Implementation of the ecosystem approach in the Adriatic through marine spatial planning

Results of Marine Research in Montenegro Summary

UN environment programme

Mediterranean Action Plan Barcelona Convention

PAP/RAC

SPA/RAC

MONTENEGRO
MINISTRY OF SUSTAINABLE DEVELOPMENT AND TOURISM

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This report has been prepared as part of the GEF Adriatic project, funded by the Global Environment Facility (GEF).

For bibliographical purposes this document may be cited as:

UNEP/MAP-PAP/RAC-SPA/RAC and MSDT (2019). Results of Marine Research in Montenegro – Summary. Ed: PAP/RAC – GEF Adriatic project. 46pp

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INTRODUCTION

In recent years, environmental policy has become increasingly focused both on the process of harmonization of national legislation with the EU acquis and the introduction of numerous standards and practices in this area, inter alia, following the requirements of the Barcelona Convention.

The policy of protection and management of the sea and coastal areas is a special topic within the environmental policy. Namely, Montenegro, as a signatory to the Protocol on Integrated Coastal Zone Management in the Mediterranean (the Barcelona Convention)[1] has worked intensively in the previous period to establish the system of integrated coastal zone management, one of the most valuable national resources. In line with that, in June 2015, the Government of Montenegro adopted the National Strategy for Integrated Coastal Zone Management for Montenegro (NSICZM), in which, based on the assessment of the state of play, pressures and impacts, key problems, weaknesses and needs for integrated management have been identified in the context of protection of natural and cultural heritage, regulation of coastal activities and application of management instruments and mechanisms. The Strategy also defines the vision of coastal zone development, as well as priority thematic areas with strategic goals, while the Action Plan defines in detail the measures with sub-measures and target outcomes in the time horizon of the Strategy implementation. Also, in June 2015, the Government adopted the Decision in which it has extended the competence of the National Council for Sustainable Development and Climate Change[2] to the area of integrated coastal zone management, thus becoming the National Council for Sustainable Development, Climate Change and Integrated Coastal Zone Management. In this way, the strategic and institutional framework for integrated coastal zone management in Montenegro has been fully developed.

The key legislation governing specific issues related to this area in Montenegro are the following laws: Law on Marine Environment Protection (“OG of MNE” 73/19), Law on Environment (“OG of MNE” 52/16), Law on Nature Protection (“OG of MNE” 54/16), Law on Maritime Domain (“OG of MNE” 14/92, 59/92, 27/94, 51/08, 21/09, 73/10 and 40/11), Law on Strategic Environmental Assessment (“OG of MNE” 52/16), Law on Environmental Impact Assessment (“OG of MNE” 75/18), Law on Spatial Planning and Construction of Objects (“OG of MNE” 64/17). This legislation serves as the basis for the implementation of the Directive 2008/56/EC of the European Parliament and of the Council establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive-MSFD), Directive (EU) 2017/845 amending MSFD (as regards the indicative lists of elements to be taken into account for the preparation of marine strategies) and related Commission Decision (EU) 2017/848 repealing Decision 2010/477/EU (laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment), as well as Directive 2014/89/EU establishing a framework for maritime spatial planning.

The project “Implementation of Ecosystem Approach in the Adriatic Sea through Marine Spatial Planning" (hereinafter: GEF Adriatic) is an important contribution to the implementation of the NSICZM, as well as the above-mentioned national legislation. GEF Adriatic is a subregional project implemented in Albania and Montenegro that aims to contribute to the restoration of the ecological balance of the Adriatic Sea through the implementation of the ecosystem approach and marine spatial planning. In Montenegro, the project is implemented in cooperation with the Ministry of Sustainable Development and Tourism and UNEP/MAP.

[1] "OG of MNE, no.16/11" from 5 December 2011.

[2] "OG of MNE, no. 39/15" from 21 July 2015.

One of the key components of the project is the development of the Integrated Monitoring and Assessment Programme (IMAP) of the marine environment. The contracting parties to the Barcelona Convention are required to take the national implementation measures of such a programme, which is fully harmonized with and contributes to the implementation of the MSFD.

As a support to the development of the monitoring programme, field data collection was conducted within the project in early October 2019, which helped, to some extent, overcome the lack of data on the state of the marine environment and test some of the proposed monitoring stations. The results of the research and other project documents (including the monitoring programme) will significantly contribute to the implementation of the MSFD and the related IPA project "Support to Management and Monitoring in Water Management in Montenegro", the implementation of which started in November 2019.

The document has been prepared as a summary of two key reports:

- UNEP/MAP-PAP/RAC-SPA/RAC i MORT (2019). Izvještaj o rezultatima istraživanja morske sredine Crne Gore. Autori (po abecednom redu): Željka Ćetković, Dragana Drakulović, Branka Grbec, Danijela Joksimović, Bojana Knežević, Davor Lučić, Vesna Mačić, Branka Pestorić, Slavica Petović, Danijela Šuković, Vladimir Živković. Ur: PAP/RAC - GEF Adriatik projekat. 154 pp. + Prilozi;
- UNEP/MAP-PAP/RAC-SPA/RAC and MSDT (2019). Investigation of hard bottom habitats with special attention given to Anthozoa and their taxonomy in Boka Kotorska Bay, Montenegro. By: Egidio Trainito. Ed: PAP/RAC – GEF Adriatic project. 67pp.

Field research of marine habitats in Montenegro in the period July – October 2019

In the period July – October 2019, field research of marine habitats was conducted for the following three categories:

1. Biodiversity

1.1 To monitor the habitat attributes of the Posidonia (*Posidonia oceanica* L.), three (3) locations were established, namely:

- hrid Đeran in the southern part of the coast;
- Buljarica bay; and
- Crni rt in the central part of the coast.

1.2 Coralligenous assemblages in Boka Kotorska Bay – for monitoring of coralligenous assemblages in Boka Kotorska Bay, the following three (3) locations were selected:

- Dražin vrt;
- Sopot; and
- Turski rt (the narrows at the site called Verige).

1.3 For monitoring of coralligenous assemblages outside Boka Kotorska Bay the following three (3) locations were selected:

- Velika Krekavica;
- Rt Mačka; and
- Ponta Veslo.

2. Hydrography, eutrophication and contaminants

The research area covered the part stretching from the delta of the Bojana River in the south to Boka Kotorska Bay in the north. Seawater sampling was performed at a total of 17 collection points, divided into groups across five transects.

BIODIVERSITY

1 BIODIVERSITY OF POSIDONIA MEADOW (*Posidonia oceanica*)

To monitor the habitat attributes of the seagrass Posidonia (*Posidonia oceanica* L.), three (3) locations were established: hrid Đeran in the southern part of the coast, Buljarica bay and Crni rt in the central part of the coast (Figure 1.1).

As for the location of the hrid Đeran, this is the first measurement of this kind, so it will also serve as a zero state in the future. At all three sites, diving was done at locations where previous research showed the presence of Posidonia meadows, although there was no precise information about the distribution of this habitat, in particular at the locations of the hrid Đeran and Crni rt. Bearing that in mind, diving was done according to navigation courses that were defined based on previously existing maps and expert assumptions. At all locations, the goal was to reach the lower limit of the meadow and measure the density and coverage.

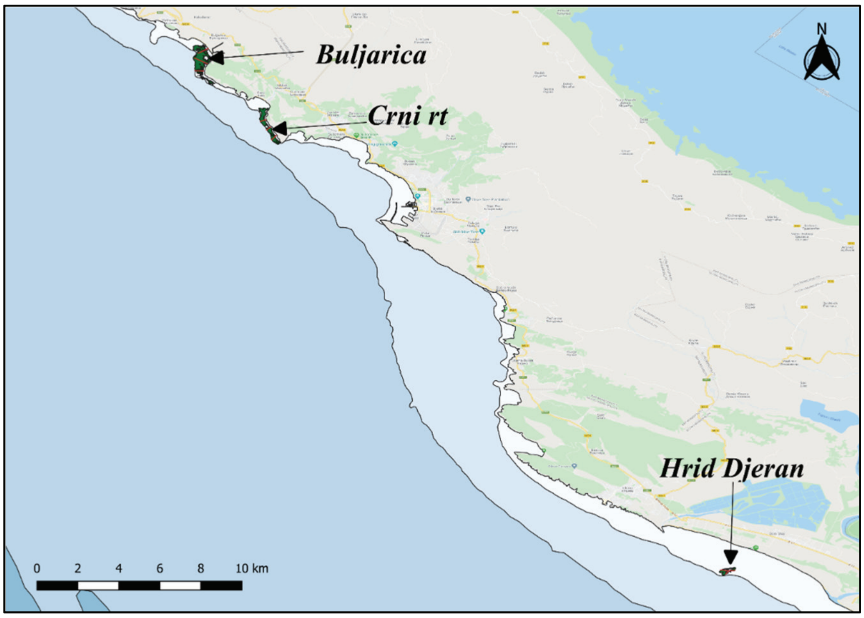


Figure 1.1. Posidonia monitoring sites

Taking into account the previously applied methodology used in Montenegro by the NGO Green Home and the NGO Sunce throughout the 4M project (Guala *et al.*, 2017), the POMI method was used in this research (RAC/SPA – UNEP/MAP, 2014) measuring the following parameters:

- shoot density;
- coverage/distribution of meadows and dead rhizomes;
- the lower and upper depth limit;
- the lower limit type[3].

In the process, it was necessary to opt for autonomous diving because the analysis was widely conducted *in situ*.

Based on the coverage/distribution, the Conservation index (CI) was calculated (Moreno *et al.*, 2001; Montefalcone *et al.*, 2006) showing the state of meadow and the interactions between the living and dead parts of the meadow (Table 1.1).

Table 1.1. Classification of coverage/distribution of Posidonia meadow based on CI

Very good	Good	Moderate	Weak	Very weak
> 0.9	0.7 – 0.9	0.5 – 0.7	0.3 – 0.5	< 0.3

[3] According to the UNEP/MAP-RAC/SPA (2011) modified classification based on the lower limit type, Posidonia settlements are classified into five categories: Very good, Good, Moderate, Weak and Very weak.

1.1 HRID ĐERAN LOCATION

The hrid Đeran location (Figure 1.2) is located in the far eastern part of the Montenegrin coast, approximately 5 km from the delta of the Bojana River and around 1.5 km from the coast. The wider surrounding area has a sandy base, while the cliff itself with a small underwater area is the only rocky base in the wider area of this part of the seabed. More detailed research of this location has not been done yet, but it is evident that the water clarity is reduced and sedimentation is increased, most likely due to the influence of the Bojana River. This location is very much exposed to the winds, particularly from the south, so the hydrodynamic response is rather intense.

The hrid Đeran location is a well-known and attractive area/post for fishermen, and it is a popular boat tour destination. The ancient archaeological finds on the sites of sunken ships could probably be found at this location. The presence of several protected species was established at this location, and it should be noted that the Fan Mussel (*Pinna nobilis*) was dead. Invasive species have not been found.

At the hrid Đeran location, it was established that the Posidonia settlement extended at a depth between 8 m and 17 m, and that along two out of three monitored transects, this settlement ended regressively. The meadow density analysis has shown that density values were low, and the coverage was relatively small so, together with the regressive lower limit at a shallow depth, this meadow can be assessed as very weak, but with very good CI.

Along the transect I (T1, Figure 1.2), in the deeper part of the meadow, some dead rhizomes were identified, whereas that was not the case in the shallow part. The Conservation index (CI) at a depth of 15 m was good (0.95), as well as at a depth of 8 m (1).

