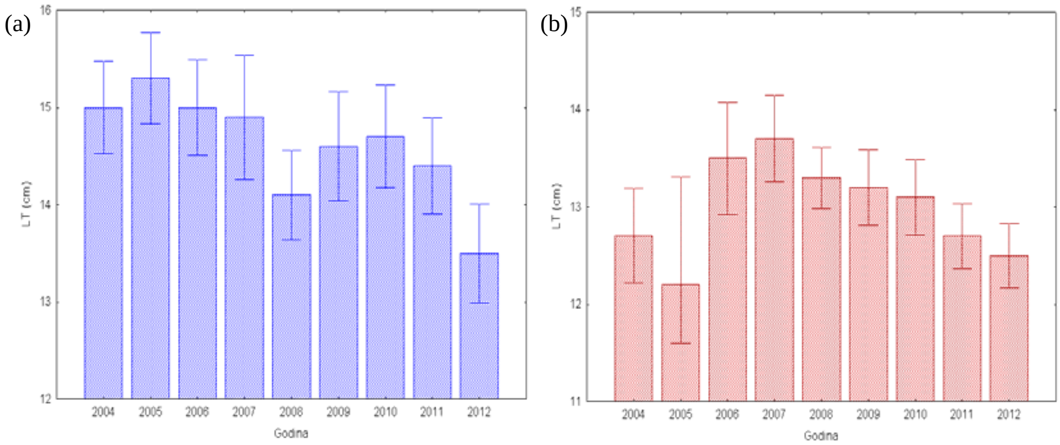

Figure 3.2.17. Mean yearly total body lengths of sardine (a) and anchovy (b) in the Istria county (fishing zone A) during period 2004 -2012.

Sardine and anchovy age structure

In the observed period (from 2004-2012) sardine and anchovy age was determined using otoliths. Results showed (Fig. 3.2.18) that sardines were in range from 1 to 7 years old, and anchovy from 0 to 4.

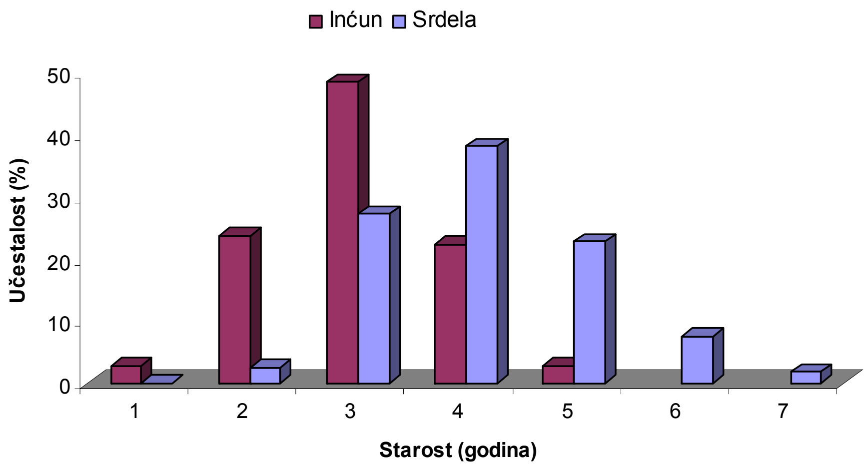

Figure 3.2.18. Age structure of sardine and anchovy in the Istria County (fishing zone A) in the period from 2004 to 2012

Sardine and anchovy length-weight relationship

Length-weight relationship of this two commercially important fish species in the analysed period (2004-2012) can be presented with equations: $W=0.0133LT^{2.7962}$ (sardine) and $W=0.0149LT^{2.6804}$ (anchovy) (Fig. 3.2.19). Alometric coefficient *b* for both species was statistically different from 3.00 ($P<0.05$), meaning that both sardine and anchovy in the Istria county grows more in weight then in the length during their life.

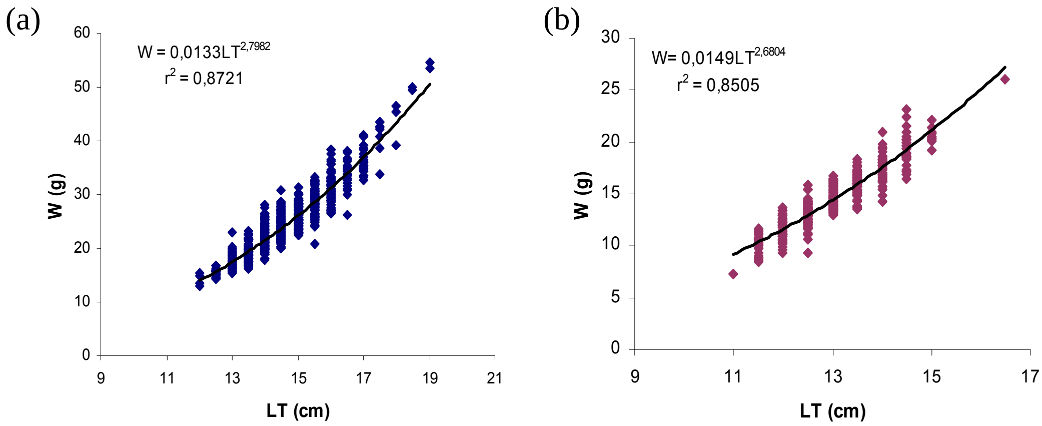

Figure 3.2.19. Length-weight relationship of sardine (a) and anchovy (b) from the purse seiners in the Istria county (fishing zone A) in the period from 2004 to 2012.

Sardine and anchovy spawning cycle and spawning area

Spawning cycle is parameter that changes over the years (Fig. 3.2.20) regarding the changes in the environment - foot accessibility, temperature, salinity and so on (Sinovčić, 1994b, 1995; Sinovčić and Alegria, 1997).

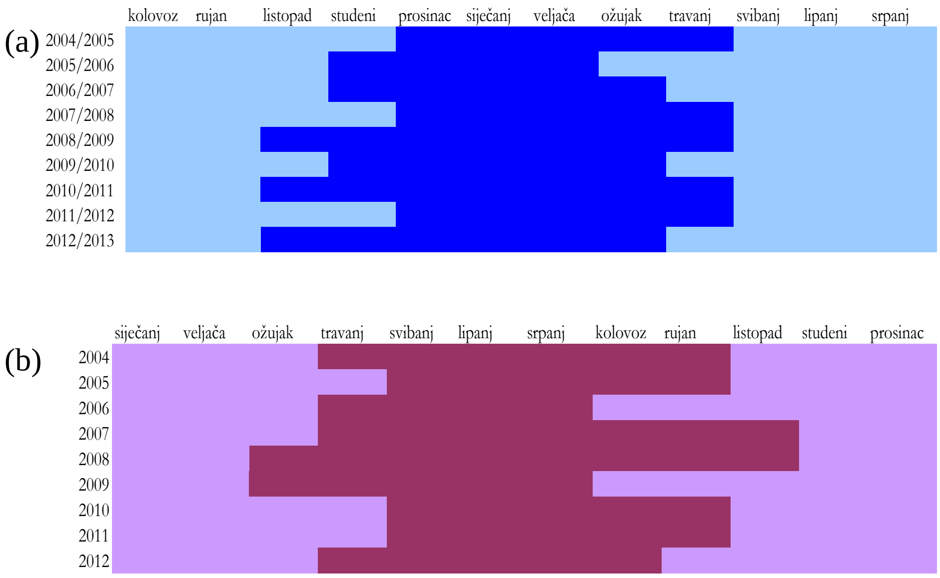

Figure 3.2.20. Monthly distribution of spawning period for sardine (a) and anchovy (b) from 2004 to 2012.

Nevertheless, colder part (December – February) of the year can be acknowledged as the period of most intense spawning of sardine and the warmer part (May-July) for the anchovy.

Sardine and anchovy eggs and larvae were investigated in the 80ties as well as recently (2012-2013) by the IOF Split. The results of eggs abundance showed potential spawning ground of this two species in the Kvarner area (Fig. 3.2.21) but also, since this area were represented with larger number of juveniles and larvae (Fig.3.2.22), potentially important nursery ground.

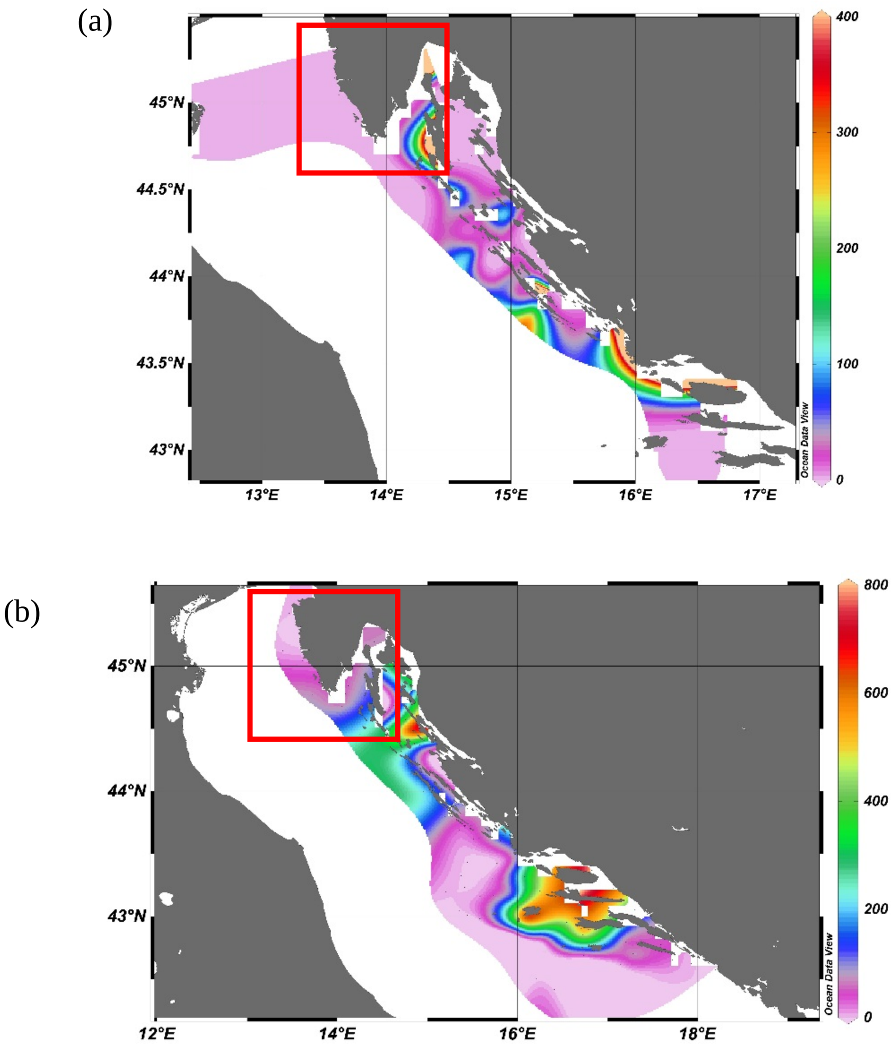

Figure 3.2.21. Distribution of sardine (a) and anchovy (b) egg abundance in the eastern side of Adriatic Sea during 2012 and 2013.

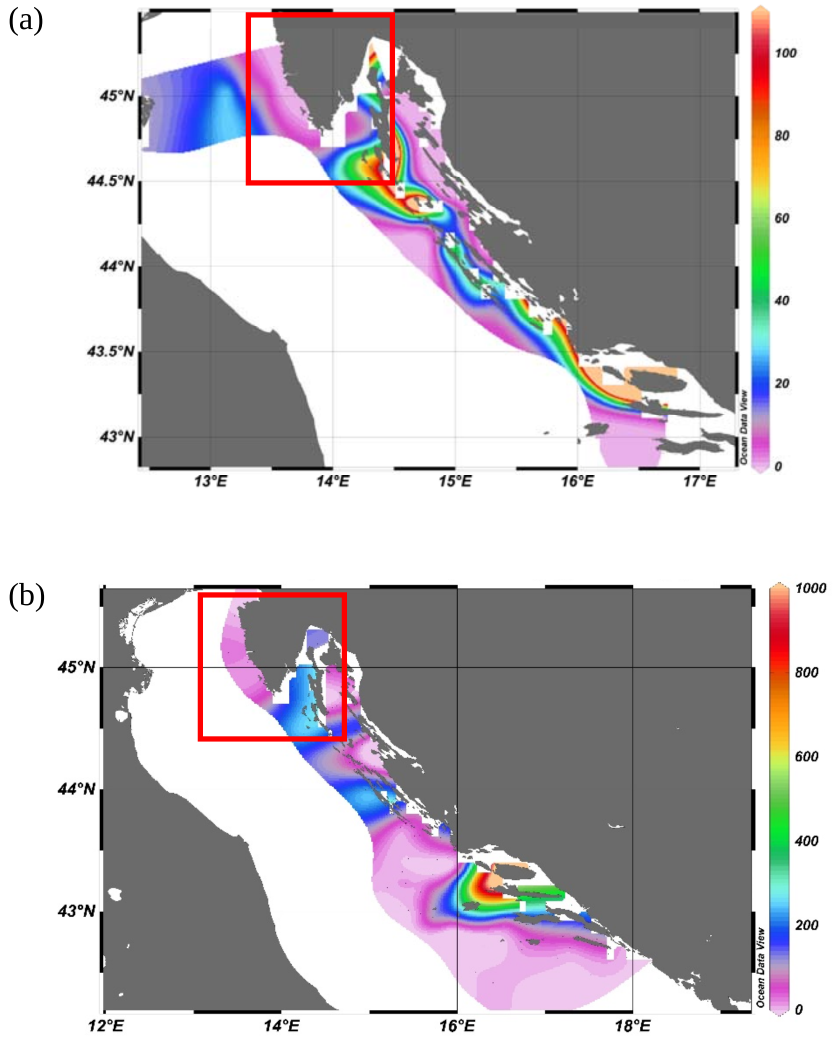

Figure 3.2.22. Distributiony of sardine (a) and anchovy (b) larvae abundance in the eastern side of Adriatic Sea during 2012 and 2013.

Bivalve in beam trawl catch along the eastern coast of Istria

European flat oyster (*Ostrea edulis*) and Mediterranean scallop (*Pecten jacobaeus*) were the most commercially important bivalve species present in the catch of beam trawl while Noah's Ark shell (*Arca noae*) was present in the catch only sporadically. Beside those species, small scallops (*Aequipecten opercularis* and *Fexopecten glaber*) (Fig. 3.2.23) were also abundant in the catch but they aren't target species because of their low commercial value.

