

Creating the base for MSP; depicting the environmental status of Inner Ionian-Korinthiakos Gulf

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Abstract Marine Spatial Planning (MSP) reflects the need to plan and regulate all human uses taking place in the marine environment, under the scope of protecting marine ecosystems. MSP requires the identification of the specific ecological characteristics of the marine area to be managed, as well as the human uses taking place and the main pressures and impacts induced. The present work focused on Inner Ionian-Korinthiakos Gulf, situated in Western Greece, defining the status of the coastal and marine environment of the area in the framework of MSP. Existing information was collected, gathered in a geodatabase and mapped; biological and ecological distributions, areas of importance for particular species, communities or habitats; oceanographic and other physical environmental features (bathymetry, currents, sediments, seismicity), spatial and temporal information regarding human activities and pressures caused. The data collected was related to MSFD characteristics and pressures, based on Directive 2017/845, Annex III. The outputs included maps depicting the interrelation of the physico-geographical features with important biological and ecological characteristics as well as the current pressures in the Inner Ionian-Korinthiakos Gulf marine area.

Keywords: Marine Policy, MSFD, Ecosystem Approach.

1. Introduction

Over the past two decades Marine Spatial Planning (MSP) has matured from a concept to a practical approach to moving toward sustainable development of the ocean (Ehler, 2020b) and has grown globally to be acknowledged by practitioners as the best available process to manage comprehensively marine resources in space and time (Ehler, 2020a).

The Marine Strategy Framework Directive (MSFD) 2008/56/EC provides a mechanism for EU Member States to identify criteria and targets for Good Environmental Status (GES). The activities or uses taking place in the marine environment that compromise environmental status must be addressed explicitly when identifying management measures to achieve GES (Gilbert et al 2015). However, the MSFD does not

provide the operational framework to manage those activities (Frazão Santos et al. 2012). This is where the MSPD 2014/89/EU is introduced, acting complementarily with the MSFD, focusing on activities at sea and how they could be planned and regulated under the scope of protecting marine ecosystems. The integration of the MSFD implementation with the ongoing MSP processes have several advantages as they perform; assessment of the marine environment; environmental monitoring; actions to preserve and obtain GES (PoMs), robust consideration of the marine environment in the planning process; and promotion of the application of Ecosystem Based Management (Abramic A., 2020). MSFD (Art. 1) clearly states that marine strategies “shall apply an ecosystem-based approach to the management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of GES. Also, MSPD makes explicit reference to the MSFD within its legal text, stipulating that MSP should apply an ecosystem-based approach and help achieve GES. Thus, Ecosystem Based MSP has been developed and identified as a process to favour and even ensure the good quality state of the sea in parallel with the human sustainable economic growth (McLeod et al., 2005). It should provide spatial solutions for the management of human activities in a way that is compatible with the achievement of GES and the capacity of marine ecosystems to respond to human-induced changes” (Ansong et al., 2017). A major challenge to apply the Ecosystem Based MSP is to gather knowledge on the structures and functions of ecosystems, as well as on the pressures and direct and indirect impacts induced on these ecosystems from various human activities (Dassenakis et al, 2019).

The scope of this study is to define the current status of the coastal and marine environment of Inner Ionian-Korinthiakos Gulf in Western Greece, in order to inform the subsequent steps of the planning process in the framework of Ecosystem Based MSP application.

2. Methodology

The MSP process in the area of Inner Ionian-Korinthiakos Gulf entailed the collection and mapping of

existing information concerning; ecosystem components (habitats, species) of conservation importance; oceanography and other physical parameters; human activities and associated pressures. The information was gathered in a geodatabase, and related to MSFD characteristics and pressures, based on Directive 2017/845/EU, Annex III. The outputs provided the interrelation of the physico-geographical features with important biological and ecological characteristics as well as the current pressures.