Along the transect II (T2, Figure 1.2) two depths were also monitored as the meadow starts at 8 m and extends only up to a depth of 14 m. Along this transect, the meadow ends on a rocky base and no dead rhizomes have been found there. The density of the meadow at both investigated depths was weak, i.e. 223 shoots/m^2 at a depth of 14 m and 321 shoots/m^2 at a depth of 9 m. Regarding the coverage/distribution of the Posidonia meadow at a depth of 14 m and 9 m, here is documented the extensive presence of rocky substrate, and given that no dead rhizomes were identified, the CI amounted to 1.

Along the transect III (T3, Figure 1.2), the settlement extends to a depth between 8 and 16 m and ends regressively. The density of the meadow at both depths was weak, i.e. 222 shoots /m^2 at a depth of 15 m and 331 shoots/m^2 at a depth of 9 m. Regarding the coverage/distribution of the Posidonia meadow along the transect III, the significant presence of a rocky base on which no meadow has developed was documented here, and some dead rhizomes were found. However, the CI was very good at both depths, 0.97 and 0.96 respectively.

Figure 1.2 shows the total analysed seagrass meadow *Posidonia oceanica* at the hrid Đeran location. The summary assessment is that the density of the meadow was weak, but that the CI was very good, amounting to 0.98.

This state can be explained as the most probable consequence of the Bojana River influence, low water clarity and eutrophication.

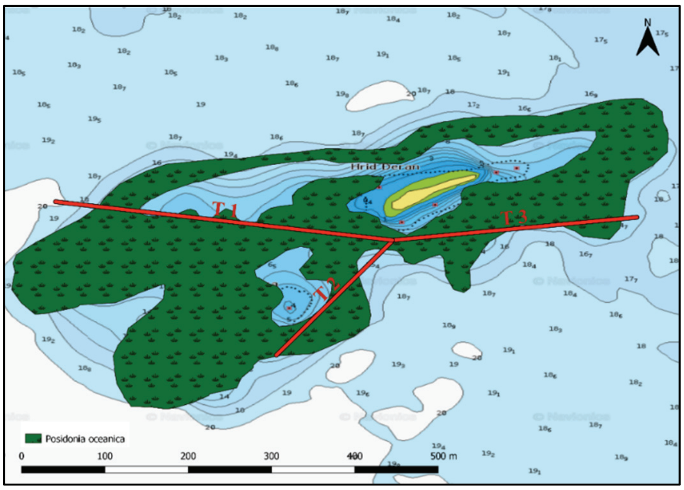


Figure 1.2. Positions of the monitored transects at the hrid Đeran location

1.2 CRNI RT LOCATION

The transects monitored at the location of Crni rt are shown in Figure 1.3. This area is entirely defined as non-urban, so the coast is completely natural. The coast is rocky in the narrow coastal area, while the sandy base continues along the rest of the coast.

Regarding the previous research in the area, only one dive was done when the density of the settlement of Posidonia on Crni rt was monitored and assessed as good, and the lower limit was marked at a depth of 23 m (DFS 2010). As part of this research (May 2010), basic hydrographic parameters were monitored using a CTD probe once and no deviations from the usual values were found. During the 2019 research, hydrographic parameters were not monitored.

The presence of several protected species was confirmed at this location, as well as the presence of invasive algae *Caulerpa cylindracea*.

This location is well-known among local divers and fishermen, but for now, it is not under intense anthropogenic influence. There is a military base with radars on the mainland of Crni rt.

The habitat map for this location from previous research lacked precision, i.e. it was based on the satellite image processing. Based on the experience of local experts, it was to be expected that Posidonia meadows would be present in a wider area than one shown on the map, so the main goal of the 2019 monitoring was checking the width of that habitat. Once monitoring was completed, the map of the distribution of Posidonia settlements was corrected and the basic characteristics of the meadow were measured.

The density of the Posidonia settlement at the Crni rt location was assessed as good and, based on the coverage and the lower limit, the state could also be assessed as good. The analysis of the conservation index (CI = 0.9) showed that the state of these meadows was very good.

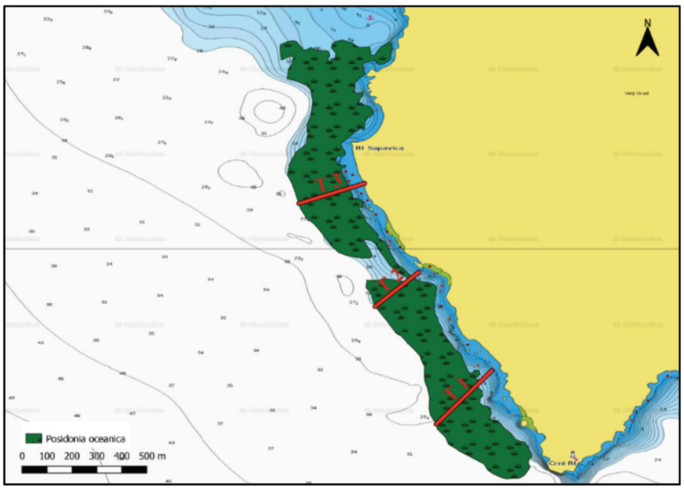


Figure 1.3. Positions of monitored transects at the Crni rt location

1.3 BULJARICA LOCATION

Buljarica beach is a well-known tourist resort and in the summer months, it is under the intense anthropogenic influence, particularly the northern part of the beach and the whole bay. This area is also known among local divers and fishermen, while the tourist boats typically do not anchor in this area.

The area is almost entirely defined as non-urban and it has been the subject of previous research. The most detailed research aimed at establishing the marine protected area Katič (DFS, 2010), as part of which one-time monitoring of the basic hydrographic parameters was done using the CTD probe. In this research, no deviations from the usual values were found. The densities of Posidonia settlements and the lower limit parameters were then monitored in the middle of the Buljarica Bay, where the state was assessed as poor, while in the southern part of the bay, near the Mravinjak cliff, as well as in the northern part of the bay, the state of Posidonia meadows was assessed as good. The transect locations during the 2019 monitoring had not been previously monitored (Figure 1.4). The presence of several protected species was identified at this location, while invasive species were not found.

There is no precise habitat map for this area either, so this research has contributed to improving it, but further research should certainly be done to clearly define the lower limit of Posidonia meadows in specific parts of the Buljarica Bay.

Along the transect I (T1, Table 1.4), the Posidonia meadow starts growing at 6 m, ends regressively at a depth of 22 m and continues to grow in a mosaic manner. The density of Posidonia settlements at intermediate water depth is medium (255 shoots/m^2), while it is weak at the lower and upper limit (117 and 406 shoots/m^2). Regarding the coverage/distribution of Posidonia meadows at all three locations, a strong presence of sandy surface is evident, whereas the meadow is mosaic in the entire zone. There were some dead rhizomes, but the CI was 0.98 at the upper and lower limit, and 0.97 in the middle, due to which its condition could be classified as very good.

The second investigated transect (T2, Table 1.4) had a central position and the end of Posidonia meadow was not found because it is very far from the coast. At a depth of 12 m, the density was low, i.e. 224 shoots/m^2, whereas at the upper limit of the Posidonia meadow, at a depth of 8 m, density was average with 427 shoots/m^2. It should be emphasized here that at the upper limit, the density of the meadow varied significantly and ranged from good to very weak. Regarding the coverage/distribution of the Posidonia meadow along this transect, it was established that there was a significant proportion of the sandy base, and that, unfortunately, there were also dead rhizomes of Posidonia. The CI at a depth of 12 m was very good, while the CI at a depth at 8 m was good, amounting to 0.93 and 0.89 respectively.

Along the third investigated transect at the Buljarica location (T3, Table 1.4), the Posidonia meadow ends regressively at a depth of 23 m. The middle value of the density at the lower limit was 133 shoots/m^2, which is considered a low density. Also, the density was low at the

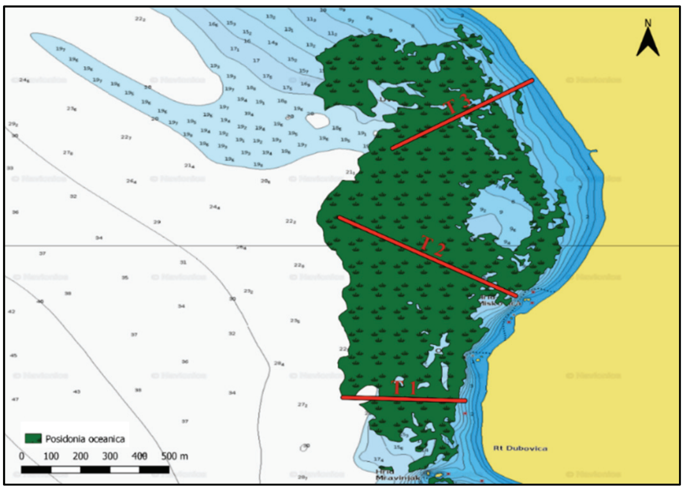


Figure 1.4. Positions of monitored transects at the Buljarica location

upper limit (409 shoots/m^2), while in the central part of the meadow, the density was medium, i.e. 367 shoots/m^2. Regarding the coverage/distribution of Posidonia meadows, clusters of dead rhizomes may be observed at the lower limit, while the shallower parts have significantly fewer dead rhizomes. For these reasons, the lower limit of the CI was 0.74, which indicates that a meadow is in a good state, while the middle and upper limit of CI was 0.96, indicating a very good state.

The conducted research has shown that the density of this settlement at a depth of 15 m belongs to the category of medium density, and based on the depth and type of limit at the lower level of the settlement, they are defined as weak. However, it should be kept in mind that the Conservation Index is 0.8, which indicates that the Posidonia settlement is in a good state.

1.4 CONCLUSION

The external conditions for the development of *Posidonia oceanica* meadows in the Adriatic Sea are different from those in the rest of the Mediterranean. Ecological conditions in the Adriatic are different, especially at some very specific locations. Such locations, even if they are not under the measurable anthropogenic influence, have their own specifics that influence the development of Posidonia. That is the reason why the research of the density and depth distribution of Posidonia settlements has found different values across the three monitored locations (Table 1.2).

The best values were found at the Crni rt location, at medium depths, where the density was good, while medium densities were found at the lower and upper limits. The Buljarica location comes next, as the value of meadow density was medium at a medium depth, and it was weak at the lower and upper limits. The lowest density values for Posidonia meadows were found along the hrid Đeran, where the density was generally low, or even very low at one upper limit. At the hrid Đeran location, the influence of freshwater from the Bojana River, large quantities of suspended particles, increased sedimentation and reduced transparency may not support the development of Posidonia meadows, i.e. these factors limit the deep distribution and development of dense Posidonia meadows.

Table 1.2. Summary average values of Posidonia meadow densities at a medium depth (15 m)

Site	Depth 15 m
Hrid Đeran	223
	222
	163
Average value	203 (weak)
Crni rt	424
	430
	336
Average value	397 (good)
Buljarica	255
	367
	224
Average value	282 (moderate)

Regarding the Conservation Index (CI), the values for medium depths are shown in Chart 1.1. At the Crni rt location, the index was good, while at the other two locations it was very good. This is a very good indicator of the overall condition of and pressures on the Posidonia meadows, so it can be concluded that the overall state is good. However, it should be kept in mind that the cumulative effects are intensifying both spatially and temporally, so further measures should be implemented to monitor these protected habitats, along with measures for their conservation, those for punishing their violation, as well as educational activities.