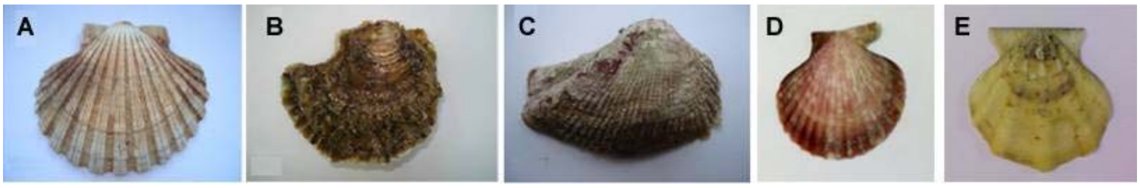

Figure 3.2.23. (a) Mediterranean scallop *Pecten jacobaeus*; (b) European flat oyster *Ostrea edulis*; (c) Noah's Ark shell *Arca noae*; (d) small scallop *Aequipecten opercularis*; (e) small scallop *Flexopecten glaber.*

Mediterranean scallop is considered as one of commercially most important bivalve species which is manly harvested with beam trawl along the west coast of Istria. According to data from period from 2002 to 2004 this species made up from 37 to 81 % of beam trawl commercial catch (Cetinić *et al*., 2003, 2004; Jardas *et al*., 2007). Data collected in the spring of 2008, showed that Mediterranean scallop contributed with ~71 % to total commercial catch (Vrgoč *et al.*, 2009). Result of beam trawl catch analysis performed by IOF, Split, during the 2013 showed that this species contributed with only 6 to 20 % in total commercial catch. Reason of such low share of *P. jacobaeus* in total commercial catch might not indicate considerable decrease in biomass of this species but might indicate changes of community structure. Surveys mentioned above didn't use the same methodology and thus results are not completely comparable. However, if data collected during the period 2002-2004 are recalculated in terms of catch per fishing hour it can be seen that catch per hour of *P. jacobaeus* in that period ranged approximately from 5 to 9 kg per fishing hour (both specimens smaller and larger than MLS). According to data collected during the 2013 catches of this species were between 4 and 7 kg/h (IOF, unpublished data). Furthermore, comparison of logbook data during the period from 2001 to 2006 showed that contribution of *P. jacobaeus* has considerably decreased in 2006 (Figure 3.2.24) as a consequence of increase of oyster *O. edulis* contribution in the catch. Although according to logbooks contribution of *P. jacobaeus* decreased, biomass decrease was not recorded (Table 3.2.2). Data collected through logbooks might not provide the most objective indicators but could indicate some trends that are in this case confirmed by direct beam trawl catch analysis. All mentioned above confirmed that lower contribution of *P. jacobaeus* to the commercial catch is more due to changes in community/catch structure than due to decrease of biomass index of this species.

Oyster *O. edulis* showed considerable increase in commercial catch in terms of biomass and caused changes in the catch structure. In the research in period from 2002 to 2004 oyster was not recorded in commercial catch (Jardas *et al.*, 2007). In the spring of 2008 this species contributed with ~6% to commercial catch (Vrgoč *et al.,* 2009; IOF, unpublished data) while during the 2013 this species contributed between 58 and 84 % and dominated in terms of biomass. This was also confirmed with logbooks data which showed considerable increase of oyster contribution during the 2006 (Figure 3.2.24, Table 3.2.2). Based on the data collected through logbooks it is not possible to distinguished whether bivalves were collected by beam trawl or by SCUBA, but such high portion of oyster in the catch also indicates changes in catch composition.

Two species of small scallops *Aequipecten opercularis* and *Flexopecten* were constantly present in the beam trawl catch but fishermen collect those species only on order, otherwise they are returned to the sea. Although those species still don't have significant commercial value, considering their current price per kilo (up to 30 kn/kg, Vrgoč *et al.*, 2009) and access to international markets commercial value of those species might increase with time.

Table 3.2.2. Total catch of bivalves Mediterranean scallop *Pecten jacobaeus* and European flat oyster *Ostrea edulis* based on data recalculated from Vrgoč *et al.* (2009).

		Pecten jacobaeus		*Ostrea edulis*	
Year	**Total catch (t)**	**Share (%)**	**Biomass (t)**	**Share (%)**	**Biomass (t)**
2001	82,833	49,5	41,00	12,3	10,19
2003	32,109	87,4	28,06	3,9	1,25
2004	47,24	70,8	33,45	13,2	6,24
2005	61,923	66,8	41,36	9,4	5,82
2006	111,311	27,1	30,17	64,0	71,24

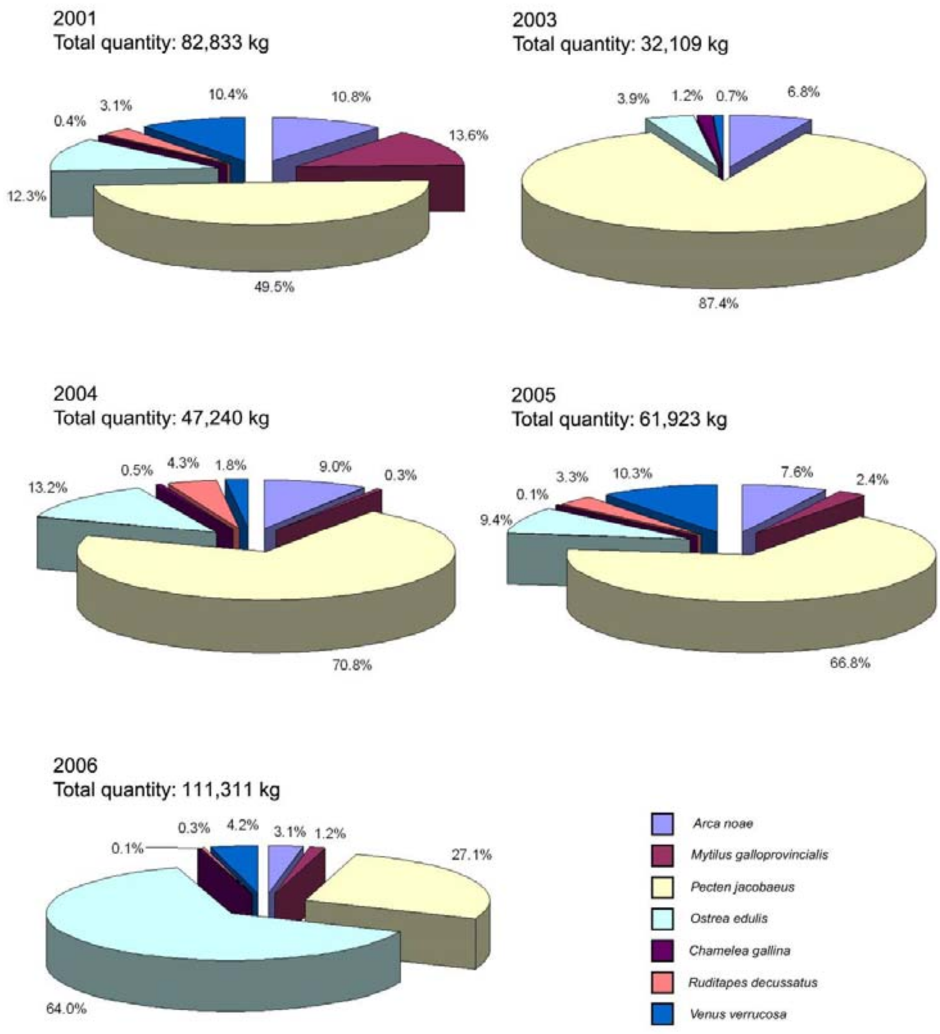

Figure 3.2.24. Contribution of different bivalve species in total catch in the Istra County during the period from 2001 to 2006 according to logbooks (adopted from Vrgoč *et al.*, 2009).

Beside above mentioned species, other bivalve species such as *Mytilus galloprovincialis*, *Chamelea gallina*, *Venerupis decussatus* and *Venus verrucosa* are harvested in Istra County (Fig. 3.2.24). Species are harvested mainly by SCUBA without systematic monitoring and analysis of the catch.

Population structure of Mediterranean scallop Pecten jacobaeus

Mediterranean scallop *Pecten jacobaeus* lives on the sand, mud and gravel bottoms from 25 to 250 m (Poppe and Goto, 2000). Length of this species usually ranges between 80 and 150 mm, and the largest specimen found along the eastern Adriatic coast was 162 mm in length (Onofri and Maguš, 1995). Oldest specimen found along the east coast of Istria was 13 years old, while majority of analysed specimens were between 3 and 5 years old (~69 %; Peharda *et al.*, 2003). In the period from 2002 to 2004 based on the 356 analysed specimens length range varied between 7.8 and 14.2 cm (mean value±standard deviation=10.92±1.24 cm; Cetinić *et al*., 2004). During survey in 2008 on the 1156 measured specimens length of this species ranged from 3.2 i 13.8 cm, and 43 % of collected animals were larger than minimal landing size (MLS). Specimens measured during the 2013 (N=1885) ranged in length from 3.8 to 12.8 cm (Figure 3.2.25). Specimens smaller than 10 cm contributed with 42 % and those specimens were returned to the sea alive after the measurement. Specimens larger than 10 cm contributed with 58 % and those specimens were placed on the market.

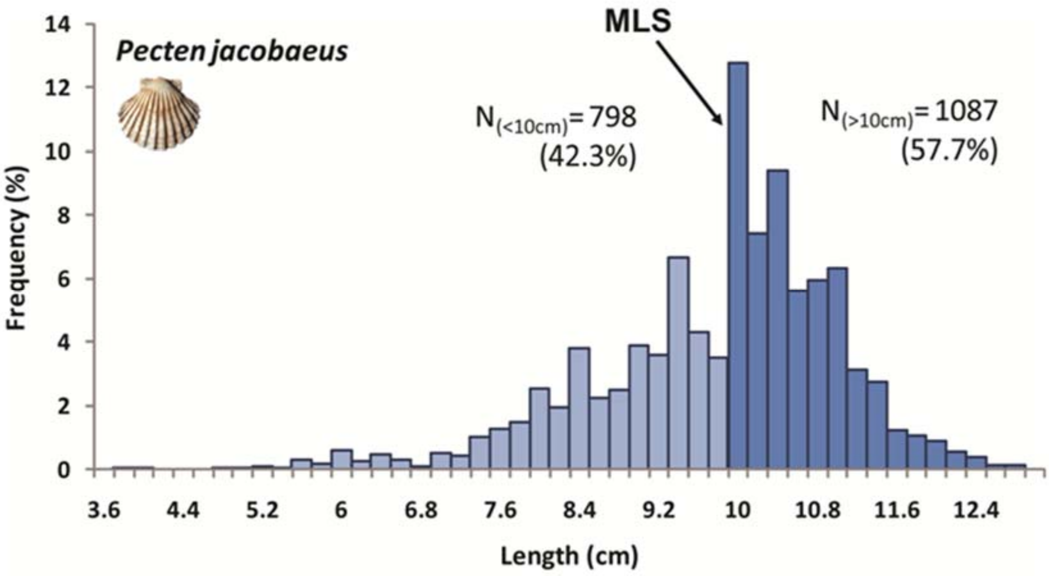

Figure 3.2.25. Population structure of Mediterranean scallop *Pecten jacobaeus* along the west coast of Istria in the 2013.

Population structure of European flat oyster Ostrea edulis

European flat oyster *Ostrea edulis* is commercially important species harvested from natural population and cultured in some regions along the eastern Adriatic coast. This species has high growth rate and attains minimal landing size (7 cm) in approximately two years. Since this species was not significantly represented in the beam trawl catch during the previous study there is no data about its length frequencies. In the survey performed by the Institute for Oceanography and Fishery in Split, in 2013 this species became dominant in the beam trawl catch. Length range of specimens analysed during 2013 was between 3.5 and 11.2 cm. Out of 710 measured specimens, 45.5 % of them were larger than MLS, while 46.5 % were smaller than MLS and were returned alive in the sea (Fig. 3.2.26).

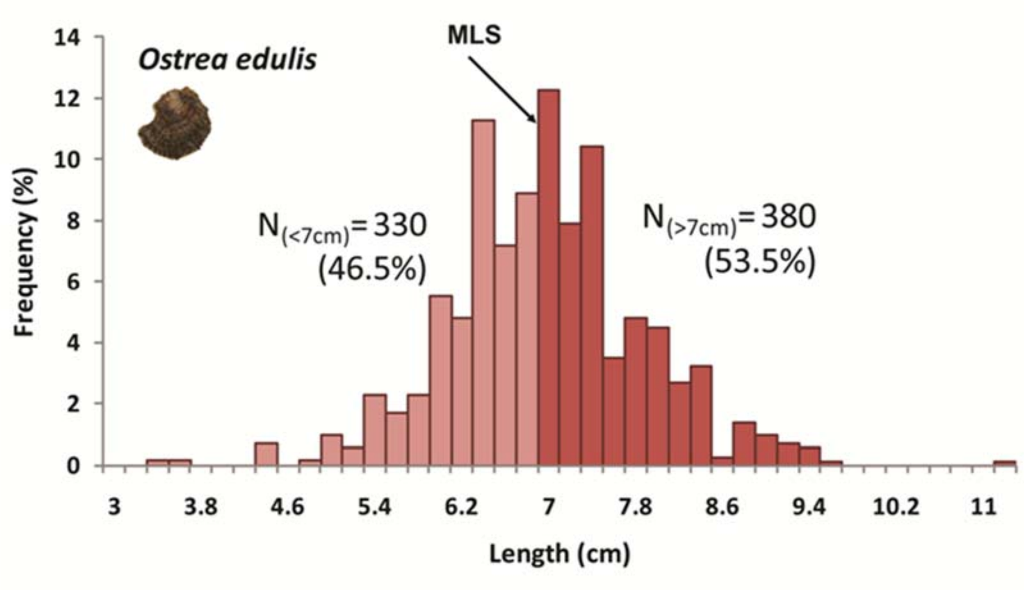

Figure 3.2.26. Population structure of European flat oyster *Ostrea edulis* along the west coast of Istria in the 2013.

Population structure of small scallops - Aequipecten opercularis and Flexopecten glaber

Small scallops *Aequipecten opercularis* and *Flexopecten glaber* are considered fast growing species. According to Poppe and Goto (2000) *A. opercularis* can attain 110 mm although their length is usually between 40 and 80 mm. Length of this species reported for the spring 2008 was between 28 and 62 mm (Vrgoč *et al.*, 2009). Similar range was recorded during the 2013 when length range for this species was between 9 and 58 mm (Fig. 3.2.27).

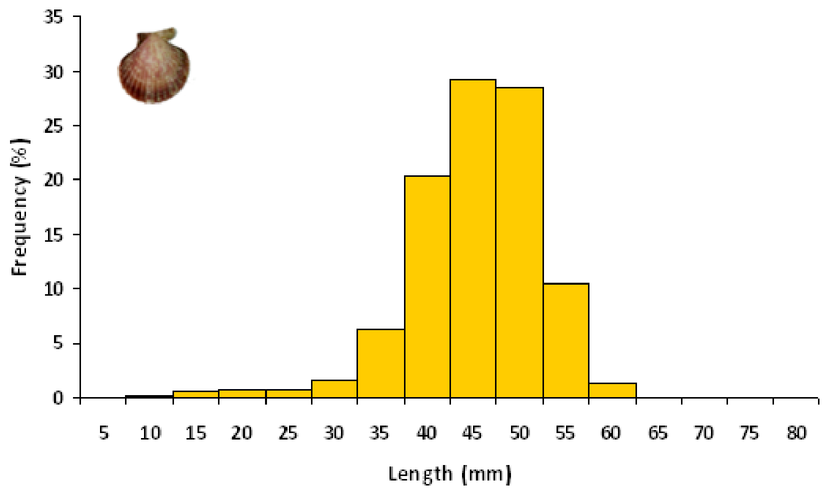

Figure 3.2.27. Population structure of small scallop *Aequipecten opercularis* (N= 616) along the west coast of Istria in the 2013.

Other small scallop species *Flexopecten glaber* has smaller body size and can attain length up to 70 mm (Poppe and Goto, 2000). In the survey from 2008 length range of this species was between 25 and 70 mm (Vrgoč *et al.*, 2009), and almost same range was recorded during 2013 when length was between 20 and 70 mm (Fig. 3.2.28).