3. Results & Discussion

3.1. Physico-geographical setting

The area of Inner Ionian - Korinthiakos Gulf is about 13,400 km², limited to the West in the Ionian Sea (from South to North) by Kyllini cape, Zakynthos, Kefalonia, Lefkada and the deltaic plain of Acheloos River and to the East by the Corinth canal (Gulf of Corinth). The bathymetry of the Patraikos Gulf is rather shallow, with the deeper part being in the inner part of the gulf, reaching a depth of 130 m. In Patraikos gulf, an extensive active faulting of WNW-ESE trend is present, crossing the fault system obliquely (Ferentinos et al., 1985).

Korinthiakos Gulf is rather deeper, with a maximum depth of 850 m, due to the typical of an active, elongated tectonic area (graben) (Moretti et al., 2003), with a WNW-ESE direction. Inland, at the areas neighbouring Korinthiakos Gulf, the morphology is rather steep, following that of the underwater area. The Inner Ionian Sea is shallow at its Eastern part up to the depth of 100 m, due to the deltaic deposits of Acheloos River which prodeltaic progradation deposits reaches the coasts of Zakynthos, Kefalonia and Lefkada Islands at the western part and deepens steeply from 100 to 200 m at the central part of the Inner Ionian. Bathymetry in the Western part is steeper, reaching the depth of 200 m. The main tectonic features of the Inner Ionian area are two elongated synclinal basins oriented in an NNW-SSE direction, the Zakynthos and Kefalonia basins, and the E-W oriented Lefkada basin.

The hydrographic network of the area is relatively extended, mainly in the south part of the study area i.e. northern Peloponnese. The study area involves 4 different River Basin Districts (RBD), according to the provisions of the WFD 2000/60/EC.

Regarding water circulation, the western part (gulf of Patras) has significantly warmer surficial flows of ~23cm/s velocity, reducing their temperature and reaching maximum velocities of 100cm/s at the straits of Rio-Antirio as they enter in the deeper Korinthiakos Gulf (SoHelME, 2005; Laskaratos, 1989). The mean annual wave heights range between 0.1m and 0.5m, increasing from East to West (SoHelME, 2005). The mean annual wind speeds are ~7 m/s with the maximum values reaching 15m/s at the straits of the outer Patraikos Gulf and Rio - Antirio, having minor contribution to the general circulation.

Extensive shoreline retreat is observed at Korinthiakos Gulf and mainly to the south coast, where coastal slopes are high and coastal geomorphology favours erosion. Patraikos Gulf coasts are less prone to erosion. The most resilient part is the north Patraikos coast where Achelloos

River debouches (EUROSION, 2004). The Inner Ionian-Korinthiakos Gulf area includes 662 beaches (<https://beachtour.geol.uoa.gr/el/>) which cover a total area of 3.93km². Most of them are numbered on the north inner Ionian coast, whilst the greatest area is held on the north Peloponnese coast (South Inner Ionian Coast).

3.2. Living resources

The coastal and marine environment of the Inner Ionian-Korinthiakos Gulf is characterised by important ecosystems and high biodiversity, including numerous rare species of community interest. However, major knowledge gaps exist concerning the biology and ecology of most marine species; life cycle, competence, sensitivity-tolerance, genetics. Besides, there is limited information about the status and trends of highly variable habitats such as the *Posidonia oceanica* meadows, coralligenous deep corals and marine caves.

Species: The study area hosts some of the most important marine species; (a) about 230 species of macrophytes (e.g. *Padina pavonica*, *Cystoseira* sp., *Corallina elongata*, *Peyssonnelia tubra* etc.) and 2 species of angiosperms (*Posidonia oceanica*, *Cymodocea nodosa*); (b) 7 species of cetaceans (*Delphinus delphis*, *Stenella coeruleoalba*, *Tursiops truncatus*, *Grampus griseus*, *Ziphius cavirostris*, *Balaenoptera physalus*, *Physeter macrocephalus*); and the Mediterranean monk seal *Monachus monachus*; (c) 3 species of marine reptiles (*Caretta caretta*, *Dermochelys coriacea*, *Chelonia mydas*); (d) about 60 marine fish species (*Sardina pilchardus*, *Scorpaena* sp., *Hippocampus* sp., etc.); (e) more than 250 species of invertebrates (*Pinna nobilis*, *Savalia savaglia*, *Leptogorgia sarmentosa*, *Octopus vulgaris*, etc.); (f) important species of seabirds (*Calonectris diomedea*, *Phalacrocorax aristotelis*, etc.) (Greek Red Book, 2009; Bearzi et al., 2020).