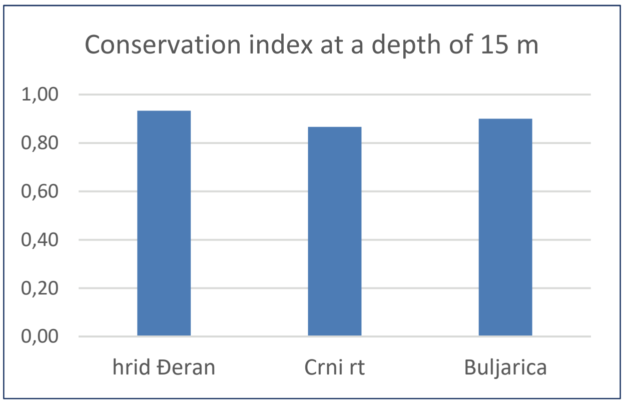


Chart 1.1.
Conservation Index of Posidonia meadows at three monitored locations

Lower density values than expected most likely result from local environmental conditions, rather than anthropogenic activity. This is also evident from the Conservation Index data, which demonstrated that there was no or minimal death of individual Posidonia plants.

At the locations where monitoring was conducted, the measured data should be taken as the zero state, and possible changes should be monitored.

2 CORALLIGENOUS ASSEMBLAGES

Coralligenous habitats are the most important coastal ecosystems in the Mediterranean for distribution, biodiversity, biomass and their role in the carbon cycle (Ballesteros, 2006; Bertolino *et al.*, 2013). This habitat type is characterized by a basal layer built of bioconstructors mainly composed of calcified red algae such as *Corallinales* and *Peyssonneliales*, such as *Lithophyllum spp*., *Lithothamnion spp*., *Mesophyllum spp*., *Neogoniolithon spp*. and *Peyssonnelia spp*. (Oprandi *et al.*, 2016), and has a high structural and functional complexity and great sensitivity to global and local influences (Gatti *et al.*, 2015; Gatti *et al.*, 2017; Montefalcone *et al.*, 2017).

In addition to this layer, there is a middle layer up to 15 cm high and a high layer consisting of species whose height exceeds 15 cm. Long-lived upright corals, such as gorgonians, are considered key species in coral reefs because they contribute to the typical three-dimensional structure of coral assemblages, providing biomass and biogenic substrate, and greatly contributing to the aesthetic value of the Mediterranean sublittoral landscape (Gili & Coma, 1998; Harmelin & Marinopoulos, 1994).

Within the GEF Adriatic project, coralligenous community research was conducted as part of two separate field studies – in Boka Kotorska and on the high seas, using two different methodological approaches.

2.1 CORALLIGENOUS ASSEMBLAGES IN BOKA KOTORSKA BAY

Boka Kotorska Bay is considered the largest bay in the Adriatic Sea and Europe's southernmost fjord (Bosak *et al.*, 2012). The Bay, occupying an area of 87.3, km^2 and having a coastal perimeter of 105.7 km, is divided into 4 smaller parts: Herceg Novi Bay, Tivat Bay, Risan Bay and the Bay of Kotor. The Bay is situated in a karstic mountainous setting that, in the hinterland of Risan, reach up to 1894 m a.s.l. with Mount Orjen. In Boka Kotorska Bay precipitations reach the European maximum of 4584 mm per year (Magaš, 2002), with high variations throughout the year, with almost no rainfall in late spring and summer. A huge amount of freshwater flows into the Bay from the five small rivers, and also from numerous streams and karstic submarine springs (*vrulja*). In summary, the influence of geographical, orographic and hydrographic conditions of the Bay determine a very different situation from the open sea, influencing the abiotic and biotic factors (Badalamenti & Treviño-Otòn, 2012).

In agreement with the researchers of the Institute of Marine Biology of Kotor, three sites were chosen to carry out the assignment (Figure 2.1): Dražin Vrt, Sopot and Turski rt (in the Verige strait). At the same time, all three sites meet three objectives: they represent different examples of typical bioconstructions in the Bay; they offer biotic features of absolute value both for the Adriatic Sea and the entire Mediterranean, and host a population of rare and protected Anthozoa.

The assignment was carried out following these methodologies:

1. a review of the available literature about general environment and benthic communities in Boka Kotorska Bay and Anthozoa; a literature review on the assessment of coralligenous assemblages; definition of the sites for fieldwork;
2. fieldwork to collect geographical data, proper documentation and samples, including on-the-job training;
3. laboratory work aimed at the treatment of samples for identification;
4. final rendering of collected photographs, measurements, rendering of panoramic images;
5. choice of a proper methodology for GES assessment;
6. data analysis and processing within the chosen methodology for GES assessment.

The research activities took place between September 11, 2019 and September 17, 2019 using the boat, and taking into account the characteristics of the terrain, the MAES index[4] was selected for the assessment and GES evaluation. The index takes into account the structure of the community, the conditions of the dominant erect species and the presence of visible signs of anthropogenic influence (Table 2.1).

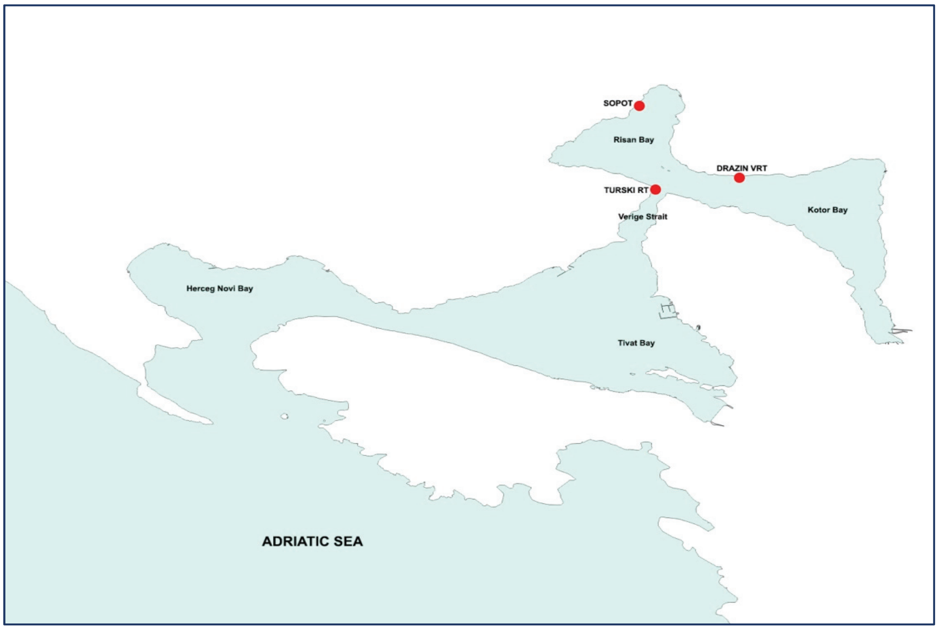


Figure 2.1. Locations monitored in Boka Kotorska Bay

Table 2.1. Summary of the elements and methods for calculating the MAES index

Metrics	Score 1	Score 2	Score 3	References
Number of megabenthic taxa	< 19	> 19 – < 30	> 30	Canovas-Molinas *et al*.. 2016
% biotic cover in the basal layer	< 43.5	> 43.5 – < 69.6	> 69.6	Canovas-Molinas *et al*., 2016
Density erect species (N°/area) Savalia savaglia	< 0.1	> 0.1 – < 0.5	> 0.5	Canovas-Molinas *et al*., 2016
Density erect species (N°/area) Spinimuricea klavereni	< 0.1	> 0.1 – < 0.2	> 0.2	Topçu & Öztürk, 2015
Average height dominant erect species (h = cm) *Savalia savaglia*	< 30	> 30 – < 60	> 60	Gaglioti et al, 2019; Pais *et al*., 1992; Cerrano *et al*. 2007; Trainito & Baldacconi, 2016.
Average height dominant erect species (h = cm) *Spinimuricea klavereni*	< 10	>10 – < 20	> 20	Carpine & Grasshoff,1975; Topçu & Öztürk, 2013-2015
% dominant erect species with epibiosis, necrosis	> 15.4	< 15.4 – > 9.6	< 9.6	Canovas-Molinas *et al*., 2016; Topçu & Öztürk, 2015
Density marine litter (N°/area)	> 0.1	< 0.1 – > 0.6	< 0.6	Canovas-Molinas *et al*., 2016

Ecological status	Score	References
Bad	6 <> 9	Canovas-Molinas *et al*., 2016
Moderate	10 <> 14	
Good	15 <> 18	

[4] MAES index – Mesophotic Assemblages Ecological Status, Cánovas-Molina *et al*., 2016

2.1.1 Dražin vrt

This site, located 35 m from the coastline, has been the subject of previous research that highlighted the singularity of the ecological conditions and, consequently, of the invertebrate populations (Badalamenti & Trevino-Oton, 2012; Golder/RACSPA, 2013). The site has a few meters high slope, covered by shrub vegetation, ending on the coastal road of the Bay. Along the east side of the site, there is a water pipe, and a lot of material of anthropic origin is observed on the slope and in the shoreline area. Just a few meters from the shoreline, the bottom reaches a depth of 5 m and continues with greater steepness up to 15-25 m into the area where monitoring was carried out, 30-40 m from the coastline. In the first few meters, the bottom of the sea is characterized by a stony ground with few metric blocks, covered with photophilic algae (mainly Cystoseira corniculata, Padina pavonia), ending at around 10 m of depth on a mixed bottom of coarse sediments and bioconcretions, with some scattered rocky blocks. The coral blocks end at a depth of 25 m on a bottom covered with thin sediments. In the sedimentary areas, there are clear signs of important sediment transport that interferes with the development of colonies of erect species. The area is characterized by submerged springs that were not active at the time of this monitoring.

At this site, 50 Operative Taxonomic Units (OTU) were detected. The algal component mainly consisted of brown turf algae covering the surface of rocky and coral blocks. The encrusting calcareous algae are rare and make an insignificant contribution to the external layers of bioconstructors. The emisciaphilic *Halimeda tuna* is the most common algal species, while *Padina pavonia* is widespread in shallow waters. Among the invertebrates, *Porifera* was found with 18 OTUs: the most common was *Acanthella cannabina* reaching about 1 specimen/10 m^2 and an average height of 36 cm.

Anthozoa comes as the second largest group with 10 species. Among them, *Savalia savaglia* is undoubtedly the species that is characteristic of the site. It has depth ranges between 9 and 22 m. The average height of this colony is 54 cm, and the maximum height is about 100 cm. The largest community occupies an area of about 6.5 m^2. The community shows no signs of epibiosis or necrosis in the distal branches, while the lower parts of the colony, which are in contact with the bottom, show obvious consequences of high sediment transport characteristic of this area (mainly due to air and subsurface sources), which is further driven by debris accumulation (mostly plastic bottles) at the base of the colony.

Less scenic but no less important is *Polycyathus muellerae*: it effectively structures the habitat, building articulated or compact blocks that provide a fundamental substrate for the installation of other organisms. Isolated coral herms, formed by *Polycyathus muellerae* and *Phyllangia americana mouchezii*, may reach heights that exceed 1 m (1.16 m) and volumes that exceed 1 m^3 (1.24 m^3). The *Gorgonidae Leptogorgia sarmentosa* is scattered across the site with few colonies (17.2 each 100 m^2), but probably it has played an important role in the diffusion of *Savalia savaglia*, offering, along with its ramifications, suitable substrates for the settlement of zoanthid's larvae. The discovery of colonies of the stolonifera *Sarcodictyon catenatum* requires specific insights.