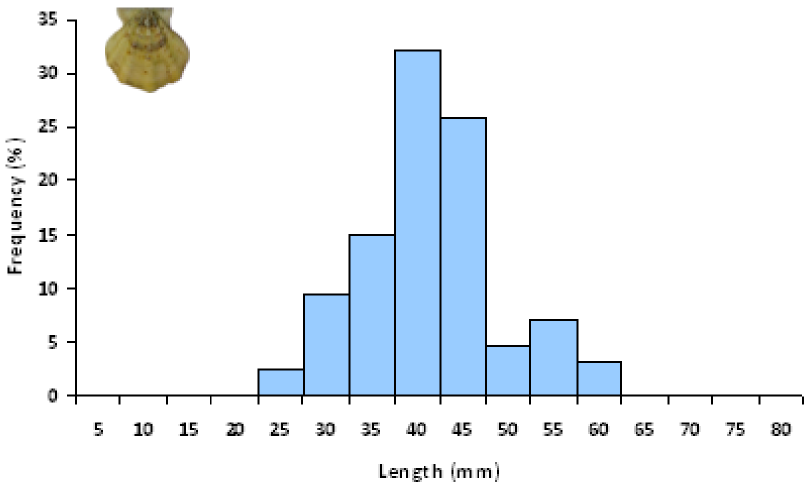

Figure 3.2.28. Population structure of small scallop *Flexopecten glaber* (N= 127) along the west coast of Istria in the 2013.

Other bivalve species in the catch of beam trawl

During the survey in 2013, beside above mentioned species, 16 other species of bivalves were recorded. Most of them don't have any commercial value. Following species were recorded: *Anadara inaequivalvis*, *Anadara transversa*, *Anomia ephippium*, *Arca noae*, *Atrina fragilis*, *Clausinella fasciata*, *Heteranomia squamula*, *Hiatella arctica*, *Laevicardium oblongum*, *Limaria tuberculata*, *Mimachlamys varia*, *Modiolus barbatus*, *Mytilus galloprovincialis*, *Pinna nobilis*, *Polititapes virgineus* and *Striarca lacteal*. Two of those species, *Anadara inaequivalvis* and *Anadara transversa* are considered as alien and invasive species that were already describe in this area (Nerlović *et al.*, 2012, Despalatović *et al.*, in press).

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3.3. Descriptor 5: Eutrophication

Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of nutrients causing changes to the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services. These changes may occur due to natural processes; management concern begins when they are attributed to anthropogenic sources. Additionally, although these shifts may not be harmful in themselves, the main worry concerns 'undesirable disturbance': the potential effects of increased production, and changes of the balance of organisms on ecosystem structure and function and on ecosystem goods and services.

TG5 arrived at the following definition as the basis for interpreting the MSFD descriptor:

> Eutrophication is a process driven by enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services.

Recommendations for Quality Descriptor 5: Eutrophication: Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

The Regulation indicate that during the process of assessment of eutrophication in marine waters it is to be taken into account the assessment of coastal and transitional waters under national legislation in the field of water management, in a way which ensures comparability, taking also into consideration the information and knowledge gathered and approaches developed in the framework of regional sea conventions. Based on a screening procedure as part of the initial assessment, risk-based considerations may be taken into account to assess eutrophication in an efficient manner. The assessment needs to combine information on nutrient levels and on a range of those primary effects and of secondary effects which are ecologically relevant, taking into account relevant temporal scales. Considering that the concentration of nutrients is related to nutrient loads from rivers in the catchment area, cooperation with landlocked MS using established cooperation structures in accordance with the 4th subparagraph of Article 8 of the Regulation (OG 136/11) is particularly relevant.

Accepted indicators are:

Nutrients levels:

- nutrients concentration in the water column,
- nutrient ratios (silica, nitrogen and phosphorus), where appropriate.

Direct effects of nutrient enrichment:

- chlorophyll *a* concentration in the water column,
- water transparency related to increase in suspended algae, where relevant,
- abundance of opportunistic macroalgae,

- species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities.

Indirect effects of nutrient enrichment:

- abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency,
- dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned.

Status of eutrophication in the waters of Istria County

Status of eutrophication in the waters of the Istria County was estimated based on data that were systematically collected by the CMR from 1972 to date. It should be noted that from the stations shown in Figure 3.3.1. only stations that belong to the profile Po River Delta - Rovinj (SJ107, ZI032 and RV001) were collected continuously from the start with almost monthly frequency. The remaining stations are part of completed projects and were collected during their realisation (usually two to three years).

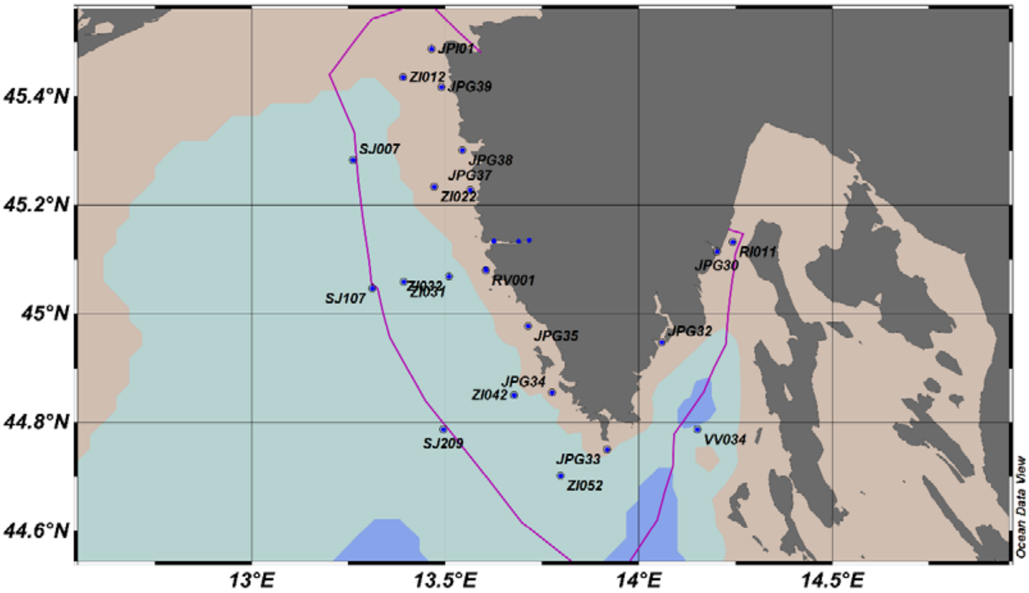

Figure 3.3.1. Stations relevant for the assessment of eutrophication in the waters of the Istria County where data were collected in the period 1972-2011.

As described in the methodology the assessment of the ecological status regarding the 5th descriptor is made using the Regulation on water quality standards (OG 73/13). The value of chlorophyll *a* concentration of 5 mg L^{-1} and trophic index of 5 should be the boundary between good and moderate, and 1 mg L^{-1} and trophic index of 4 between high and good ecological status. As can be observed in Figure 3.3.2. all mean values of mentioned parameters on the investigated stations in the waters of the Istria County indicate high status and can be considered that the quality of water related to eutrophication are of the highest quality. This is also supported by the data presented in the station eutrophication profiles (Figures 3.3.3.-15 and Tables 3.3.1.-13). The exception is the station LKR03 located at the bottom of Limski kanal whose values are at the boundary between high and good status, which meets the criteria of at least good ecological status.

It should be noted that certain trends were observed in the data: the trend of increasing total inorganic nitrogen over the last 10 years, and systematically higher N/P values in this period. The observed trends can be related to lower river flows, primarily the Po River, in the wider area (Mozetič *et al.*, 2011, Cozzi *et al.*, 2013). Decreased input of nutrients in the area enhance significantly the limitation of phosphorus, which contributes to the accumulation of nitrogen nutrients in the system, and increasing the N/P ratio.

Such estimates of GES are preliminary because the 5th descriptor provides for it assessment also to use changes in the composition of phytoplankton species, the frequency of blooms, the occurrence of toxic species and increase of their frequency. For now, at the level of the Mediterranean only estimates based on the concentration of chlorophyll *a* are used. The remaining are under development and testing.

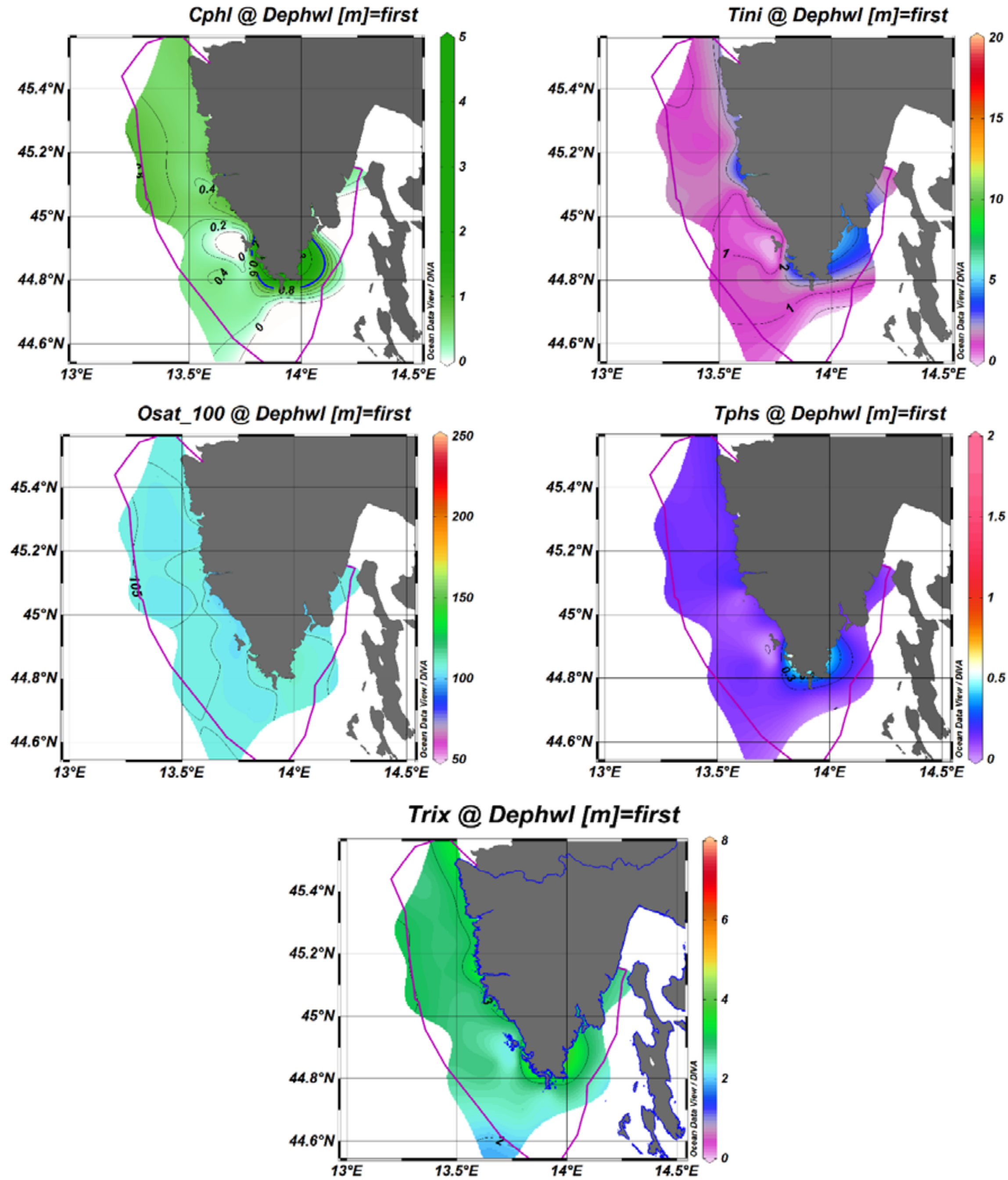

Figure 3.3.2. Distribution of surface concentrations of chlorophyll *a* (Cphl), total inorganic nitrogen (Tini) and total phosphorus (Thps), and of oxygen saturation (Osat) and trophic index (Trix) for the assessment of eutrophication in the waters of the Istrian county in the period 2000-2011.

JPG39

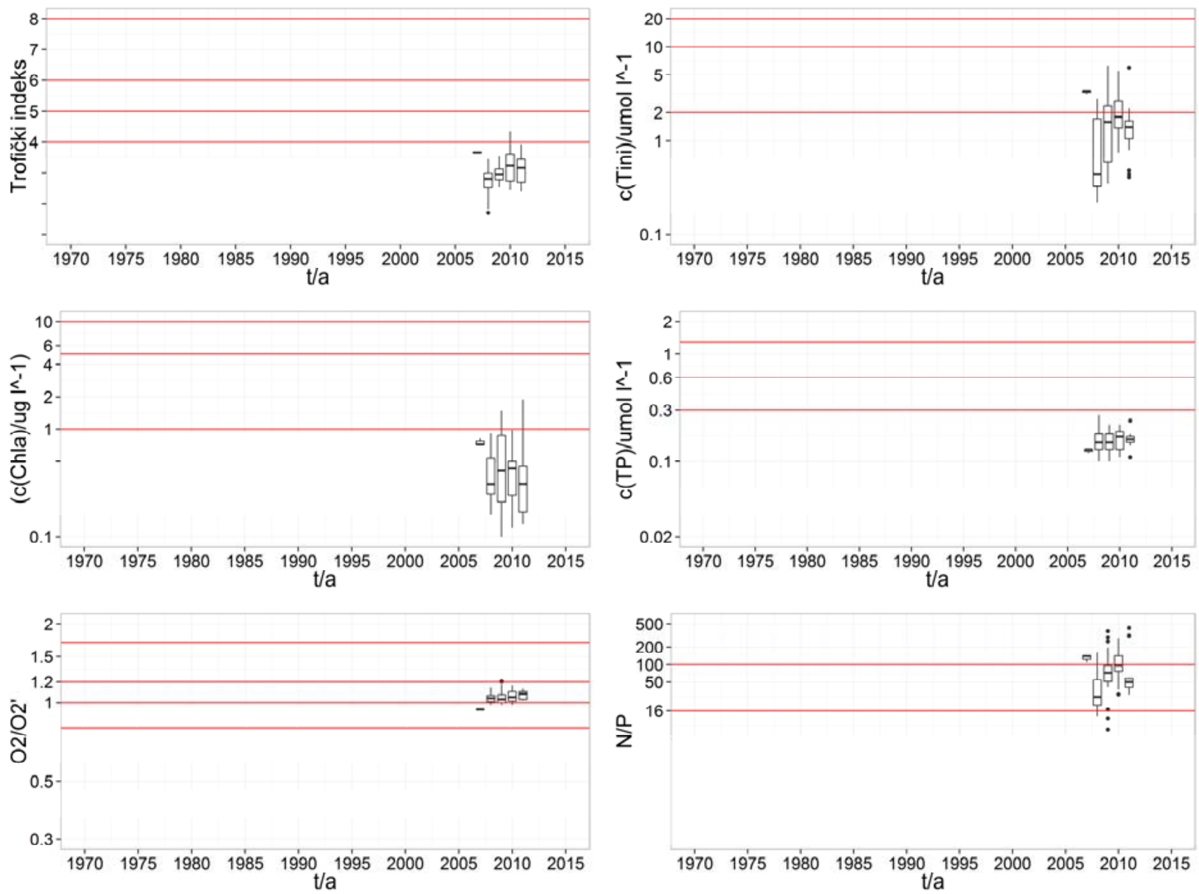

Figure 3.3.3. Box and Whisker representation of trophic index, concentration (c) of chlorophyll *a*, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station JPG39 (1 Nm W off Umag). Limits of classifications are from the Regulation on water quality standards (73/13).