Habitats: The most common habitats of biodiversity significance and vulnerable to environmental pressures are: (a) *Posidonia oceanica* meadows; a priority habitat type for conservation under the Habitats Directive (92/43/CE), settled in shallow waters of less than 45 m depth, occurring more commonly in the Ionian Sea where the depth gradient develops gradually and to a lesser extent in the Korinthiakos Gulf where the bottom profile is generally steeper. Bottom-trawling is forbidden on seagrass meadows (Ministerial Decision 2442/51879/2016 as amended in 2826/68784/2017); (b) Coralligenous formations; two major sites of interest identified along the southern coast of the Korinthiakos Gulf, where steep rocky cliffs extend to depths often greater than 200 m and favour the development of typical coralligenous assemblages some of which host rich gorgonian and gold corals (Issaris et al., 2012) (c) Marine caves; submerged and semi-submerged caves and overhangs of scattered presence (Papanikolis cave in Meganisi, Lefkada, N.Kefalonia cave Karst and Blue Caves in Zakynthos) occur mainly in the Inner Ionian Sea and to a lesser extent in the Korinthiakos Gulf (<https://www.rac-spa.org/>, April 2021).

Natura 2000 sites: The study area comprises 12 marine and coastal NATURA-2000 sites and includes two national marine parks; the National Marine Park of Zakynthos and the National Park of Messolonghi -

Etoliko Lagoons. The entire Korinthiakos Gulf has been designated as a protected area and included in the Revised National Catalogue of the European Ecological Network of the Natura 2000 protected areas (Government Gazette B 4432/2017), with a Management Body established by Law 4519 (Government Gazette 25_20/2/2018).

Living resource exploitation: The study area belongs to the following fishing areas: (a) S5-Coasts of Kefallonia, Zakynthos, and Patraikos Gulf and (b) S9-Korinthiakos Gulf. The overall catches in 2019 amounted to 6,105.6 tons of fish (ELSTAT; <https://www.statistics.gr/>, April 2021). Overfishing, illegal fisheries, non-indigenous species, pollution, loss and degradation of natural habitats, climate change, and aquaculture constitute an important threat to commercially exploited species.

3.3. Non-Living resources

Two published areas of gas venting are located within the area; one in Patraikos Gulf in the vicinity of Patras Harbour (Hasiotis et al., 1995) and one in Korinthiakos Gulf in Elaiona Bay (Christodoulou et al., 2003). There are some desalination units in the Inner Ionian area, whereas regarding marine aggregates there are no appropriate fields for extraction (Stamatakis et al., 2015). There is interest for developing off-shore wind farms and conducting research for hydrocarbon exploitation.

3.4. Human pressures on the coastal and marine environment

The coastal and marine environment of the Inner Ionian-Korinthiakos Gulf are influenced by multiple human activities which induce pressures causing pollution problems and ecosystem degradation. It is an area with urban agglomerations and islands, of dense maritime transportation activity, a significant number of ports and developed coastal and nautical (cruise, yachting, diving etc) tourism. Fishing and marine aquaculture are intensive in the area. In addition, the submarine cable and pipeline network is dense. The main pressures are presented below and summarized in Figure 1.

Microbial Pathogenes: Despite the intense activity in the area, in 2018, 210 bathing waters sites were assessed in the coastal waters of the case study area, of which 207 were found of excellent quality and only three of good quality (www.bathingwaterprofiles.gr).