Table 2.2. Assessment of ecological status, considering the MAES index, has shown that it would be classified as moderate

Site	N° megabenthic taxa	% biotic cover basal layer	Density erect species	Average height dominant erect species	% colonies epibiosis/necrosis	Litter density	Tot score	Ecological status
DV01	50	50	0.63	54	0	0.18	14	Moderate
Score	3	2	3	2	3	1		

2.1.2 Sopot

This site has not been the subject of previous monitoring research. The monitored site is about 35 m from the coastline. Morphological and environmental aerial conditions are quite similar to those reported for Dražin Vrt. A few meters high slope, covered by shrub vegetation, ends on the coastal road of the Bay. Along the east side of the site, there is a huge water inlet that drains at sea level and in winter, while it forms a waterfall with important flows in spring. At the time of this monitoring, freshwater was not released. The karstic system of Sopot was thoroughly explored and described by Eusebio *et al.*, 2007. It consists of a large main aerial cavity and an important submerged spring at a depth of about 30 m. The system is typically intermittent, with maximum flow rates in winter and spring, while in late summer and early autumn it is almost always dry.

The location is significantly burdened with waste, which is most likely the result of the proximity of construction work on the road construction project.

At this site, 46 Operative Taxonomic Units (OTU) were detected. The algal component mainly consisted of brown turf algae covering the surface of rocky and coral blocks. The encrusting calcareous algae are rare and make an insignificant contribution to the external layers of bioconstructions. The emisciaphilic *Halimeda tuna* is the most common algal species, while *Padina pavonia* and *Cystoseira corniculata* are diffused in shallow waters.

Among the invertebrates, *Porifera* was found with 22 OTUs: the most common among them was *Aplysina aerophoba/cavernicola* reaching about 1.2 specimens/10 m^2 and an average height of 14 cm. The species shows a high rate of necrosis.

Anthozoa comes as the second largest group with 7 species. Among them, *Savalia savaglia* is undoubtedly the species characteristic of the site. *Polycyathus muellerae* is quite important in effective structuring of the habitat, building articulated or compact blocks that provide a fundamental substrate for the installation of other organisms. Isolated coral herms, formed by *Polycyathus muellerae* and *Phyllangia americana mouchezii*, rarely reach heights that exceed 1 m. Gorgonia *Leptogorgia sarmentosa* is scattered across the site with few colonies highly affected by epibiosis (13%).

Table 2.3. Assessment of ecological status, considering the MAES index, has shown that it would be classified as moderate

Site	N° megabenthic taxa	% biotic cover basal layer	Density erect species	Average height dominant erect species	% colonies epibiosis/necrosis	Litter density	Tot score	Ecological status
SO01	45	50	0.60	45	2	0.14	14	Moderate
Score	3	2	3	2	3	1		

2.1.3 Turski rt

This site has not been the subject of previous monitoring research. It was included in the monitoring programme mainly to investigate a population of *Alcyonacea* observed by IBM researchers during the previous dives and to verify its relevance.

The site is located in the corner at the northwest end of the Verige Strait and the monitored area is about 30 m from the coastline. Morphological and environmental aerial and underwater conditions are quite different from those reported for the two other sites.

Anthropogenic material occupied the first meters of the submerged area, and the marine environment was severely degraded. The site is located at the narrowest point of the Verige Strait, approximately 280 m wide (each day a great number of small vessels and up to 3 cruise ships navigate through the strait).

In the first few meters, the bottom is characterized by coarse sediment, scattered pebbles often covered by a layer of encrusting red algae, and colonized by the sponge *Dysidea avara*. Colonies of *Leptogorgia sarmentosa* are scattered as the depth increases. Visibility was poor. At a depth of 28 m, the bottom was silty and the first colonies of *Spinimuricea klavereni* were observed in the turbidity. They remained sparse until they reach a depth of 32 m. At first, the bottom was covered by sparse and small colonies of *Cladocora caespitosa*, some with evident bleaching. Around the area, many colonies were damaged and surrounded by fragmented corallites and other debris. Reflecting the state of the coast, all kinds of anthropogenic material was found: a minivan, a cage, the chassis of a car, cables, metallic objects, glass and plastic bottles, two cars, a rubbish container. Some biogenic blocks were sparse until the bottom became uniformly covered by building waste. Then, at a shallow depth, past the corner, coarse sediment alternated with rocks covered by photophilic algae and *Aplysina aerophoba*. A total area surveyed in the two dives covered about 6,000 m^2.

At the site, 40 Operative Taxonomic Units (OTU) were detected. Comparably to the other two locations, the algal component consisted of brown turf algae covering the surface of rocky and coral blocks. The discovery of Sargassum acinarium is relevant. Among the invertebrates, *Porifera* was found with 11 OTUs. The most common species was *Dysidea avara* forming a facies in the southern part of the site.

Anthozoa comes as the second largest group with 10 species. The plexaurid Spinimuricea klavereni was the most common species distributed across the muddy bottom within 28 and 33 m of depth: Spinimuricea klavereni is a typical mesophotic species that until now had been found in the infralittoral zone only in Marmara Sea (Topçu & Öztürk, 2015).

The range of waste materials of human origin found at this site is much wider than at the other two sites.

Table 2.4. Assessment of ecological status, considering the MAES index, has shown that it would be classified as moderate

Site	N° megabenthic taxa	% biotic cover basal layer	Density erect species	Average height dominant erect species	% colonies epibiosis/necrosis	Litter density	Tot score	Ecological status
TR01	40	30	0.72	<10	0	high	13	Moderate
Score	3	1	3	1	3	1		

2.1.4 Conclusion: Coralligenous assemblages in Boka Kotorska Bay

The undertaken activities improved the knowledge concerning the three monitored sites from both quantitative and qualitative perspectives, providing key information for the conservation of key habitats and species and future monitoring activities.

The monitoring shed new light on the importance of the *Savalia savaglia* assemblages in Boka Kotorska Bay. The number of colonies at the two sites of Dražin Vrt and Sopot is a few units less than a thousand: this means that the Montenegrin contingent of the species is not only double in size compared to all the other colonies known in the Mediterranean, but that it is close to the consistency of the species at the Atlantic sites (Giusti *et al.*, 2015).

Also, the discovery of *Spinimuricea klavereni* was the first time that the presence of the species could be reported for the Adriatic Sea, which confirms special environmental conditions in Boka Kotorska Bay, where mesophotic species can be found at medium depths.

However, as all three sites were significantly affected by human activities, urgent measures are needed to preserve their outstanding environmental values, not only in Montenegro but also globally. In that regard, no-take, no-entry conservation status for these areas, in total smaller than 2.5 ha (0.3% of the total area of Boka Kotorska Bay), would make it possible to eliminate the impact of possible anchoring and fishing gears. These locations can also be used to organize guided underwater tours with trained professionals, which would promote the protection and need to monitor the condition of coralligenous assemblages. Besides, the implementation of such activities should be accompanied by the involvement and education of the general public on the global importance and pressures to which these extremely valuable and sensitive marine species are exposed. The high value of Boka Kotorska Bay lies not only in its history and tradition and peculiar marine and terrestrial landscapes but also in the richness and rarity of its depths.

2.2 CORALLIGENOUS ASSEMBLAGES IN THE OPEN SEA

Research of coralligenous habitats in the open sea was conducted at three (3) locations (Figures 2.2, 2.3 and 2.4). At the site of the Luštica Peninsula, two locations were selected: rt Mačka and Ponta Veslo, as they represent typical coralligenous assemblages, whereas the Krekavica cave in the Platamuni area represents the biocenosis of semi-dark caves. However, due to the importance of the present assemblages and the importance of the location, this site was also included in the research.

The applied sampling methodology is described in the National Monitoring Programme in the part concerning the monitoring of the state of biodiversity or coralligenous habitats, according to Garrabou *et al.* (2014). Having in mind that this is the first time this research has been conducted according to this method, it is considered the first testing in the context of the Montenegrin coast.

Using autonomous diving, several parameters were analysed by using photo squares:

1. Structure and abundance of species;
2. The degree of complexity of coralligenous habitats;
3. Influence of different pressures on the habitat.

In determining the target species, Annexes II and III of the Barcelona Convention, CITES II and the Decision on the protection of certain plant and animal species were taken into account.

At the site of Velika Krekavica cave, due to the limited space, there was a deviation from the proposed methodology, so square format photography was done at three depths (17, 19 and 21 m) and these photo squares were also used to assess the degree of complexity of the habitat. At the sites of Ponta Veslo and rt Mačka, the research included taking 3 series of 10 squares in the area of approximately 20 x 5 meters in the depth range of 28-35 m, as well as three transects of 10x1 m to assess the complexity of habitats.

2.2.1 Velika Krekavica cave

The site of Velika Krekavica cave is located in the zone of future marine protected area Platamuni and it represents a vertical type of distribution of this type of habitat (Figure 2.2). For this site, there is a certain amount of cave biodiversity data obtained during the research conducted for the MedKeyhabitats project (RAC/SPA-UNEP/MAP, 2016).

The research of the structure of the coralligenous assemblages included the interior of the cave, which went to a depth of 25 m, representing a vertical wall. Photo squares were made at depths of 17, 19 and 21 m. The analysis of all species based on the collected photo squares present in the interior of the Velika Krekavica cave identified 48 species, of which 11 are protected based on national and international law. Species identification included the analysis of photo squares, as well as identification of species recorded during the visual census.

The most common protected species include the sponge *Sarcotragus foetidus*, which was present in squares at a depth of 21 m, as well as the anemone *Leptopsammia pruvoti*, which was present in all squares at all depths and is the dominant species. Analysis of the coverage/distribution of protected species in photo squares showed that the largest area covered by the target species was at a depth of 19 m due to the presence of *Leptopsammia pruvoti.*

Analysis of coralligenous habitat complexity was done through the analysis of layers. The coverage/distribution of the base and middle layers was addressed through the calculation of their percentage share in squares. Given that there were no upright species in the cave, the corresponding (upright) layer was not taken into consideration.

The presence of plant and animal species belonging to the community builders group was evident, so in most squares, their coverage/distribution was at 100%. As for the presence of bioeroders, i.e. organisms that destroy the coralligenous substrate, the presence of *Rocellaria dubia* was recorded with a very low prevalence.

Habitat pressure analysis showed complete absence of fishing equipment, while the degree of sedimentation was negligible at a depth of 21 m. Sedimentation was very limited and did not appear to pose a threat to the coralligenous assemblages. No presence of muciligenic aggregations was noted in the researched area.