Table 3.3.1. Eutrophication profile, with an assessment of trends and ecological status for station JPG39.

JPG39			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Enter the range for oligotrophic coastal sea	enp	very good
c(Chla)	Enter the limits for oligotrophic coastal sea	enp	very good
O_2/O_2'	Enter the limits for oligotrophic coastal sea	enp	very good
c(Tini)	Enter the limits for oligotrophic coastal sea	enp	very good
C(TP)	Enter the limits for oligotrophic coastal sea	enp	very good
N/P	Enter the limits for oligotrophic coastal sea, slightly increased values	enp	

enp – evaluation not possible

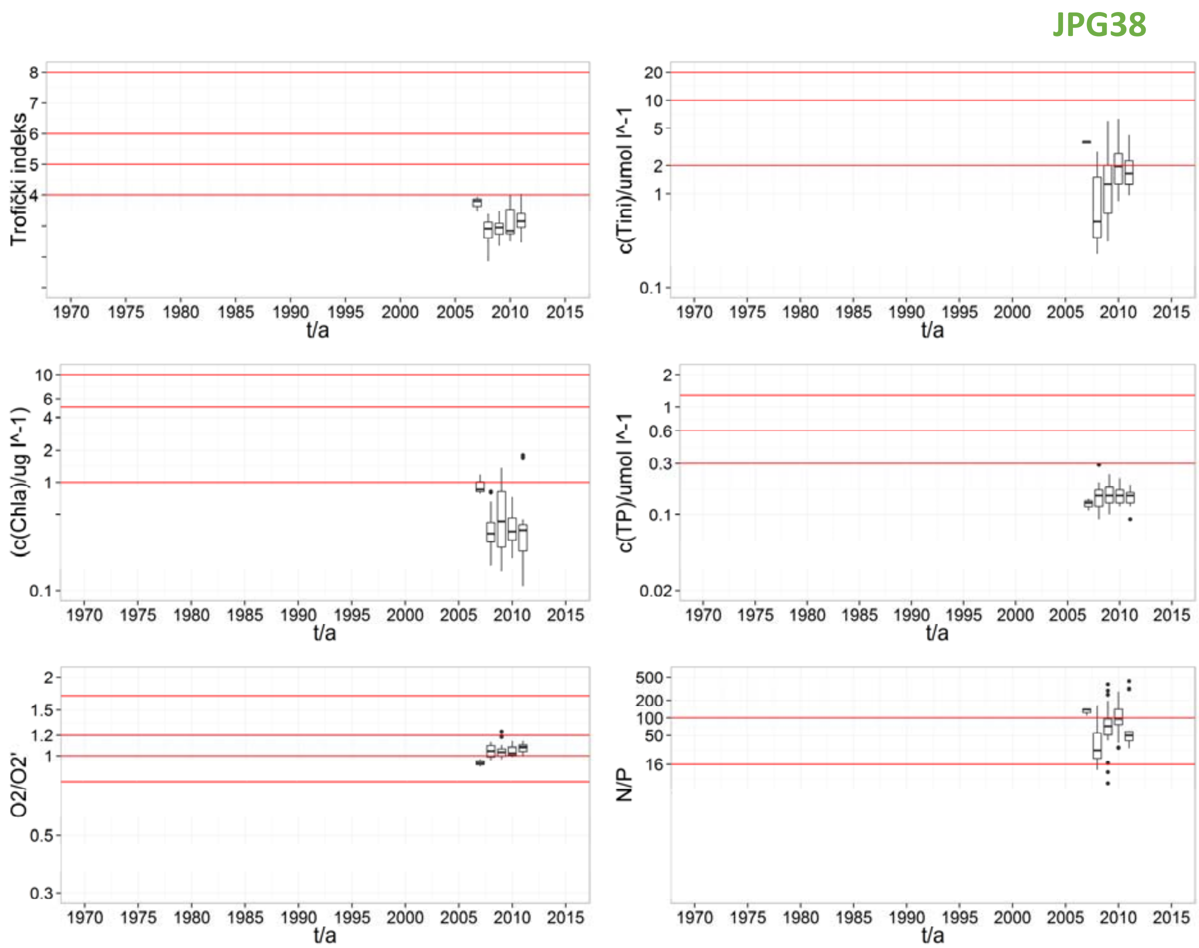

Figure 3.3.4. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-20011 at station JPG38 (1 Nm W off Mirna River mouth). Limits of classifications are from the Regulation on water quality standards (73/13).

Table 3.3.2. Eutrophication profile, with an assessment of trends and ecological status for station JPG38.

JPG39			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Enter the range for oligotrophic coastal sea	enp	very good
c(Chla)	Enter the limits for oligotrophic coastal sea	enp	very good
O_2/O_2'	Enter the limits for oligotrophic coastal sea	enp	very good
c(Tini)	Enter the limits for oligotrophic coastal sea	enp	very good
C(TP)	Enter the limits for oligotrophic coastal sea	enp	very good
N/P	Enter the limits for oligotrophic coastal sea, slightly increased values	enp	

enp – evaluation not possible

SJ007

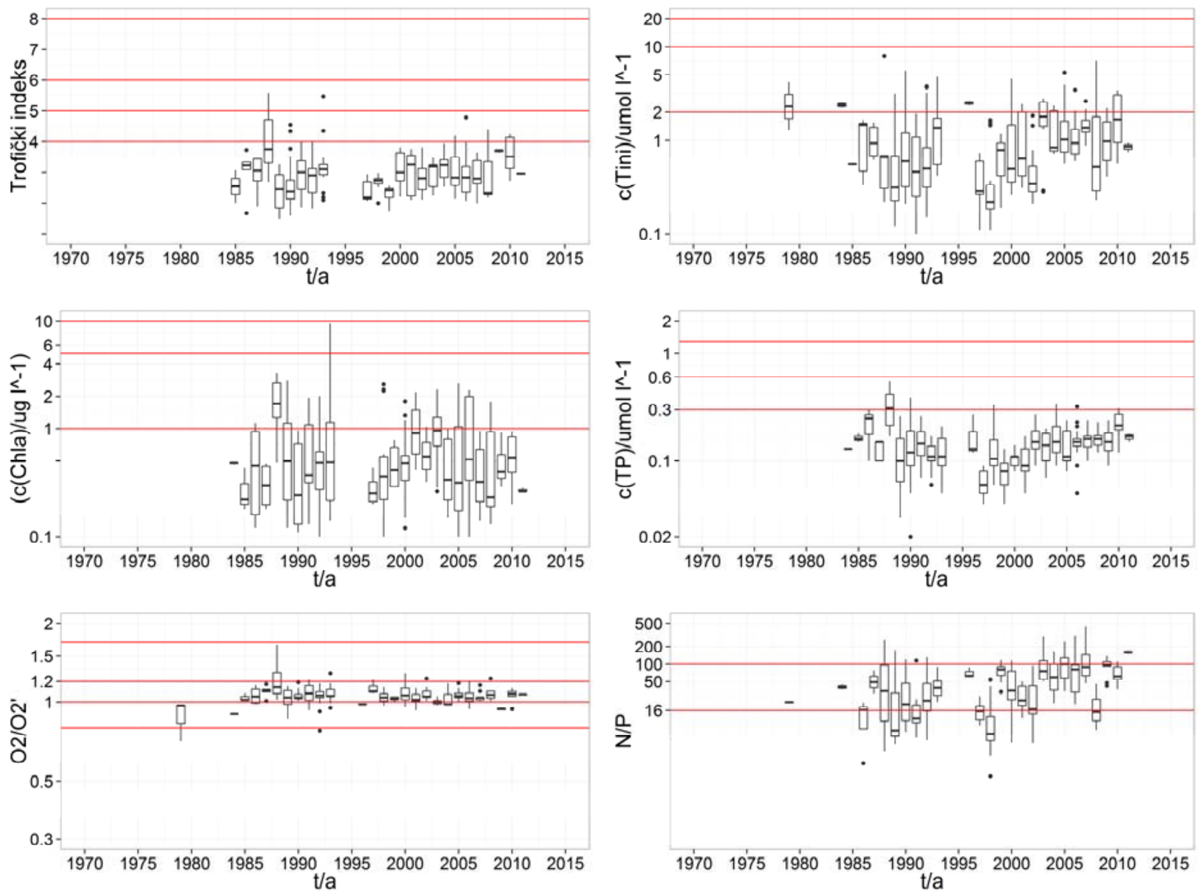

Figure 3.3.5. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station SJ007 (13 Nm W off Poreč). Limits of classifications are from the Regulation on water quality standards (73/13).

Table 3.3.3. Eutrophication profile, with an assessment of trends and ecological status for station SJ007.

SJ007			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Systematically in the range for oligotrophic coastal sea	absent	very good
c(Chla)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
O_2/O_2'	Significant variability in the limits for oligotrophic coastal sea	absent	very good
c(Tini)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
C(TP)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
N/P	Significant variability in the limits for oligotrophic coastal sea, observed increasing trend in the last 10 years	increasing	

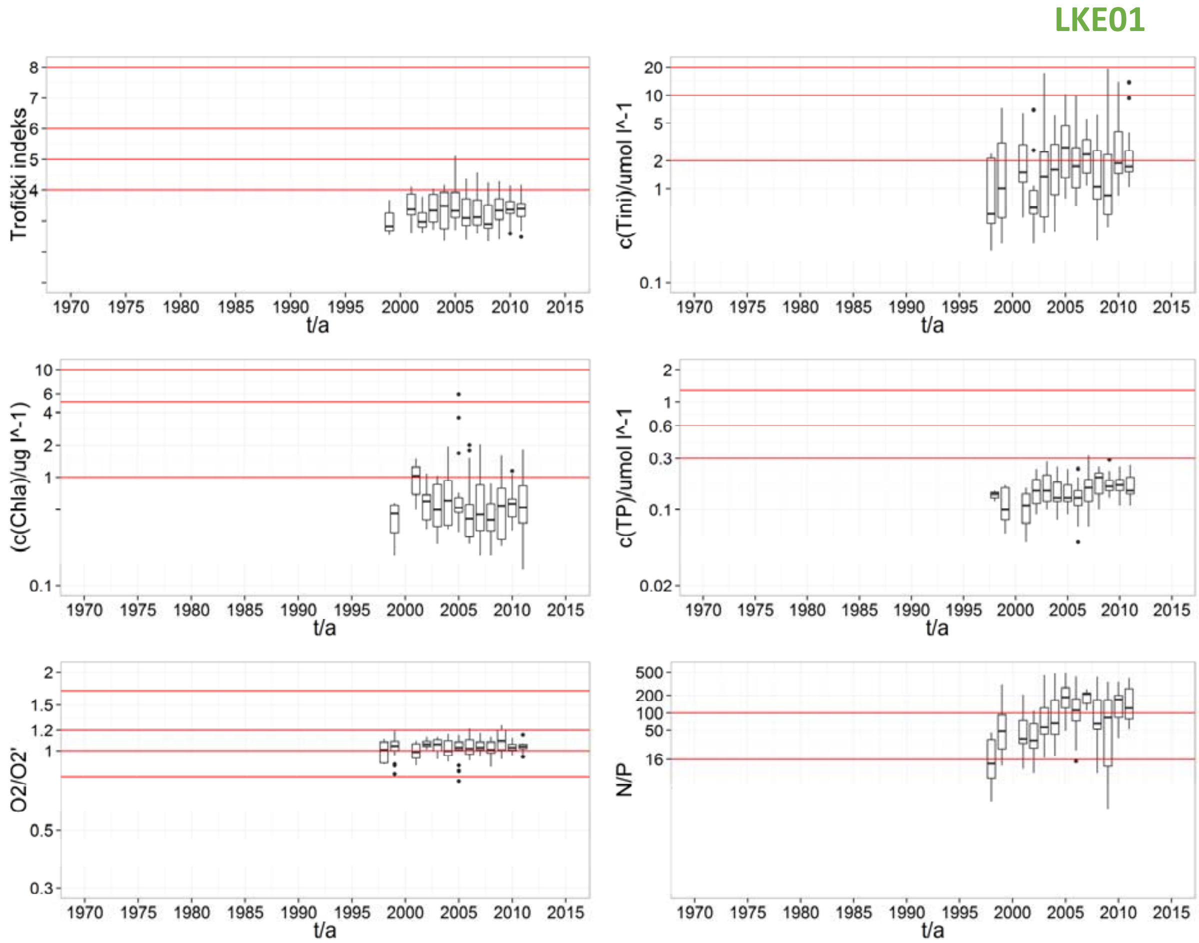

Figure 3.3.6. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station LKE01 (at the entrance of Limski kanal). Limits of classifications are from the Regulation on water quality standards (73/13).

Table 3.3.4. Eutrophication profile, with an assessment of trends and ecological status for station LKE01.

LKE01			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Enter the range for oligotrophic coastal sea	absent	very good
c(Chla)	Enter the range for oligotrophic coastal sea	absent	very good
O_2/O_2'	Enter the range for oligotrophic coastal sea	absent	very good
c(Tini)	Slightly increased values	absent	very good
C(TP)	Enter the range for oligotrophic coastal sea	absent	very good
N/P	Observed increasing trend	increasing	

LKR02

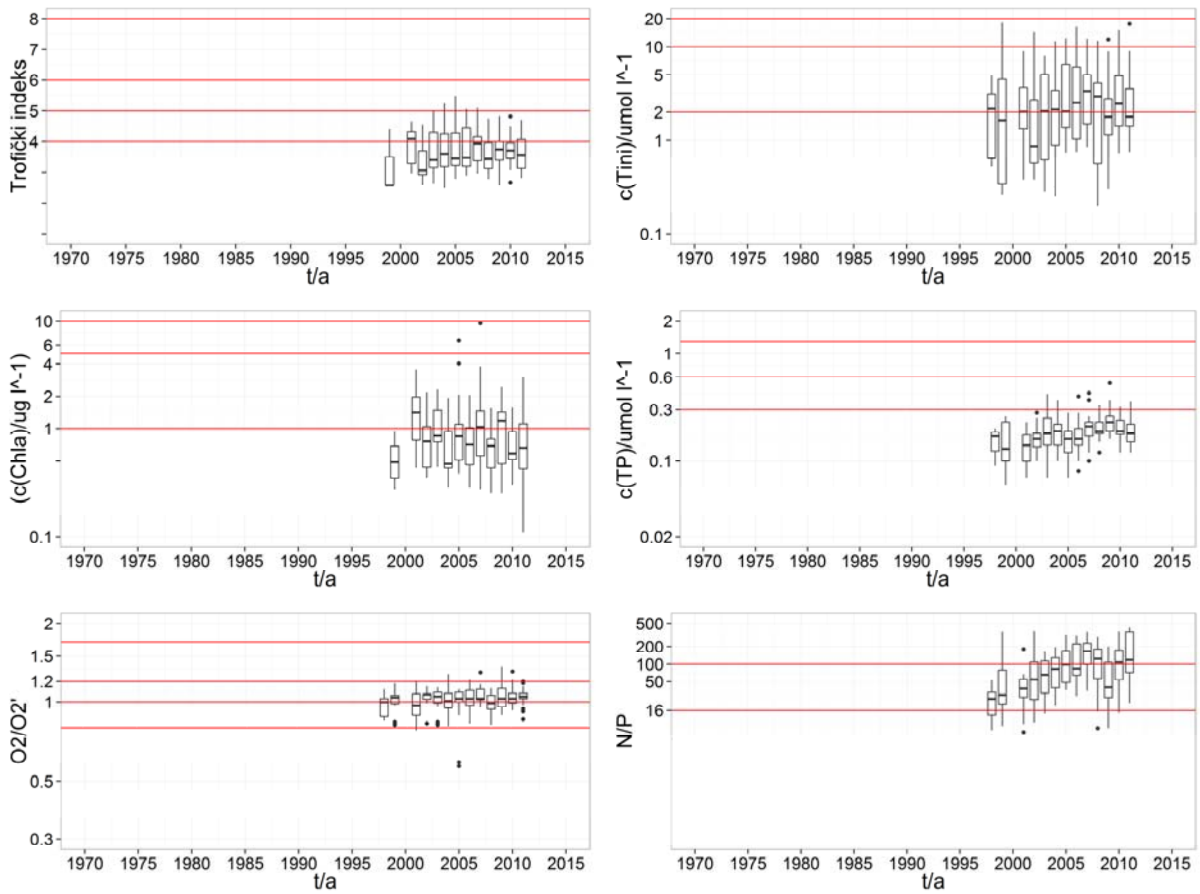

Figure 3.3.7. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station LKR02 (in the middle of Limski kanal). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.5. Eutrophication profile, with an assessment of trends and ecological status for station LKR02.