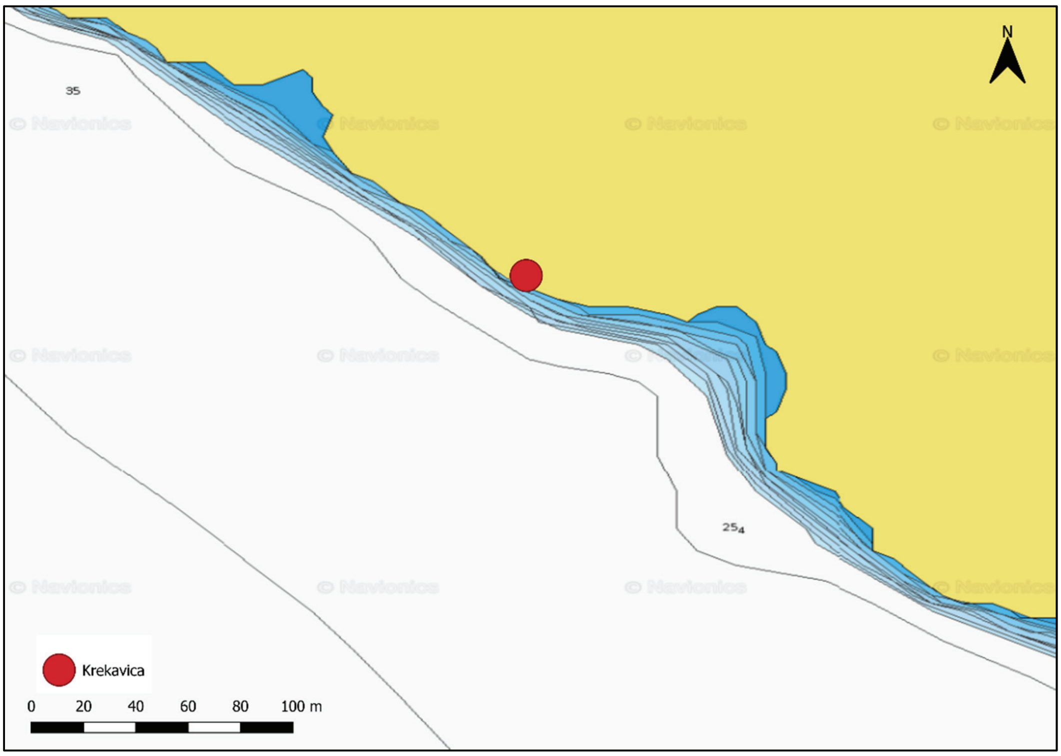


Figure 2.2. Site of Velika Krekavica

2.2.2 Ponta Veslo

Ponta Veslo is located on the Luštica Peninsula (Figure 2.3) and the area is characterised by a terraced terrain, i.e. rocks overgrown with algae on the upper side and algae and macroinvertebrates on the lateral vertical side. This site was proposed to be included in the research because, according to previous records, red coral was once collected at this site.

The configuration of the ground at the Ponta Veslo site is represented by cascading rocks that descend to a depth of 35 m and a muddy-sandy base with a much smaller slope extending further. The research included taking 3 series of 10 photo squares on the vertical side of the rocks and transects to determine the complexity of the habitat. Habitat analysis was performed in the depth range of 30-35 m.

Analysis of the species at the investigated locality showed the presence of 54 taxa out of which 9 species are included in the protection lists, whereas *Caulerpa cylindracea* is an invasive species.

Analysis of the coverage/distribution of target species based on photo squares, which primarily refers to protected species, showed their very low representation (Table 2.5). The largest representation was observed in the third series of photo squares. Protected species *Axinella verrucosa* and *Axinella damicornis* were present among the sponges, and since all species of the genus *Axinella* are protected under national law, even at locations where it was not possible to determine the species (Axinella sp.,) their coverage/distribution was calculated. *Leptopsammia pruvoti* was present as a representative of the corals.

Analysis of the complexity of the coralligenous assemblages in the Ponta Veslo area showed the complexity of the basal and intermediate layers, while the vertical layer was completely absent. The complexity of the primary layer was emphasised, amounting to over 99% along all three transects, while the coverage/ distribution of the middle layer was very low.

The presence of bioconstructors was strong, especially from the group of algae. High coverage/distribution was reported for *Gloiocladia repens, Peyssonnelia rubra, Peyssonnelia rosa-marina, Mesophyllum expansum, Peyssonnelia squamaria,* as well as for macroinvertebrates *Myriapora truncata, Spirastrella cunctatrix* and *Leptopsammia*. The presence of bioeroders was very weak, outside the photo square, it was in a somewhat wider zone.

Analysis of habitat pressure showed that there was a significant impact of fishing gear, specifically nets, in the researched area. Based on the number of fishing tools, it can be stated that it belongs to the category of medium (Garrabou *et al.*, 2014), and the fishing net stretched several tens of meters in length.

Sedimentation was present in the field but to the extent that could not endanger community development. Mucilagen aggregations were not present in the researched area, while the presence of the invasive species *C. racemosa* was observed, but in the area outside the photo square, so an assessment of its presence was not conducted.

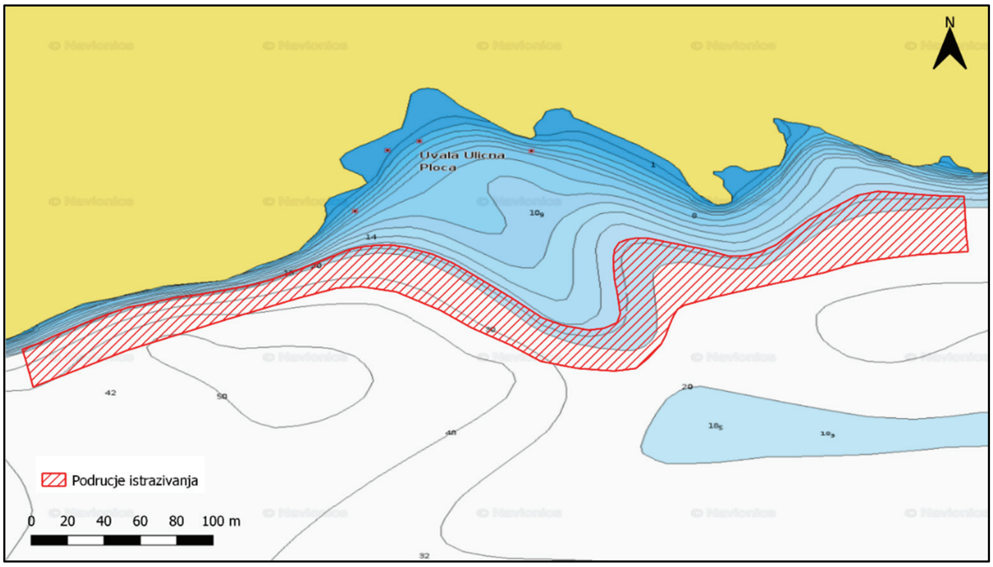


Figure 2.3. Ponta Veslo site

2.2.3 Rt Mačka

The researched site of rt Mačka, which is also located on the Luštica Peninsula (Figure 2.4), covers a sub-horizontally developed coralligenous habitat.

The terrain on which the research was conducted descends to a depth of 33 m and, at that depth, the solid surface turns into a sandy-muddy soft surface. Photo squares were made within the depth range of 28-33 m. The solid base overgrown with calcified algae was slightly lowered to that depth so that the position of the square was sub-horizontal.

Identification of the present taxa showed the presence of 43 plant and animal species. The research included the area covered by photo squares and the immediate environment that depicts the state of the community. Of the total number, 5 species are on the protection lists, while *Caulerpa cylindracea* and *Womersleyella setacea* are invasive species that dominated the researched area.

Coverage/distribution of protected species was extremely low due to the dominance of algae. The highest total coverage/distribution of target species was achieved in the first series of photo squares. *Axinella damicornis* was the only sponge species from the list of protected species.

Analysis of the complexity of coralligenous assemblages in the area of rt Mačka showed the complexity of the basal and intermediate layer, while the vertical layer was completely absent. The complexity of the primary layer along the transects I and II was evident, while the middle layer dominated along the transect III. Both the basal and intermediate layers were composed of algae. There were very few invertebrate species. The macroinvertebrate group was composed of only a few sponges or bryozoa.

There was a large presence of algae-bioconstructors in this area, especially the species *Peyssonnelia rubra, Peyssonnelia rosa-marina, Mesophyllum expansum, Peyssonnelia squamaria*, as well as *Myriapora truncate* for macroinvertebrates. The presence of bioeroders was very weak and outside the scope of the photo square, that is in the somewhat wider zone, the presence of *Cliona viridis* and *Rocellaria dubia* was recorded, as well as two specimens of *Sphaerechinus lividus*. In general, the presence of bioeroders cannot significantly affect the degradation processes in the community.

When visiting the area, the presence of the remains of fishing tools was observed, primarily the fishing net, which covered about ten m^2 of the terrain. Based on the number of fishing tools, impacts of marine litter can be categorised as medium (Garrabou *et al.*, 2014).

Sedimentation was kept to a minimum and posed no threat to the coralligenous community. Mucilagen aggregations have not been reported in this area.

The presence of invasive species was very noticeable. A large area was covered with algae *Caulerpa cylindracea* and *Womersleyella setacea*. In the series of photo squares taken along the transect I, their coverage/distribution was relatively low and uniform. The transect II was dominated by *C. cylindracea*, while the transect III was dominated by *W. Setacea*. This situation may indicate a high degree of endangerment of other species by the presence of invasive species.

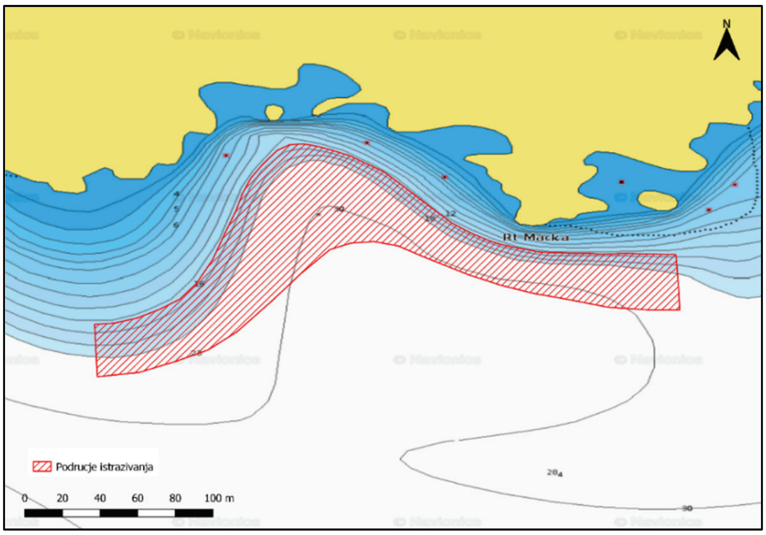


Figure 2.4. Rt Mačka site

2.2.4 Conclusion: Coralligenous assemblages in the open sea

The undertaken research at selected locations in the open sea, within the GEF Adriatic project, has provided insight into the state of species and habitats that can be important for future research on coralligenous assemblages in Montenegro.

The Velika Krekavica cave site is located in the zone of the future protected area Platamuni. Based on previous research conducted at this location, some data indicate the presence of protected species of sponges and corals that are not common along the Montenegrin coast. The specificity of environmental factors prevailing in cave conditions has led to the development of adaptive sciaphilous species. Even if this locality does not belong to the category of typical coralligenous habitats, it was selected for research due to the importance of the assemblages living in it. For this reason, it will not be used for comparison with other localities, but it will help provide an overview of the condition and quality of the living world that can be used for comparison in further monitoring activities.