LKR02			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Enter the range for oligotrophic coastal sea	absent	very good
c(Chla)	Enter the range for oligotrophic coastal sea	absent	very good
O_2/O_2'	Enter the range for oligotrophic coastal sea	absent	very good
c(Tini)	Slightly increased values, at class limits	absent	good / very good
C(TP)	Enter the range for oligotrophic coastal sea	absent	very good
N/P	Observed increasing trend	increasing	

LKR03

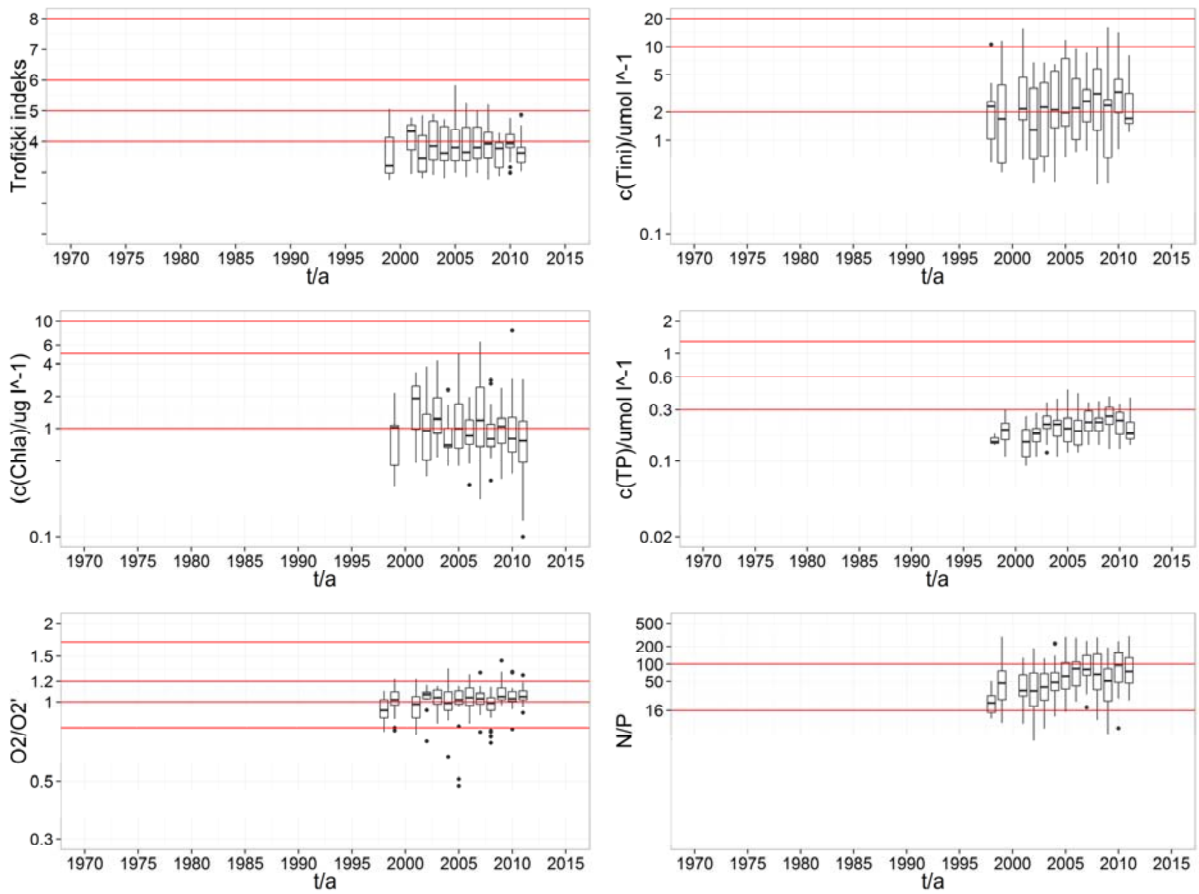

Figure 3.3.8. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station LKR03 (at the bottom of Limski kanal). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.6. Eutrophication profile, with an assessment of trends and ecological status for station LKR03.

LKR02				
Parameter	**Status description**	**Trend (10 a)**	**Status**	
Trophic index	Slightly increased values, at class limits	absent	good	very good
c(Chla)	Slightly increased values, at class limits	absent	good	very good
O_2/O_2'	Enter the range for oligotrophic coastal sea	absent	very good	
c(Tini)	Slightly increased values, at class limits	absent	good	very good
C(TP)	Enter the range for oligotrophic coastal sea	absent	very good	
N/P	Lower values then in the rest of Limski kanal	absent		

RV001

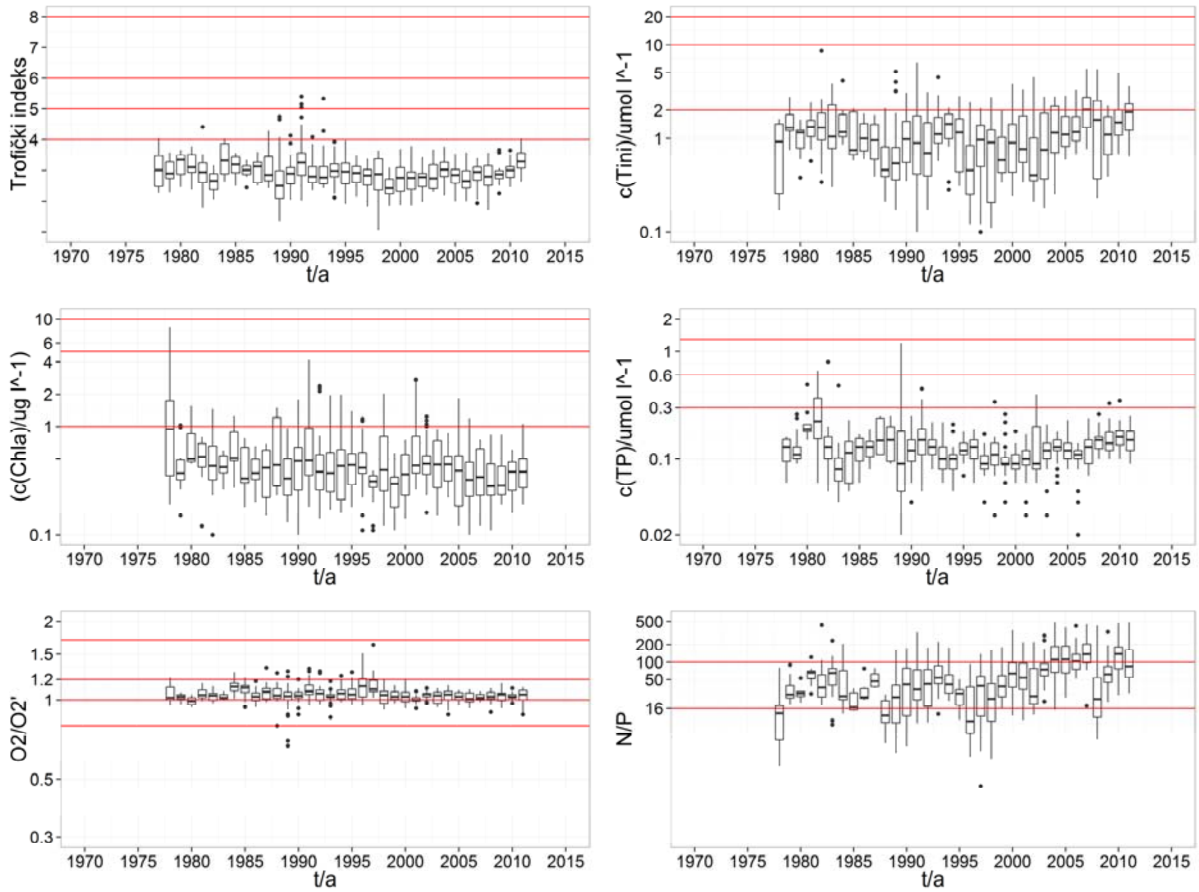

Figure 3.3.9. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station RV001 (1 Nm W off Rovinj). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.7. Eutrophication profile, with an assessment of trends and ecological status for station RV001.

RV001			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Systematically in the range for oligotrophic coastal sea	absent	very good
c(Chla)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
O_2/O_2'	Significant variability in the limits for oligotrophic coastal sea	absent	very good
c(Tini)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
C(TP)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
N/P	Significant variability in the limits for oligotrophic coastal sea, observed increasing trend in the last 10 years	increasing	

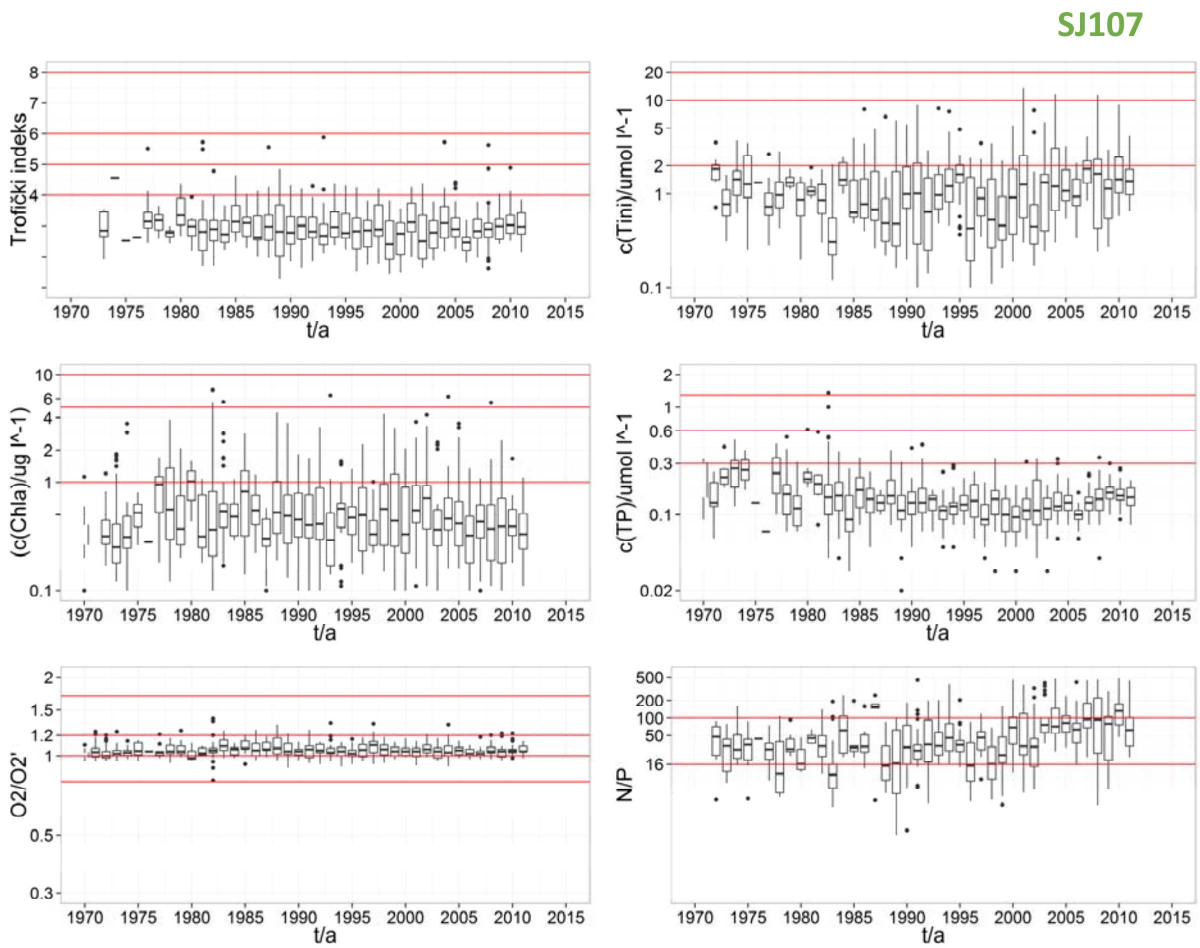

Figure 3.3.10. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station SJ107 (13 Nm W off Rovinj). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.8. Eutrophication profile, with an assessment of trends and ecological status for station SJ107.