Based on the data obtained from the analysis of habitat complexity at the sites of Ponta Veslo and rt Mačka, the upper layer is missing. This indicates that erect species whose height exceeds 15 cm have not been developed in that area. At the Ponta Veslo site, the basal layer was dominant, with coverage/distribution going up to 99.8% in photo squares, while the middle layer was present in the range of 0.15-0.45%. The base layer was dominated by algae, namely *Gloiocladia repens, Peyssonnelia rubra, Peyssonnelia rosa-marina, Mesophyllum expansum, Peyssonnelia squamaria,* whereas vertebrates were dominated by *Myriapora truncata, Spirastrella cunctatrix* and *Leptopsammia*. At the locality of rt Mačka, the representation of the basal layer ranged from 28.04 to 93.4% coverage/distribution, while the middle layer was represented in the range from 6.6 to 71.96%. However, the coverage/distribution and abundance of these species does not necessarily indicate the quality of the environment (Casas-Güell *et al.*, 2015), but rather the influence of some specific natural factors on the local level (Linares *et al.*, 2008). In any case, a coralligenous community, even without erect anthozoa can have a good ecological status (Piazzi *et al.*, 2014).

Coralligenous assemblages in the Mediterranean are often exposed to invasion by introduced macroalgae, which most often show seasonal dynamics and therefore contribute to modifying the structure of the coralligenous community (Cebrian *et al.*, 2012; Piazzi *et al.*, 2007). The most common invasive species on the coral reef are *Rhodophyta Womersleyella setacea* (Hollenberg) R.E. Norris and *Chlorophyta Caulerpa cylindracea* Sonder (Cebrian *et al.*, 2012). The conducted research has shown that these two invasive species of *C. cylindracea* and *W. setacea* were present at the rt Mačka site, which, due to their dominance, threaten to endanger other present species.

Determining the quality of the ecological status of a coralligenous habitat depends on a large number of parameters and may include erect bryozoa (de la Nuez-Hernández *et al.*, 2014), erect anthozoa (Cerrano *et al.*, 2014), as well as sensitive macroalgae such as *Udoteaceae, Fucales* and upright *Rhodophyta* (Balata *et al.*, 2011), as the most effective indicators of good ecological status. On the other hand, the dominance of algal turf, hydrozoa and overgrown sponges indicates degrading conditions (Piazzi *et al.*, 2017).

Considering the results obtained by the analysis of present species and habitat complexity, the conclusion is that the locations of Ponta Veslo and rt Mačka, even if they are not the most important in terms of the type of coralligenous habitats, are of good ecological status with moderate pressure of fishing gear, and at the location of rt Mačka, the pressure coming from by invasive algae has been emphasised.

HYDROGRAPHY, EUTROPHICATION AND CONTAMINANTS

During a three-day cruise, parameters important for hydrography, eutrophication and polluting particles were measured in the coastal and open waters of Montenegro in October 2019. Experts from three institutions participated in the research (Institute of Oceanography and Fisheries from Split – IOR, Center for Ecotoxicological Research from Podgorica – CETI and Institute of Marine Biology from Kotor – IBM), using the research ship BIOS TWO.

The measurement was performed at a total of 17 measuring stations distributed along 5 transects from Boka Kotorska Bay to the delta of the Bojana River (Figure 3.1). For a simplified explanation of the results, the research points were divided into five transects, namely: transect I (points 1, 2, 3), transect II (4, 5, 6), transect III (7, 8, 9, 10), transect IV (11, 12, 13, 14) and transect V (15, 16, 17). The depth at the measuring stations varied from the shallowest station at a depth of 15 m (measuring station 11) to the deepest station at a depth of 217 m (measuring station 3).

Under the influence of the gradient-free air pressure field, calm and stable weather prevailed during the first day of monitoring. The atmosphere was dry and very warm for that time of year. From the 8th day of the month until the end of the cruise, the warming of the atmosphere and the increase of relative humidity with the wind of mostly low intensity were visible. Very warm and sunny weather prevailed, mostly without rain. At the beginning of the cruise, it was rather calm, or the wind of coastal circulation prevailed. Later, the wind from the south became stronger, causing occasional moderate to larger waves.

Map of researched area for biological, chemical and hydrographic parameters

Measuring station	Date (d/m/y)	Time (UTC+1)	Depth (m)
1	09.10.2019	08:11	103
2	09.10.2019	10:21	117
3	09.10.2019	12:55	217
6	09.10.2019	16:27	123
8	09.10.2019	18:35	67
7	10.10.2019	08:04	36
4	10.10.2019	09:41	29
5	10.10.2019	10:57	87
10	10.10.2019	13:13	86
9	10.10.2019	15:30	81.5
15	11.10.2019	09:17	11.5
16	11.10.2019	10:21	59
17	11.10.2019	12:00	83.5
14	11.10.2019	13:44	87
13	11.10.2019	15:17	77
12	11.10.2019	16:28	55
11	11.10.2019	17:30	15

3 HIDROGRAPHY

To gain insight into the hydrographic properties of the aquatorium, during the three-day cruise, the vertical variability of temperature, salinity, seawater density and spatial variability of transparency were measured. Temperature and salinity were measured using a multiparameter CTD probe (SBE-25) calibrated in August 2018. Transparency was measured using a SECCHI whiteboard during the bright part of the day on the side of the ship that was not facing the sun.

3.1 THERMOHALINE PROPERTIES

The vertical structure of temperature and salinity was measured at 17 measuring stations along five (5) transects. The vertical changes in temperature and salinity measured during the cruise in October 2019 show, for that time of year, a still significantly stratified water column as a result of prolonged summer conditions and the absence of stronger water column mixing. The temperature differences at the top and bottom of the thermocline were approximately 6.5°C, which indicates the water column stability.

The measured values along the first two transects (measuring stations 1-6) showed three layers: a well-mixed surface layer of uniform temperature and salinity to a depth of 30 m, a thermocline layer where vertical temperature gradients were significant, and a layer below the thermocline, below approximately 50 m, with the weakening vertical gradients. At the measuring station 3, whose depth is 210 m, the temperature at the bottom was below 15°C, and the salinity was 38.9 ‰.

The third profile has shown a well-mixed surface layer of uniform temperature and salinity from the coast to the open sea. In the surface part, extending up to 40 m, the salinity was 38.9 ‰. At measuring stations 8, 9 and 10, below the halocline (layer with vertical gradients of salinity), a water core of reduced salinity was observed as a consequence of specific conditions of local circulation. Relatively high salinity values in the surface layer, slightly higher than the layer below the halocline, can be attributed to local evaporation-related conditions increasing the salt content.

At the measuring stations closer to the delta of the Bojana River (fourth and fifth profile; measuring stations 11-17), there is also a thermocline at a depth of 30-40 m and a halocline of variable depth, mostly above 10 m. At the surface closer to the shore, up to a depth of 10 m, water with reduced salinity (38.5 ‰ -38.6 ‰) and lower density is spilled. In the layer 20-40 m deep in the central part of the transect, there is water characterised by slightly higher salinity (39.0 ‰) whose origin can be attributed to the adequacy of a water supply from the south in the presence of the eastern Adriatic current, which brings warmer and saltier water from the Mediterranean.

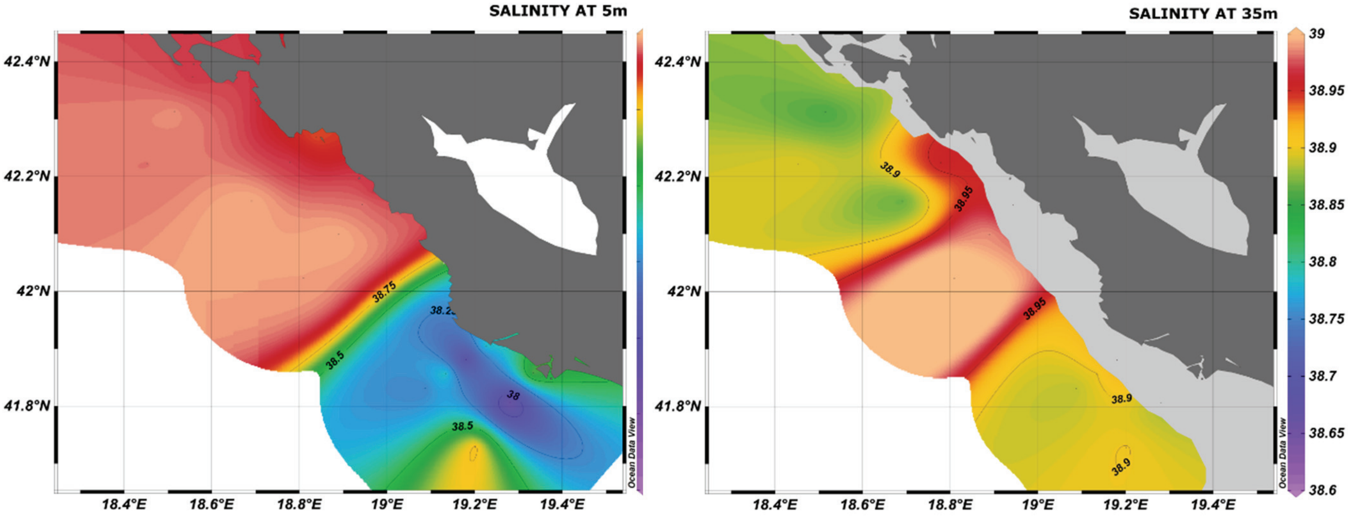
The horizontal distribution of temperature, salinity, and density was analysed for three layers: 5 m, 35 m, and the bottom. At a depth of 5 m, during this cruise, the temperature differences were within 1°C (from 22.1–22.7°C), with maximum values along the coast and in the areas of reduced salinity. The salinity range was from 37.5-39.0 ‰ in parts in which the influence of Bojana is clearly visible – the area of reduced salinity (Figure 3.2). The influence of colder and saltier water was visible in the northern part of the aquatorium, probably as a consequence of the southern Adriatic vortex.

At a depth of 35 m, the current from the open sea in the north of the aquatorium was still noticeable, as well as the increase in temperatures in the south (from 18–22°C). Regarding the salinity, the changes were small, but two completely different areas still had to be separated: the first, which is under the influence of the open sea (southern Adriatic vortex), and the second, which is under the influence of Bojana, with less pronounced gradients than at the surface.

Thermohaline properties in the bottom layer are minimal, with a visible influence of Bojana and another freshwater from the land.

Horizontal changes in temperature and salinity at various depths, although small in range, indicate the presence of waters with different characteristics, whose origin is partly from the open sea (SAG), from the influence of Bojana, as well as currents along the eastern coast (EAC).

Figure 3.1. Spatial salinity changes at depths of 5 and 35 m



3.2 TRANSPARENCY

Transparency was measured with a Secchi disk at all measuring stations except 8 and 11 due to reaching the measuring station at dusk/night. Measurements at other measuring stations show that the average transparency of this area is 17.2 m with a standard deviation of 4.51 m and a range of 7-25 m (Figure 3.2).