SJ107			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Systematically in the range for oligotrophic coastal sea	absent	very good
c(Chla)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
O_2/O_2'	Significant variability in the limits for oligotrophic coastal sea	absent	very good
c(Tini)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
C(TP)	Significant variability in the limits for oligotrophic coastal sea	absent	very good
N/P	Significant variability in the limits for oligotrophic coastal sea, observed increasing trend in the last 10 years	increasing	

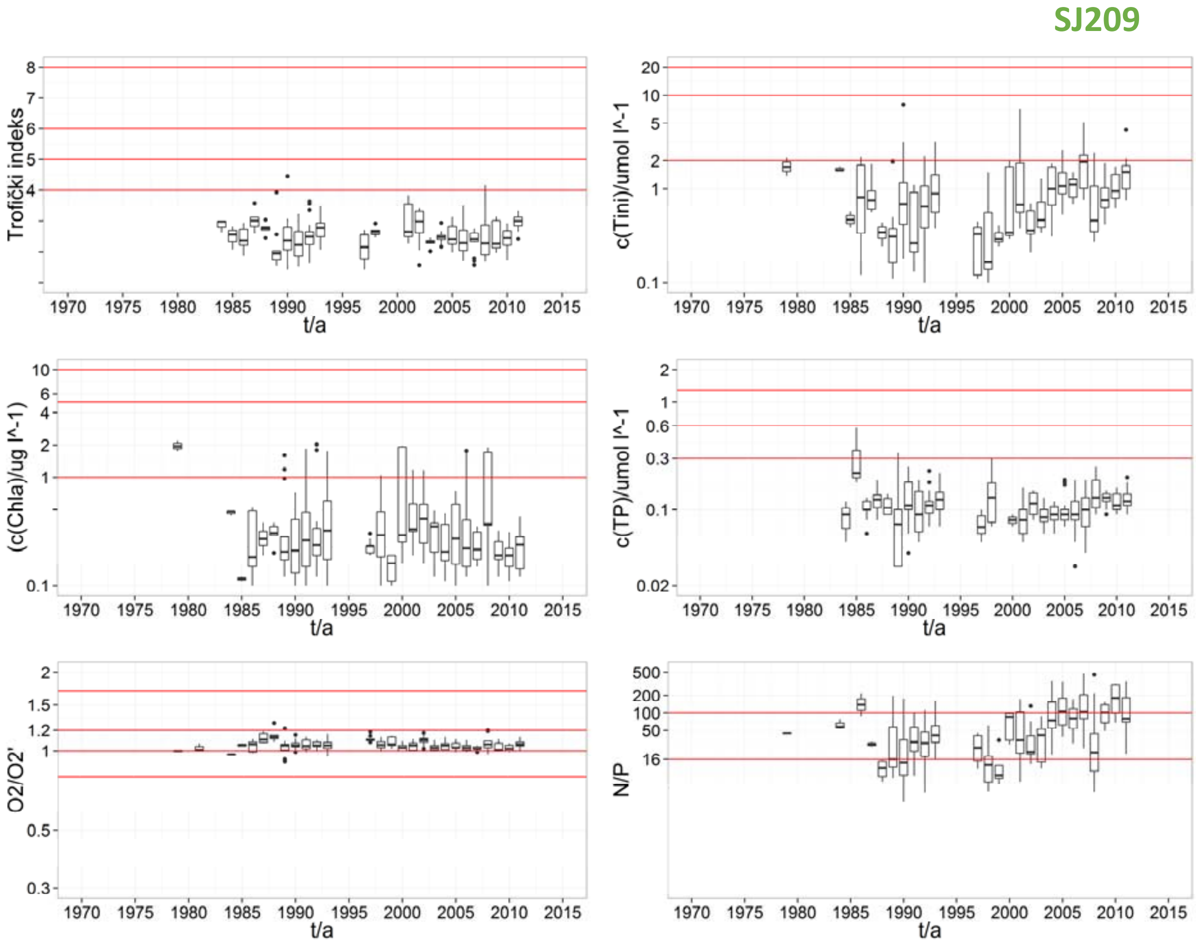

Figure 3.3.11. Box and Whisker representation of trophic index, concentration (c) of chlorophyll a, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station SJ209 (13 Nm W off Pula). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.9. Eutrophication profile, with an assessment of trends and ecological status for station SJ209.

SJ209			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Low values in the range for oligotrophic coastal sea	absent	very good
c(Chla)	Low variability in the range for oligotrophic coastal sea	absent	very good
O_2/O_2'	Enter the limits for oligotrophic coastal sea	absent	very good
c(Tini)	Enter the limits for oligotrophic coastal sea	increasing	very good
C(TP)	Low values in the range for oligotrophic coastal sea	absent	very good
N/P	Significant variability in the limits for oligotrophic coastal sea, observed increasing trend in the last 10 years	increasing	

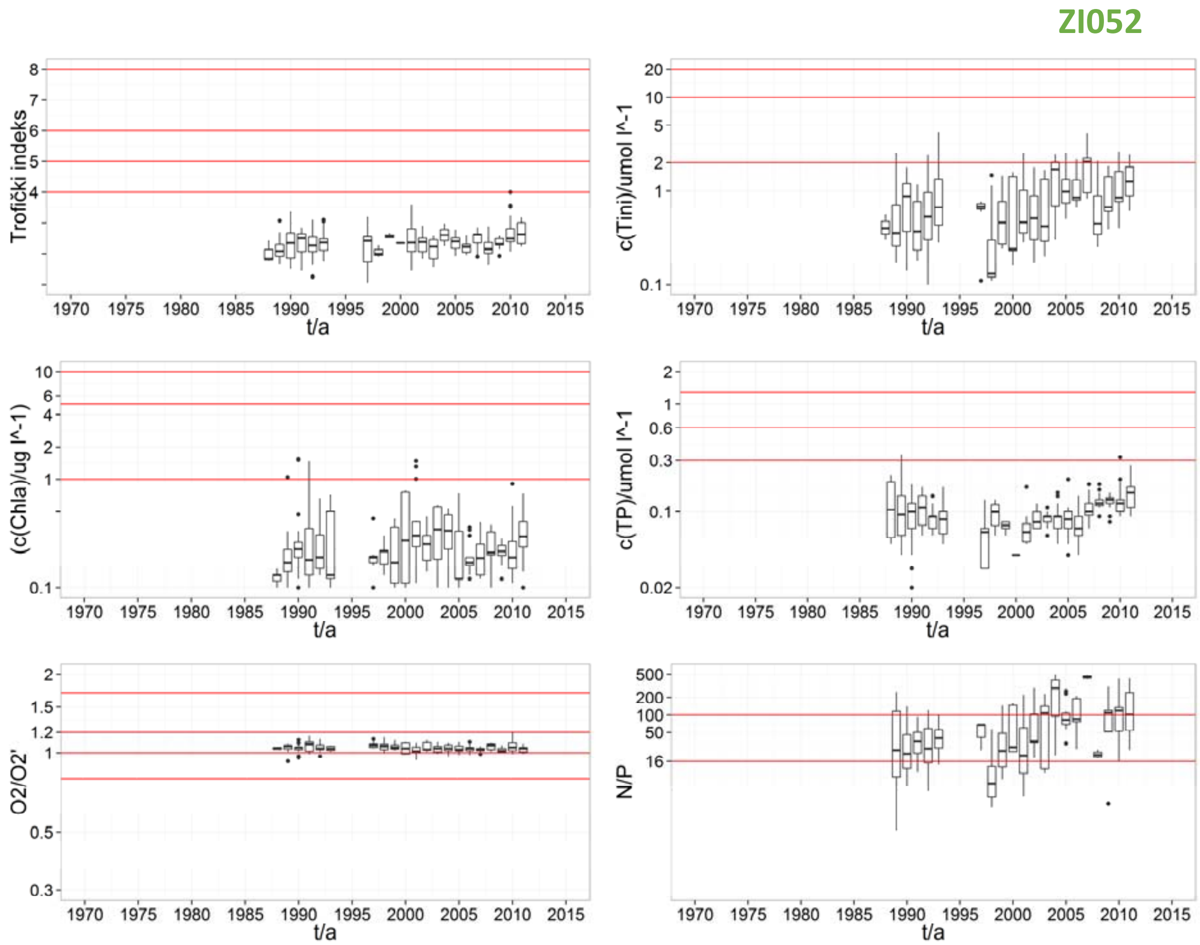

Figure 3.3.12. Box and Whisker representation of trophic index, concentration (c) of chlorophyll *a*, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station ZI052 (5 Nm W off Is. Porer). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.10. Eutrophication profile, with an assessment of trends and ecological status for station ZI052.

ZI052			
Parameter	**Status description**	**Trend (10a)**	**Status**
Trophic index	Low values in the range for oligotrophic coastal sea	absent	
c(Chla)	Low variability in the range for oligotrophic coastal sea	absent	
O_2/O_2'	Enter the limits for oligotrophic coastal sea	absent	
c(Tini)	Enter the limits for oligotrophic coastal sea	increasing	
C(TP)	Low values in the range for oligotrophic coastal sea	absent	
N/P	Significant variability in the limits for oligotrophic coastal sea, observed increasing trend in the last 10 years	increasing	

VV034

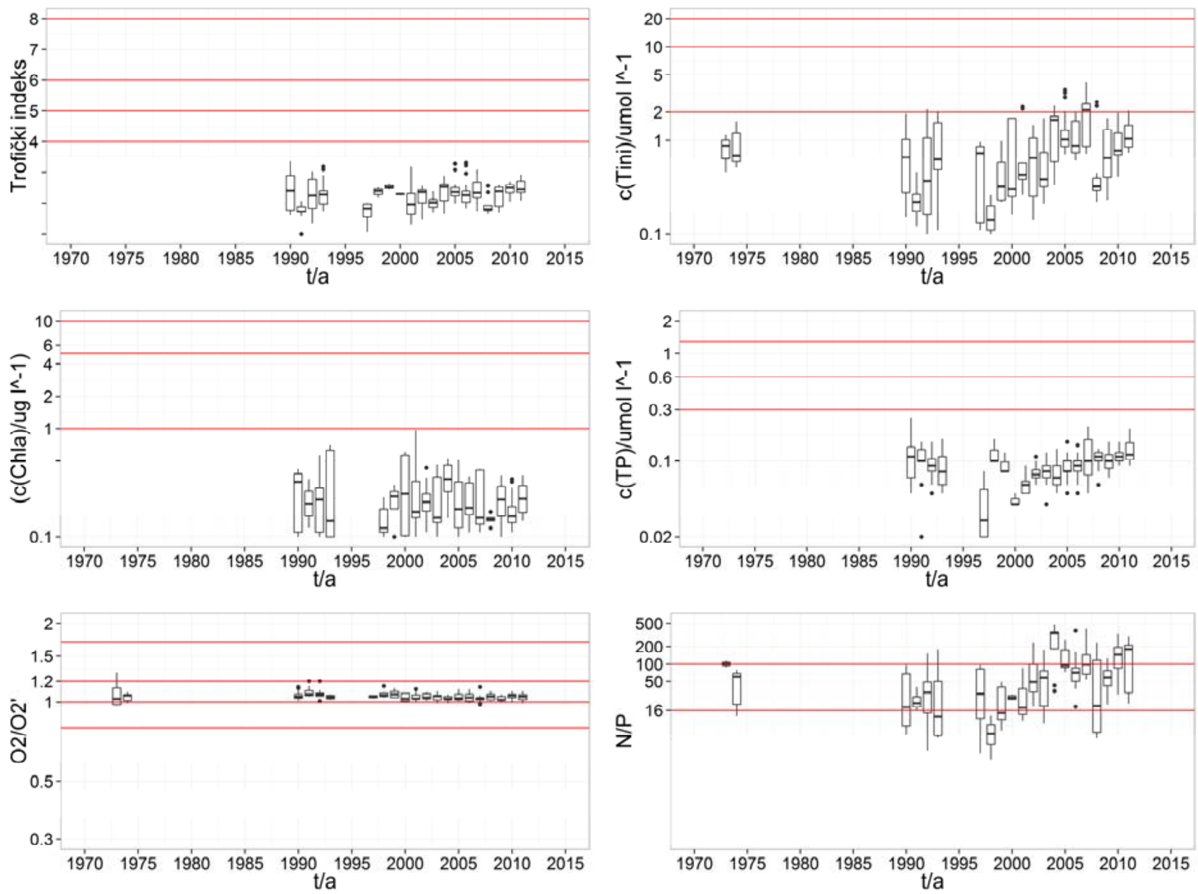

Figure 3.3.13. Box and Whisker representation of trophic index, concentration (c) of chlorophyll *a*, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station VV034 (middle of Kvarner). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.11. Eutrophication profile, with an assessment of trends and ecological status for station VV034.

VV034			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Low values in the range for oligotrophic coastal sea	absent	very good
c(Chla)	Low variability in the range for oligotrophic coastal sea	absent	very good
O_2/O_2'	Enter the limits for oligotrophic coastal sea	absent	very good
c(Tini)	Enter the limits for oligotrophic coastal sea	increasing	very good
C(TP)	Low values in the range for oligotrophic coastal sea	absent	very good
N/P	Significant variability in the limits for oligotrophic coastal sea, observed increasing trend in the last 10 years	increasing	

JPG32

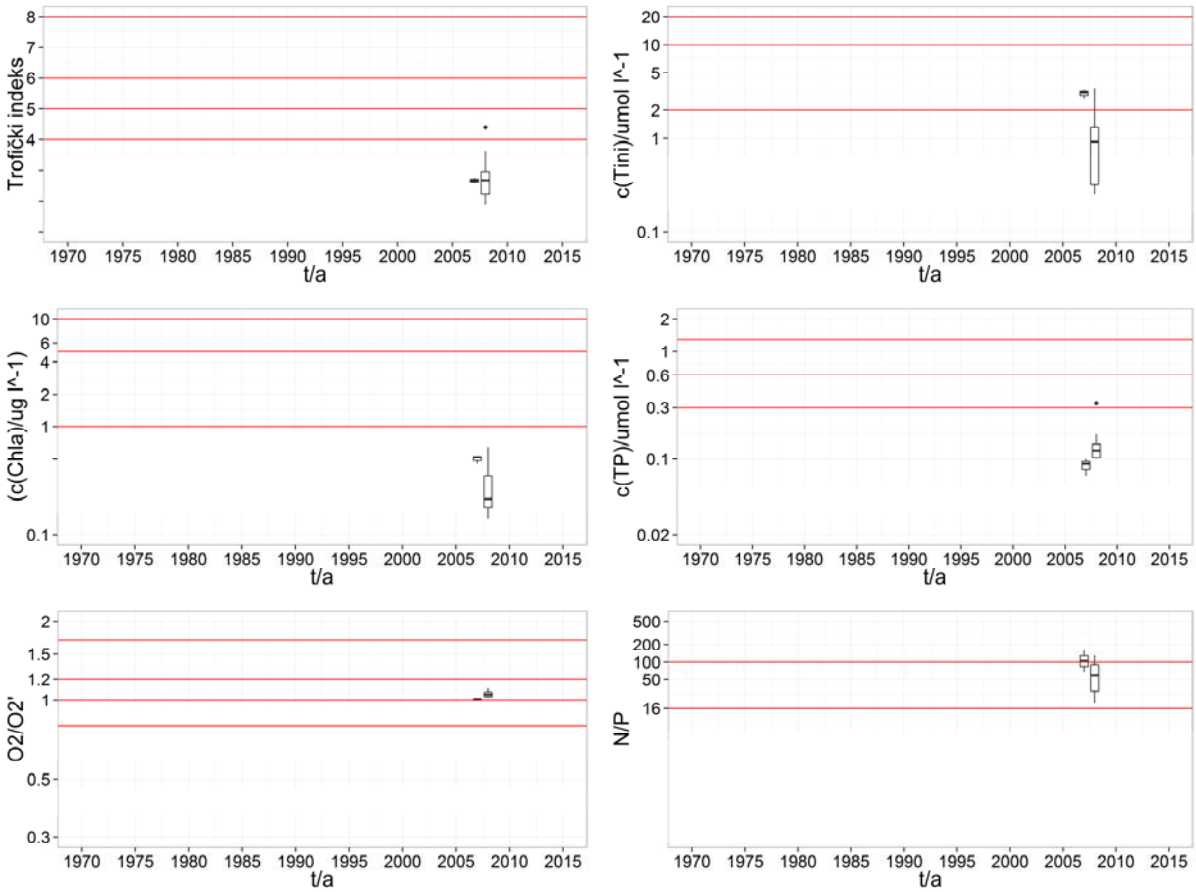

Figure 3.3.14 Box and Whisker representation of trophic index, concentration (c) of chlorophyll *a*, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation ($O_2/O_{2'}$) and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station JPG32 (et entrance into Raša Bay). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.12. Eutrophication profile, with an assessment of trends and ecological status for station JPG32.