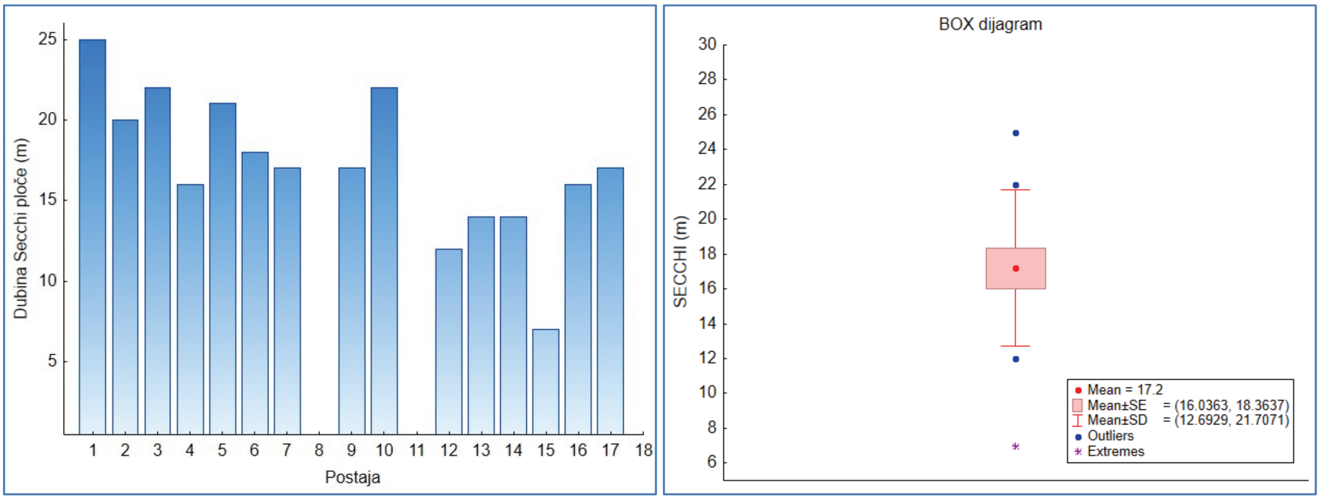


Figure 3.2. Transparency of seawater

3.3 CONCLUSIONS AND RECOMMENDATIONS

Climate change in the Adriatic Sea, deep in the Mediterranean basin sensitive to climate change, changes the heat and salt content of the sea, and thus the thermohaline circulation (Schroeder *et al.*, 2017; Vilibić *et al.*, 2013). For this reason, their effect should be continuously monitored, considering that it can permanently change the hydrographic properties of seawater. The influence of climate pressure can be monitored by measuring the thermohaline properties of the water column, i.e. by measuring temperature, salinity and transparency.

Positive trends in sea temperature have already been established (Grbec *et al.*, 2018) as well as the response of the Adriatic ecosystem to climate change (Grbec *et al.*, 2009; Šolić *et al.*, 2018). In addition to the thermohaline structure, other physical properties of the sea, such as waves or currents, can be measured too.

Climate change can have a direct impact on the marine ecosystem due to the weakening of horizontal and vertical water exchange, which can reduce, for example, oxygen content in the sea. For these reasons, it is extremely important to consider thermohaline variability under the influence of climate and climate change.

In this regard, and in line with the results of the conducted research, the following recommendations that need to be applied in future monitoring and reporting have been defined:

1. *Climate analysis* – Based on all available data on temperature, salinity and transparency, it is necessary to determine the thermohaline climate of this part of the Adriatic by using appropriate statistical analysis methods with special reference to perennial and seasonal variability;
2. *Monitoring* – The analysis of thermohaline properties of the area concluded that future monitoring should improve the spatio-temporal resolution of CTD measurements. Measurements should be carried out at multiple monitoring stations spatially distributed along multiple transects, with a larger number of stations in an area where a freshwater impact from the mainland (such as the Bojana estuary area) can be observed. Also, to determine the time variability of these properties, it is important to conduct monitoring several times a year, at least once a season, noting that the annual course of temperature and salinity can be calculated with at least 7 cruises per year. This would give a better spatio-temporal description of thermohaline variability;
3. *Physical oceanography* – It is necessary to build the capacity of experts in the field of physical oceanography who could describe and explain the specific conditions and circulation in the sea, as well as the complex dynamics of the Adriatic Sea and its ecosystem.

4 EUTROPHICATION

Eutrophication is the process of enriching ecosystems with organic substances and it can be natural and anthropogenic. Recently, anthropogenically induced eutrophication has become more frequent, which is becoming a significant problem along the Mediterranean and the Adriatic coastlines.

The growing anthropogenic impact that comes from the development of tourism, agriculture, industry, maritime transport and port activities is becoming more pronounced in the Adriatic. Due to its structure (extremely shallow, 80 m) and strong inflow of nutrients through rivers, it is often exposed to eutrophication (Revelante and Gilmartin, 1992; Turley, 1999; Faranda *et al.*, 2000). The southern Adriatic is considered highly oligotrophic. However, despite its generally oligotrophic character, the coastal part is under increasing human influence and with increased eutrophication (Drakulović *et al.*, 2017). Signs of eutrophication are becoming more common along the shores of the Montenegrin coast, especially Boka Kotorska Bay (Drakulović *et al.*, 2011, 2012). Some species are disappearing, while some opportunistic phytoplankton species are becoming dominant (McQuatters-Gollop *et al.*, 2009).

Temperature and salinity are extremely important factors in assessing the state of the sea and taking into account the eutrophication process. The analysis of the state of these hydrographic parameters is presented in Chapter 3.

4.1 DISSOLVED OXYGEN CONTENT IN THE WATER COLUMN

The amount of oxygen in mg/l of seawater is an indicator of the aeration of seawater, but also the production of phytoplankton during which oxygen is released. This indirectly shows the amount of nutrient salts without which phytoplankton cannot be produced, which come to the coastal sea mostly from the land.

The results of oxygen saturation (%) analysis showed that the values were higher in the surface and subsurface layers, and that they decreased with the depth of the values (Bellafiore *et al.*, 2011, Buljan, Zore-Armanda, 1971), with the exception of specific points. The values in the surface layer ranged from 4.80–5.33 ml/l. The maximum oxygen concentration was recorded at the measuring station 16 along the transect V at 54 m and it amounted to 5.71 ml/l. The lowest values of oxygen concentration were measured along the transect I at the measuring stations 1 (101 m) and 3 (216 m) amounting to 4.76 and 4.73 ml/l, respectively.

Increased values of oxygen saturation in the surface layer are a consequence of more intensive process of photosynthesis due to the influx of higher concentrations of nutrient salts.

4.2 CONCENTRATION OF KEY NUTRIENTS IN THE WATER COLUMN

During the research, the concentration of the following compounds was measured:

- phosphate concentration in the water column;
- the concentration of total phosphorus in the water column;
- the concentration of ammonia in the water column;
- nitrate concentration in the water column;
- nitrite concentration in the water column;
- the concentration of total inorganic nitrogen;
- the concentration of total nitrogen;
- the concentration of orthosilicates in the water column.

The variability of the orthophosphate concentration is less pronounced in the surface and subsurface layers, so the values of the orthophosphate concentration are lower compared to the bottom layers, where a slight increase in the orthophosphate concentration was recorded. This is especially notable at the measuring stations along the transects I, III and IV (2, 3, 9, 10, 11, 12, 13 and 14). The middle value of orthophosphate concentrations at the examined measuring stations was 0.117 μmol/dm^3, and the total dissolved phosphorus was 0.338 μmol/dm^3. According to the horizontal distribution of orthophosphates in the surface layer, the highest concentrations were found at points close to the coast, however, based on a comprehensive analysis, it cannot be stated that orthophosphates in this layer are of anthropogenic origin. Based on the examined parameters, it was concluded that there were differences in the average concentrations of total dissolved phosphorus in all layers of the water column in relation to orthophosphates. In general, the concentration of total phosphorus has lower values in the surface layer compared to the deeper layers.

The range of ammonium ion concentrations at the examined points had approximately equal values in the surface and subsurface layer, while in the bottom layer the range of ammonium ion concentrations had higher values. According to the average concentrations in the surface, subsurface and bottom layers, the highest values of nitrate concentration were found in the bottom, followed by the surface layer. The highest range of nitrate concentrations was found along the transect I, while the lowest was found in the transect IV. A relatively similar state was found for nitrites and ammonium salts, as well as their sum (DIN). Based on all data, i.e. the sum of the concentration of all three forms of nitrogen salts expressed in total dissolved inorganic nitrogen (DIN), the middle value (whole water column and all points combined) was 0.880 μmol/dm^3. Based on the vertical distribution, in general, the DIN concentration for most of the examined points had higher values in the surface layer, only to decrease in the subsurface layer. Also, in the deeper layers, the concentration of total dissolved inorganic nitrogen in general had significantly higher values at certain points, compared with the surface layer.

Based on the average concentration of orthosilicates, it was concluded that the values were higher in the surface layer, followed by the bottom layer.

Concentrations of nutrient salts (nitrogen and phosphorus), as well as the oxygen saturation levels of the water column are important in assessing the ecological status of the marine environment, i.e. the impact of anthropogenic pressures to which a certain area is exposed. Based on the limit values of the trophic index TRIX (Vollenweider *et al.*, 1998), which are often used for assessment, the state of oxygen saturation at the examined points from the surface to a depth of 10 m, as well as in the bottom layer is assessed as very good. When assessing the condition according to the concentrations of total dissolved inorganic nitrogen (DIN), the condition of all examined points was assessed as very good.

Assessment of the situation based on the concentration of orthophosphate, the examined points were rated Category A according to the Regulation on the classification and categorization of surface and groundwater[5], since there is no TRIX criterion for this parameter. The results for total phosphorus (PTOT) concentrations show that the points were rated as good to very good, based on the TRIX trophic index limit values. The concentration of total dissolved nitrogen, as well as the concentration of orthosilicates, do not affect the assessment of the state of the marine environment, primarily because the state of these parameters is not evaluated when calculating the trophic state of the environment.

4.3 CHLOROPHYLL-*A* AND PLANKTON

Knowledge of the taxonomic composition of phytoplankton is extremely important for the assessment of ecological characteristics of the sea – trophic status, eutrophication, sea bloom and nutritional relationships, as well as for the understanding of marine biodiversity. However, in addition to the qualitative composition of phytoplankton, the quantitative aspect should also be taken into account, as it indicates the trophic state of the ecosystem. Given that the pigment is chlorophyll and serves as an indicator of phytoplankton biomass, it is very important for assessing the degree of trophicity.

The methodology used for biological sampling – phytoplankton and chlorophyll-a complies with the ISO 5667-9:1992 standard. The methodology used for the analysis of phytoplankton complies with the MEST EN 15204:2014 standard.

[5] "OG of MNE", no. 2/07

In the process of conducting the research, the recorded values of chlorophyll-a concentration are characteristic of less oligotrophic to the more oligotrophic areas, according to the criteria used by Simboura *et al.* (2005), which coincide with 5 levels of ecological status as proposed in the Water Framework Directive (WFD).

The recorded values of chlorophyll-a, as an indicator of the biomass of phytoplankton organisms, indicate lower productivity in the researched area.

During the research of the number of phytoplankton communities along the transects, recorded values showed the results characteristic of the oligotrophic area, to a lesser extent mesotrophic and, in only a few positions near the coast along the transects I and V (by Boka Kotorska Bay exit and in the area near Ulcinj), in total, plankton values were characteristic of the eutrophic area (Kitsiou and Karydis 2001, 2002). The reason for the lower number of phytoplankton organisms is because the researched area is under the strong influence of the open sea and the change of water masses is better, which in turn contributes to lower phytoplankton production, as a consequence of the lower concentration of nutrients. Higher phytoplankton values were recorded in the coastal area, which is under the influence of the coast and those with a higher influx of nutrients, while in positions that are far from the coast, phytoplankton production was lower.

The following 5 groups of phytoplankton organisms have been recorded:

- Baccillariophyceae (diatoms);
- Dinophyceae (dinoflagellates);
- Prymnesiophyceae (coccolithophorids);
- Chrysophyceae (silicoflagellates);
- Chlorophyceae (chlorophytes).