VV034			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Low values in the range for oligotrophic coastal sea	enp	very good
c(Chla)	Low values in the range for oligotrophic coastal sea	enp	very good
O_2/O_2'	Low values in the range for oligotrophic coastal sea	enp	very good
c(Tini)	Low values in the range for oligotrophic coastal sea	enp	very good
C(TP)	Low values in the range for oligotrophic coastal sea	enp	very good
N/P	Enter the limits for oligotrophic coastal sea	enp	

enp – evaluation not possible

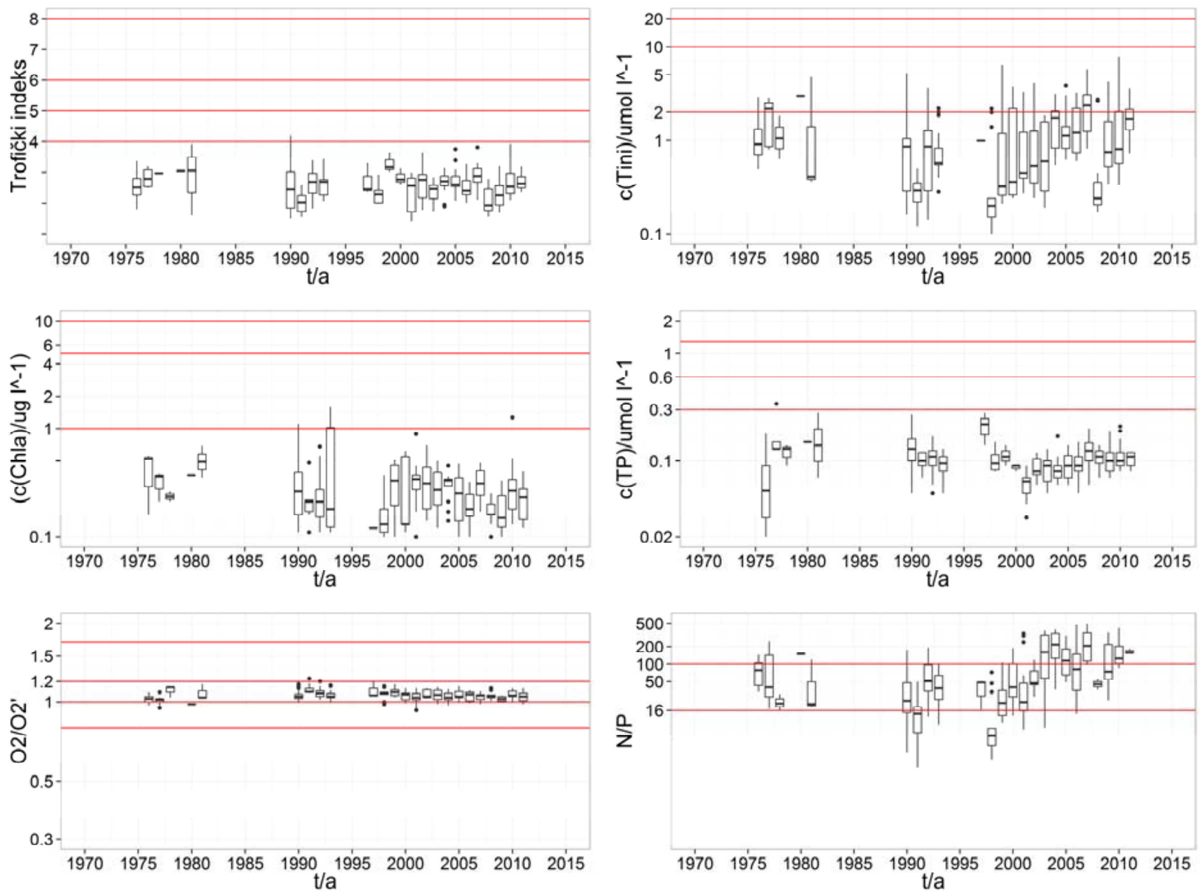

Figure 3.3.15. Box and Whisker representation of trophic index, concentration (c) of chlorophyll *a*, total inorganic nitrogen (Tini), total phosphorus (TP), oxygen saturation (O_2/O_2') and the ratio between total inorganic nitrogen and orthophosphate (N/P) for the period 1970-2011 at station RI011 (in Vela vrata). Limits of classifications are from the Regulation on water quality standards (OG 73/13).

Table 3.3.13. Eutrophication profile, with an assessment of trends and ecological status for station RI011

RI011			
Parameter	**Status description**	**Trend (10 a)**	**Status**
Trophic index	Low values in the range for oligotrophic coastal sea	absent	very good
c(Chla)	Low variability in the range for oligotrophic coastal sea	absent	very good
O_2/O_2'	Enter the limits for oligotrophic coastal sea	absent	very good
c(Tini)	Enter the limits for oligotrophic coastal sea	increasing	very good
C(TP)	Low values in the range for oligotrophic coastal sea	absent	very good
N/P	Significant variability in the limits for oligotrophic coastal sea, observed increasing trend in the last 10 years	increasing	

3.4. Descriptors 8. Contaminants and pollution effects and 9. Contaminants in fish and other seafood

Descriptor 8. Contaminants and pollution effects

In Annex I of the Marine Strategy Framework Directive 2008/56/EC (MSFD), Descriptor 8 is formulated as:

Concentrations of contaminants are at levels not giving rise to pollution effects". Contaminants are defined as substances (i.e. chemical elements and compounds) or groups of substances that are toxic, persistent and liable to bioaccumulate, and other substances or groups of substances which give rise to an equivalent level of concern

This definition is in line with the definition of hazardous substances used in the Water Framework Directive 2000/60/EC (WFD), and by OSPAR and HELCOM.

Pollution effects are defined as direct and/or indirect adverse impacts of contaminants on the marine environment, such as harm to living resources and marine ecosystems, including loss of biodiversity, hazards to human health, the hindering of marine activities, including fishing, tourism and recreation and other legitimate uses of the sea, impairment of the quality for use of sea water and reduction of amenities or, in general, impairment of the sustainable use of marine goods and services.

The assessment of achievement of GES under Descriptor 8 should be based upon monitoring programmes covering a range of chemical and biological measurements relating to the effects of pollutants on marine organisms. Monitoring programmes should include the assessment of concentrations of priority contaminants in environmental matrices, i.e. water, sediment, and the tissues of biota. Monitoring programmes should also include the quantification of biological effects of contaminants at different levels of biological organisation. The selection of priority contaminants, monitoring species and biological effects measurements may vary between assessment areas in response to local concerns and environmental conditions. Monitoring and assessment for Descriptor 8 should combine chemical and biological assessment methods and interpreted in an integrated manner. Early warning of conditions that would fail to meet the requirements of the descriptor should be built into the assessment process through temporal trend analyses of monitoring data.

Descriptor 9. Contaminants in fish and other seafood

Descriptor 9 considers the presence of hazardous substances (i.e. chemical elements and compounds) or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern, in wild caught fish, crustaceans, molluscs, echinoderms, roe and seaweed harvested in the different (sub) regions destined for human consumption against regulatory levels set for human consumption.

A number of contaminants in marine environment giving rise to concern both from an environmental and public health of view have been selected. Regulatory levels have been laid down for lead, cadmium, mercury, polycyclic aromatic hydrocarbons, dioxins and dioxin-like PCBs and radionuclides. Other substances of concern are arsenic, non-dioxin like PCBs, phthalates, organochlorine pesticides, organotin compounds, brominated flame retardants and polyfluorinated compounds. Contaminants, for which levels in fish and seafood have been set in community legislation for public health reasons, should therefore be monitored for this specific descriptor against these regulatory levels

Strictly spoken, Good Environmental Status (GES) would be achieved if all contaminants are at levels below the levels established for human consumption or showing a downward trend (for the substances for which monitoring is ongoing but for which levels have not yet been set). However, it is generally felt that GES for descriptor 9 must be judged in view out the monitoring of descriptor 8, also dealing with contaminants in marine environment. In case the analytical result of the laboratory sample exceeds beyond reasonable doubt the respective maximum level taking into account the expanded measurement uncertainty and correction for recovery if an extraction step has been applied, it should be considered as an alert for Good Environmental Status of the Marine Environment.

Analyses of Istria coastal zone

Pollution load along Istria coastal zone was analysed for the period from 1977 to 2009 based on published ecological studies and original scientific papers. Investigations have been performed in seawaters, sediment and some marine organisms by chemical and biological methods and tests. Unfortunately, investigations were sporadic and not all pollutants were investigated at certain sampling site. Thus, the data are scarce and not systematically distributed. Moreover, there is almost no data for sampling sites of contract interest (Raša, Budava, Tarska vala and Plomin Bay). Therefore the data for Pula harbour (urban and industrialized area of cca 100 000 inhabitants), Rovinj (urban area of cca 12 000 inhabitants) and Brestova (marine distance of 8 km east from Plomin Bay) were included in the analyses. Pollution load of coastal zones was mainly concentrated at point sources or urban sewage and industrial waste waters. It is necessary to point out that measured pollutants concentrations were lower in comparison to other Mediterranean regions.

Table 3.4.1. Pollutants concentrations in seawater.

Pollutant	Units	Limski kanal	Rovinj	Plomin Bay /Brestova	Pula harbour	Year
Zn	µg/l		1-14		8-9.7	1977 - 1978
Cd			0.001-0.05		0.07-0.11	
Pb			0.05-0.7		0.43-0.91	
Cu			0.1-0.6		0.7-1.3	
Phenol					1-15	
Hydrocarbons	mg/l				6-10	
Anionic tenzid	µg/l				542-1464	1994
Phenol					36-49	
Anionic tenzid	µg/l				0-1134	1995
Phenol					25-51	
Anionic tenzid	µg/l				1400-5600	1996
Phenol					13-38	
Anionic tenzid	µg/l	14.1-20.8		13.4-21.1	67-75	2004
Anionic tenzid	µg/l	0-108		13.2-23.9	11.6-149	2005

The wide range of metal concentrations as well as the concentrations of phenol and anionic tenzid was detected during the monitoring of the pollution load at certain marine areas (Table 3.4.1). Such wide range of concentrations could be a consequence of sporadic inputs of pollutants, dilution of pollutants due to the dynamic of the water masses or the seawater sampling that represents points in time and space. However, the comparison of the metal concentrations reveals the increased amount of Cd, Pb and Cu in Pula harbour in relation to the Rovinj area for the period 1997 1977/1978. The anionic tenzid (detergents) concentrations decreased in Pula harbour in 2004 (the previous investigation were performed from 1977 to 1996) on the level determined for Limski kanal (year 2005). This decrease can be due to the different composition of detergents used in modern households that find their way to urban waste waters. The range of phenol concentrations in the seawater of the Pula harbour did not change since 1977. Unfortunately, there are no available data for phenol concentration in other marine areas along the Istria coastal zone

Table 3.4.2. Pollutants concentrations in sediment.

Pollutant	Unit	Limski kanal	Rovinj	Pula harbour	Year
Hydrocarbons	mg/kg	15-250			1977
PAH	mg/kg	0.03-0.04	0.04-13.7		2004
Cd	mg/kg	0.1			2004
Cr		108			
Cu		12.7			
Pb		27.1			
Zn		81.5			
Cd	mg/kg	0.1			2005
Cr		90			
Cu		20			
Pb		20			
Zn		40			
Cd	mg/kg	0.2			2006
Cr		96.9			
Cu		19.6			
Pb		30.9			
Zn		30.5			
Cd	mg/kg	0.08			2007
Cr		114			
Cu		14.6			
Pb		31.3			
Zn		60.2			
Cu	mg/kg			25-1622	2008
Zn				100-154	
Cd				0-0.49	
Pb				37-388	
As				3.3-44	
Fe				7300-14000	
Cu	mg/kg	33.6			2009
Zn		117.3			
Cd		0.08			
Pb		29.5			
Cr		76.8			

The first data about the hydrocarbon pollution load of the sediment in the Limski kanal dates to 1977 (Table 3.4.2). There is additional data for the concentrations of policyclic aromatic hydrocarbons (PAH) in the sediment of the Rovinj area from 2004. The concentration of PAH varied from 0.04 mg/kg PAH/sediment for the recreational zone to 13.7 mg/kg for the Rovinj harbour. There are some data about the metal pollution load for the Pula harbour. The comparison of Cu, Zn Cd and Pb concentrations in the sediment revealed that, during the investigated period, the metal pollution load of Pula harbour is higher than the one in Limski kanal.

The continous monitoring of the metal pollution load in the sediment of Limski kanal from 2004 to 2008 (Fig. 3.4.1) revealed minimal variations in concentration of Cd, Cr, Cu and Pb, with a significant decrease in the Zn concentration.

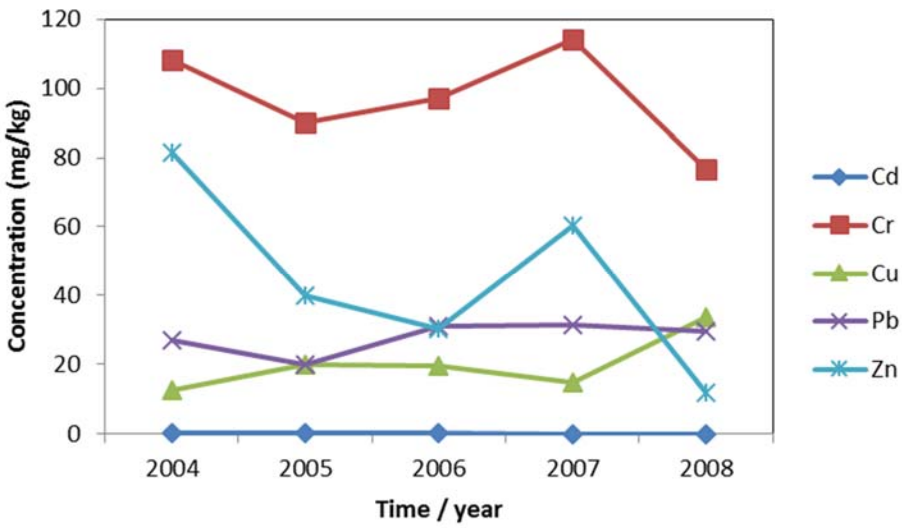

Figure 3.4.1. Time distribution of certain metal concentrations in the sediment of Limski kanal.

The concentrations of DDT and PCB in different marine invertebrates were detected in Limski kanal in 1987 and additionally, the concentration of Hg was measured in mussels *Ostrea edulis* and *Mytilus galloprovincialis* (Table 3.4.3) The invertebrate *Microcosmos sabatieri* accumulated three times higher concentrations of DDT and ten times higher concentrations of PCB than all the other marine invertebrates that were investigated. The detected Hg concentrations in mussels were below the maximal allowed concentrations (MDK).

Table 3.4.3. Koncentracije zagađivala u različitim vrstama beskralješnjaka.

Species	Pollutants	Units	Limski kanal	Year
Ostrea edulis	Hg	µg/kg	163-766	1987
Mytilus galloprovincialis			58.3-640	
Mytilus galloprovincialis	DDT		2.1-18.3	
8 invertebrates			4.1-10.1	
Microcosmos sabatieri			30.9	
Mytilus galloprovincialis	PCB		3.2-12.1	
8 invertebrates			1.1-8.9	
Microcosmos sabatieri			72.2	

The concentration of different pollutants was more substantially investigated in the mussel *Mytilus galloprovincialis* (Table 3.4.4) starting from 1977 in Pula harbour.