The largest number of species that were dominant and recorded with the highest frequency of occurrence during the research, such as *Chaetoceros affinis*, *Dactyliosolen fragilissimus*, *Leptocylindrus danicus*, *Pseudo-nitzschia spp*. and *Thalassionema nitzschioides* prefer the areas which are rich in nutrients (Pucher-Petković and Marasović, 1980). This indicates mild changes that must be continuously monitored, with the aim of avoiding possible side effects in the event of increased productivity of these organisms.

The following species have been reported as potentially toxic – diatoms of species from the genus *Pseudo-nitzschia spp*. with up to 103 cells/l. The following species have been recorded as toxic and potentially toxic species of dinoflagellates: *Dinophysis acuminata, D. acuta, D. caudata, Lingulodinium polyedra, Phalacroma rotundatum, Prorocentrum cordatum and P. micans*. The number of harmful aquatic organisms and pathogens (HAOP) is still not on the rise and alarming, however, it indicates the need for monitoring to prevent possible negative impacts on the marine environment and human health.

The obtained data indicate that there is still no increased development and increased productivity of phytoplankton organisms. However, the appearance of species that prefer areas rich in nutrients and presence of harmful and toxic organisms indicate mild changes that must be continuously monitored to avoid possible side effects in the event of increased productivity of these organisms.

Zooplankton

Based on the research on zooplankton community within transects in Montenegrin waters, a statistically significant difference in the total number was determined ($p<0.05$, Kruskal-Wallis).

The total number of zooplankton increases in the direction from the island of Mamula to the Bojana River. The highest abundance was recorded along the transect IV, at the shallowest locality in the upper sampling layer, amounting to 4,820 ind m^{-3}. Measuring stations 4, 7, 11 and 15 have a typical coastal character, and due to the shallow depth and the absence of a precisely defined thermocline, samples were collected in just one move of 2 m above the seabed to the surface.

Observing each transect separately, a slight decrease in the total number of zooplankton could be observed, going towards deeper localities and farther from the coast. The exceptions are the transect IV and the measuring station 14 at which the deviation was found. The lowest total number of zooplankton was recorded at the most remote locality of the transect I (measuring station 3), amounting to 212 ind m^{-3}.

Altogether, 11 groups of zooplankton have been found and they are as follows: *Hydromedusae, Siphonophorae, Ostracoda, Cladocera, Copepoda, Pteropoda, Appendicularia,* *Chaetognatha, Hyperiidea, Thaliacea*, as well as Meroplankton organisms. A total of 70 taxa of holoplankton organisms and 8 meroplankton were identified.

Single sampling and analysis of zooplankton in the open sea of Montenegro showed large variations in the value of zooplankton by transects, especially in the transect IV. Secondary production decreases substantially from coastal areas to the deep sea, while statistically it significantly increases from the transect I to transect V, which indicates a very strong influence of the Bojana River, i.e. the freshwater inflow.

Measuring stations 4, 7, 11 and 15 showed the characteristics of typical coastal localities with significantly higher secondary production compared to the transect localities. The only exception was the measuring station 14 along the transect IV, where higher levels of zooplankton were recorded in relation to the localities of the transect closer to the coast.

5 CONTAMINANTS

The monitoring programme of sediment quality included the analysis of the following parameters:

- Inorganic contaminants:
  - Heavy metals: Cd, HgT, Pb;
- Organic contaminants:
  - Organochlorine pesticides (hexachlorobenzene, aldrin, dieldrin, endrin, heptachlor, DDE, DDD, DDT);
  - PCB-7 congener;
  - PAHs.

Criteria used for assessment of the state are defined in UNEP/MAP guideline[6] and the OSPAR guideline[7].

Criteria used for the assessment of the level of contamination according to the UNEP/MAP and OSPAR are:

- BC – *Background concentration*, which refers to the naturally present content of contaminants;
- BAC – *Background assessment concentration*: developed by OSPAR Commission for assessment when the contamination of the content is close to the natural level;
- EAC – *Environmental Assessment Criteria* – concentrations below EAC values that do not cause any chronic effects on marine organisms;
- ERL – *Effects Range Low* – a concentration below the ERL value means that there is no significant hazard to marine organisms. Some of the living organisms in the sea can also be adversely affected by concentrations of contaminants that are higher than ERL.

To protect the marine ecosystem, it is very important to determine the level of sediment pollution, as well as to propose remedial measures for the already polluted area. In line with the OSPAR approach, UNEP MAP has established concentration thresholds for the Mediterranean Sea, which are defined as T_0 and T_1.

T_0 is defined in sediments and biota, as the concentration of contaminants in an "intact" or "remote" place, where environmental degradation cannot be expected. On the other hand, T_1 is the concentration above which significant negative effects on the environment or human health most often occur (green/red transition point). Between T_0 and T_1, pollutant levels do not pose a significant threat to the environment or human health (Figure 5.1). In this sense, the colouring represents both the status and the measures that need to be taken. An explanation of the pollution-dependent measures and status, as well as the interpretation of the scheme is shown in Table 5.1.

5.1 HEAVY METALS

Metals are naturally present in the marine ecosystem, but their content has increased significantly in the past decades due to pollution of the marine ecosystem by anthropogenic activity (industry, wastewater, transport, agriculture…). This becomes a serious environmental problem because metals are not biodegradable, so once they are introduced into the marine ecosystem, they become an integral part of it and tend to remain there permanently.

Sediment samples collected at the locations in the marine area of the northern part of the Montenegrin sea have a similar clay-sandy structure. The results show that the content of tested metals in the samples from this area is approximately the same and that the concentrations of all three tested elements are below the MedBAC value. The amount of mercury in this area is very close to natural levels.

Out of the seven sediment samples collected from the marine area in the middle part of the Montenegrin sea, samples from the measuring stations 4 and 7, in which the sand structure dominates, are distinguished by their appearance. Sand is mainly made of quartz, which, in addition to silicon and oxygen, contains a very small amount of other elements. The lowest concentrations of lead and mercury were found in the samples collected at the previously mentioned two locations. However, at the

[6] UNEP(DEPI)/MED 439/15-Pollution Assessment Criteria and Thresholds

[7] The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)

measuring station 7, the cadmium content exceeds the MedBAC value but is significantly below the ERL, which leads to the conclusion that there is no danger to the wildlife of the marine ecosystem when this element is in question. The lead content at the measuring station 9 exceeds the MedBAC value and, as is the case with cadmium, there is no danger posed to the wildlife of the marine ecosystem. The mercury content in this area is very close to natural levels.

The marine area of the southern part of the Montenegrin sea is dominated by sediment which, based on its smallest structures, can be assumed to be clay (12, 13, 14, 16 and 17). Clay and organic matter have the net negatively charged surface functional groups, so metals are most often connected with organic matter and clay. Considering that these are samples that look like clay, it should be kept in mind that the clay has a high surface-to-volume ratio due to the size of the particles (<0.004 mm), so heavy metals are allowed to bind/sorb on their surface. It can be assumed that this is the cause of a slightly higher middle concentration of lead (exceeding MedBAC) at the measuring stations 12, 13, 14 and 17. Sediments collected from the measuring stations 11 and 15 have a slightly larger grain structure, so it can be assumed that it is sand. The metal content analysis revealed that the lowest content of lead, cadmium and mercury was found in these two samples, which mostly differ in appearance. The content of cadmium and mercury in all samples from this area is below the MedBAC value.

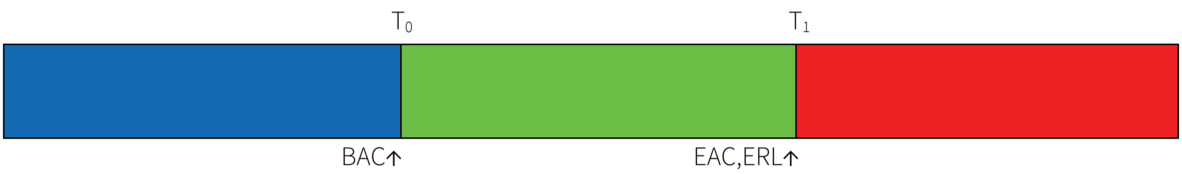


Figure 5.1. Proposed transition points for metals, PAH and chlorinated components in sediments

Table 5.1. Status and proposed measures concerning the content of contaminants

Colour	A legend that explains the meaning of colours	Possible activities
Red	Status is unacceptable	
	Concentrations of contaminants are at such levels where there is an unacceptable risk to the environment and the living world. Potential for significant adverse effects on the environment or human health.	Measures that are being applied or considered to be applied to address the cause. Regular monitoring to determine the situation and trends.
Green	Status is acceptable	
	Concentrations of contaminants are at levels where it can be assumed that there is little or no risk to the environment and wildlife. There is no significant risk of adverse effects on the environment or human health.	Measures are generally not needed to improve their status, but they may be needed if there is a deteriorating trend. Appropriate monitoring regime to ensure that there is no deterioration.
Blue	Status is acceptable	
	Concentrations are close to BC concentrations or zero, i.e. the ultimate goal of the OSPAR Strategy for Hazardous Substances has been achieved.	No measures are required. Appropriate monitoring regime to make sure that there is no deterioration.

5.2 ORGANIC CONTAMINANTS

Non-polar organic micro- contaminants, such as polycyclic aromatic hydrocarbons, PCBs and organochlorine pesticides, which are absorbed in the sediment, have low bioavailability for freshwater and marine animals compared to water. Sediment bioaccumulation factors (concentration in animals/concentration in sediment) of the tested organic contaminants range from less than 0.1 to about 20, several orders of magnitude lower than water bioaccumulation factors for the same compounds.

The bioavailability of organic microcontaminants absorbed in sediment is directly related to the solubility of the compound and the grain size of the sediment and inversely related to the concentration of organic carbon in the sediment and the size of the animal. Organic micro-contaminants adsorbed to sediment are slightly bioavailable, but sediments in contaminated areas often contain high concentrations of adsorbed contaminants; therefore, they represent an important source of pollution for both freshwater and marine animals.

The results of sediment analysis show that the content of polyaromatic hydrocarbons in sediments across the entire sampling area (southern, middle and northern part of the Montenegrin sea) is below the BAC value, which indicates that it is the natural content (BC) of these compounds. Therefore, it does not represent a risk for the environment.

The content of PCBs and organochlorine pesticides is significantly below the BAC value (all OCl and individual PCBs are below the LOD), indicating that there is no environmental risk from these sediment components in the area that was the subject of sampling and analysis.

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Implementation of the ecosystem approach in the Adriatic through marine spatial planning

The GEF-funded project "Implementation of the Ecosystem Approach in the Adriatic Sea through Marine Spatial Planning" (GEF Adriatic) is carried out across the Adriatic-Ionian region with focus on two countries: Albania and Montenegro.

The main objective of the project is to restore the ecological balance of the Adriatic Sea through the use of the ecosystem approach and marine spatial planning. Also, the project aims at accelerating the enforcement of the Integrated Coastal Zone Management Protocol and facilitating the implementation of the Integrated Monitoring and Assessment Program. Eventually, it will contribute to the achievement of the good environmental status of the entire Adriatic. The project is jointly lead by UNEP/MAP, PAP/RAC and SPA/RAC. In Montenegro, the project is being implemented with the coordination of the Ministry of Sustainable Development and Tourism. The project duration is from 2018 to 2021.

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