Table 3.4.4. Pollutants concentrations in mussel *Mytilus galloprovincialis.*

Pollutant	Unit	Limski kanal	Raša/Brseč	Plomin Bay /Brestova	Pula harbour	Year
Zn	mg/kg				149-1215	1977
Cd	mg/kg				1.7-4.0	1977
Pb	mg/kg				12.4-28.9	1977
Cu	mg/kg				2.5-7.2	1977
Hydrocarbons	mg/kg				0.1-20	1977
DDT	µg/kg				0-75	1977
PCB	µg/kg				5-148	1977
As	mg/kg		2.5-4.4			98/99
Cd	mg/kg	0.5		1	0.45	1998 -2000
Pb	mg/kg	1		1.2	6.1	1998 -2000
Cr	mg/kg	1.6		2.1	0.75	1998 -2000
Cd	mg/kg	0.19		0.38	0.22	2001
Pb	mg/kg	0.26		0.60	5.49	2001
Cr	mg/kg	1.34		0.59	0.48	2001
Cd	mg/kg	0.18		0.1	0.1	2002 - 2003
Pb	mg/kg	0.18		0.19	1.2	2002 - 2003
Cr	mg/kg	0.15		0.09	0.27	2002 - 2003
Cu	mg/kg	0.7		0.17	3.1	2002 - 2003
Zn	mg/kg	25		180	43	2002 - 2003
DDT	µg/kg	1.6		0.6	3.5	2002 - 2003
PCB	µg/kg	4		3	20	2002 - 2003
Cd	mg/kg	1.4			0.6	2004
Pb	mg/kg	1.2			14.2	2004
Cr	mg/kg	1.1			2.6	2004
Cu	mg/kg	5.0			27.6	2004
Zn	mg/kg	131			280	2004
DDT	µg/kg	6			16	2004
PCB	µg/kg	25			150	2004
Cd	mg/kg	1.1		1.4	0.7	2005
Pb	mg/kg	1.0		3	9	2005
Cr	mg/kg	1.8		2.2	1.0	2005
Cu	mg/kg	9		9	22	2005
Zn	mg/kg	150		150	140	2005
DDT	µg/kg	5		4	15	2005
PCB	µg/kg	20		15	120	2005
Cd	mg/kg	0.9		1.5	0.5	2006
Pb	mg/kg	1,1		2.1	7.4	2006
Cr	mg/kg	0.95		1.4	1.0	2006
Cu	mg/kg	5.9		6.8	17.5	2006
Zn	mg/kg	96.7		179	147	2006
DDT	µg/kg	3.8		3.8	11.5	2006
PCB	µg/kg	20		15	105	2006

Table 3.4.4. continued. Pollutants concentrations in mussel *Mytilus galloprovincialis*.

Pollutant	Unit	Limski kanal	Raša/Brseč	Plomin Bay	Pollutant	Unit
Cd		1.1		0.8	0.2	
Pb		0.9		1.2	6.4	
Cr	mg/kg	1.9		2.1	1.4	
Cu		6.4		7.1	19.2	2007
Zn		130		171	184	
DDT	µg/kg	2.5		3	8	
PCB		20		8	110	
Cu					0.8-8.3	
Zn					23-44	
Cd	mg/kg				0.04-0.17	2008
Pb					0.05-3.3	
As					1.1-5	
Fe					33-135	
Cu		9.4				
Zn		140				
Cd	mg/kg	1.0				
Pb		1.6				2009
Cr		1.7				
DDT	µg/kg	2				
PCB		10				

The concentration of certain metal detected in 1977 could not be compared with the concentrations of the same metal in subsequent years due to a difference in the methodology used for the detection of the metals under examination. Different metals, DDT and PCB were systematically investigated in mussels from Limski kanal, Pula harbour and Brestova/Plomin Bay for the period from 1998 to 2008. The highest Cd concentrations were detected in mussels from Brestova in 2006, while the concentrations of all the other pollutants were the highest in mussels from Pula harbour in 2004.

The concentrations of Pb, Cr and Zn in mussels from Limski kanal, Pula harbour and Brestova were significantly above the MDK values (Fig. 3.4.2). The concentration of Cd in mussels from all the three locations was around the MDK values. The concentration of Cu in mussels from Pula harbour were significantly above the MDK values in comparison to mussels from Limski kanal and Brestova. In the mussels from the latter locations the concentration of Cu ranged around the MDK values. Although the concentrations of DDT and PCB in mussels from Pula harbour were higher than the ones from other locations, they were nevertheless not above the MDK values.

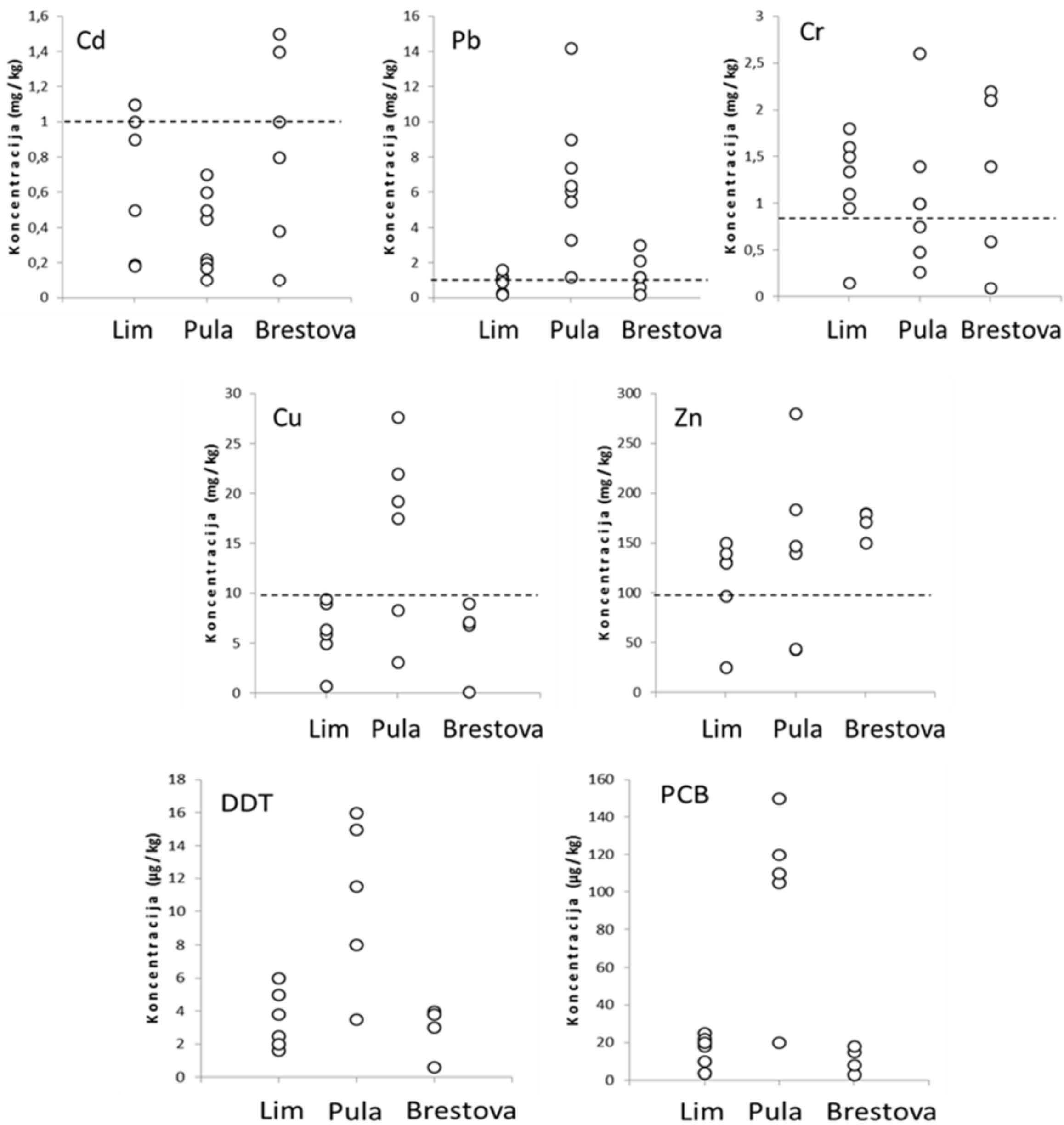

Figure 3.4.2. Pollutants concentrations in mussel *Mytilus galloprovincialis* from Limski kanal, Pula harbour and Brestova. Dashed line represents maximal allowed concentrations (MDK)

The data about beta emitters and their increased concentration in seawater, sediment and organisms from Plomin Bay and Raša Bay were not available for us in details necessary for these analyses. The increased beta activity in the sediment was not detected in Raša Bay except for Raša river mouth where negligible increase in activity was detected in comparison to the Bay entrance. However, Plomin Bay holds increased activities of certain radionuclides such as ^{234}Th, ^{235}U, ^{228}Ac, ^{212}Bi and others in sediment, seawater and biota. This is the consequence of human activity; the use of coal rich with radionuclides and the rinsing of coal ash depot (data for the period from 1983 to 1996). The atmospheric input of ^{137}Cs was significantly higher in the whole Istria coastal area after 1986 due to the Chernobyl disaster. For example, its activity was higher in the surface of the sediment than in the deeper layers. Nevertheless, it was still three times lower than the one measured in the sediment of the Po river mouth.

The marine ecosystem strategy for the investigations of anthropogenic pollutions includes the chemical monitoring (monitoring of specific pollutant concentrations in the seawater, sediment and organisms) and biological monitoring. The biological monitoring determines the pollutants effects on marine organisms at different levels of their biological organization, from molecule and cellular to individual and population levels. Biological tests measure the cumulative effects and reveal the presence of mutagens, genotoxins, toxins and neurotoxins, as well as unknown organic mixtures and general stressors. Thus, the biological monitoring at 24 sampling sites along the Adriatic coast was conducted in the period from 1999 to 2007 and it included three marine areas of the Istria Region (Limski kanal, Fažana, Pula harbour and Brestova). The results of these investigations are presented in Table 3.4.5. and includes the percentage of positive samples detected during 36 samplings and that reveal the presence of certain groups of pollutants.

Table 3.4.5. Presence of certain groups of pollutants in seawater and mussel determined with biological tests.

Pollutant	Limski kanal	Fažana	Pula harbour	Plomin/ Brestova
	Presence in 36 sampling during 1999 – 2007 (%)			
Mutagens in seawater **In vitro bacterial Ames test**	5	10	15	10
Genotoxins in seawater **In vitro bacterial umu-test**	5	10	18	10
Toxins in seawater **In vitro bacterial Microtox-test**	30	50	50	40
Genotoxins in mussels **DNA integrity assay**	0	40	25	25
General stressors **Lysosomal membrane stability**	30	30	80	18
	Presence in 2001			
Unknown organic mixtures **Neutral lipids**	-	-	+	-
Neurotoxins - PCB, Carbamates **Acethylcholinesterase activity**	-	-	+	-

(-) presence not observed

The comparison of the biomonitoring results for different areas is presented in Fig. 3.4.3. It revealed that Pula harbour is a marine environment that contain substantial amount of compounds causing biological effects such as mutagens, genotoxins, toxins and neurotoxins in addition to metals, DDT and PCB.

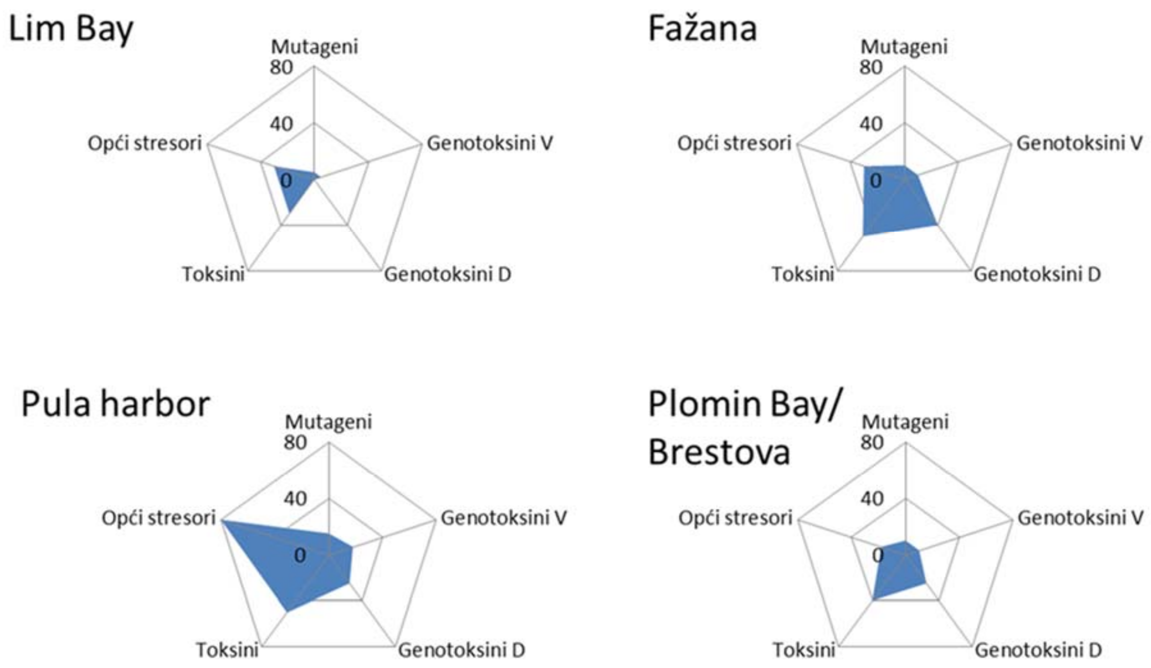

Figure 3.4.3. Results of biological monitoring in period from1999 - 2007.

CONCLUSIONS

1. Investigations of marine ecosystem quality in Istria region were sporadic and not all pollutants were investigated at certain sampling site. Thus, the data are scarce and not systematically distributed. Moreover, there is almost no data for sampling sites of contract interest (Raša, Budava, Tar Bay and Plomin Bay).
2. Systematic chemical and biological monitoring for whole Istria region is missing. It is necessary for determination of "hot spots" where remediation should be provided for decrease or possible termination of certain groups of pollutants input in marine environment and for determination of increase in marine ecosystem quality after the regulation of waste waters input.
3. Although the data about marine environment quality along Istria coast are scarce it is possible to detect areas under influence of urban and industrial waste as particularly endangered. Chemical and biological monitoring of pollutants presence and concentration in Istria region till now revealed that pollution load decrease in order Pula harbour >> Fažana > Rovinj > Brestova > Limski kanal.
4. For the purpose of integrative environmental management it is necessary to provide systematic monitoring, both chemical and biological, of seawater, sediment and organisms at potential endangered areas as well as referent/not endangered areas.
5. The implementation of measures to ensure the Good Environmental Status as described under Descriptor 8 requires a combination of several assessment tools which are at different levels of maturity. While some elements have already been used for a long time, other aspects have been introduced only recently. Still fundamental knowledge is lacking in some areas as listed below:
   - Understanding of the ecosystem responses to pollution,
   - Knowledge on the marine foodwebs with regard to contaminants,
   - Contaminant uptake and effects in marine top predators,
   - Source identification and quantitative apportionment,
   - Development of methods for the monitoring of pollutants,
   - Deep Sea Research,
   - Passive sampling techniques,
   - Biological effects techniques.

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