Non-Indigenous species: NIS constitute a considerable biological pressure on the marine environment. According to the Ellenic Network on Aquatic Invasive Species (ELNAIS), there are numerous invasive species in the study area (e.g. *Amphistegina lobifera* (Protista), *Asparagopsis taxiformis* (Rhodophyta), *Caulerpa cylindracea* (Chlorophyta), *Halophila stipulacea* (Spermatophyta), *Amathia verticillata* (Bryozoa), *Bursatella leachii* (Gastropoda), *Crassostrea gigas* (Bivalvia), *Metasychis gotoi* (Polychaeta), *Callinectes sapidus* (Crustacea), *Siganus luridus* (Fish) (<http://www.elnais.ath.hcmr.com>, April 2021).

Nutrients: Nutrients in water bodies originate from land-based point sources (river estuaries, WWTP (<http://astikalimata.ypeka.gr/Services/Pages/Browse.aspx> and <http://astikalimata.ypeka.gr/>), municipal/ industrial

wastewater effluents) and diffuse sources (land washout, farming, agriculture). In the Inner Ionian-Korinthiakos Gulf there are 12 monitoring stations of coastal waters in the framework of WFD National Monitoring Program (<http://www.ypeka.gr/Default.aspx?tabid>). The TN (4.3-8.36 $\mu\text{mol/L}$) and TP (0.08-0.22 $\mu\text{mol/L}$) are mainly of organic origin due to the activities in the area. CHL-a levels (0.08-0.61) and eutrophication index EI (0.17-1.18) as well as the biological index Bentix (3.16-5.04) reveal mainly good and moderate eutrophication and ecological status in the study area, thus the integrated status is considered good or moderate where possible to be assessed (Simboura et al., 2016). Data inadequacy on organic matter and nutrient load input, as well as an official registry of all point and diffuse sources remain the main knowledge gaps.

Heavy metals: Regarding heavy metals in the coastal seawater, based on WFD data (Simboura et al., 2016), the coastal waters of the study area are in Good Environmental Status as increased concentrations of heavy metals are not frequent even in areas of high anthropogenic activity; ($\mu\text{g/L}$) Cd: 0.01, Pb: 0.08-0.40, Cu: 0.27-0.55, Zn:1.05-2.26, Ni:0.44-0.71, Cr:<0.61. Sediments in Patraikos Gulf in the vicinity of Patras are more impacted by pollution compared to other areas in the Ionian Sea and the level of contamination in sediments is extremely high in Antikyra Bay because of the alumina production plant which deposited red mud on the seabed after refining and smelting of bauxite.

Levels of *pollutants in fish* (Cd, Hg and Pb in fish muscle or edible tissues) and other seafood are compliant with Community legislation levels (regulation 1881/2006 & 1259/2011 amendment). PCBs and DDTs concentrations (not included in Regulation 1881/2006) do not exceed the maximum permissible levels for human health set by other authorities (Hatzianestis 2016). Consequently, the marine waters are in GES.

Marine Litter: Marine litter on the sea bottom in Patraikos and Echinades Gulfs showed higher density values than those proposed as baseline limit values for the Mediterranean (130-230/ km^2) (Ioakeimidis et al, 2014).

4. Conclusion

The coastal and marine environment of the Inner Ionian-Korinthiakos Gulf is characterised by vital ecosystems and high biodiversity, including numerous rare and protected species of community interest. These important ecosystems, species as well as Natura 2000 sites must remain in a protection regime to maintain the high biodiversity in the area. Generally, the Inner Ionian-Korinthiakos Gulf is in GES concerning contaminants or nutrient levels. Although the area is highly developed with multiple activities taking place there are limited hot spots (Patraikos Gulf, Antikyra) with higher contaminant concentrations or areas of moderate ecological status. Marine litter constitutes an issue requiring monitored and controlled land-based activities to reduce the amounts of litter reaching the coastal and marine environment. Based on the data presented through the MSFD concept, it becomes apparent that planning in the area should follow an ecosystem-based approach, to maintain GES (excellent bathing water quality, high/good ecological

status, good chemical status) and regulate uses and activities (industrial activities, shipping, commercial/recreational fishing, tourism, aquaculture) that can degrade the status of the case study area.

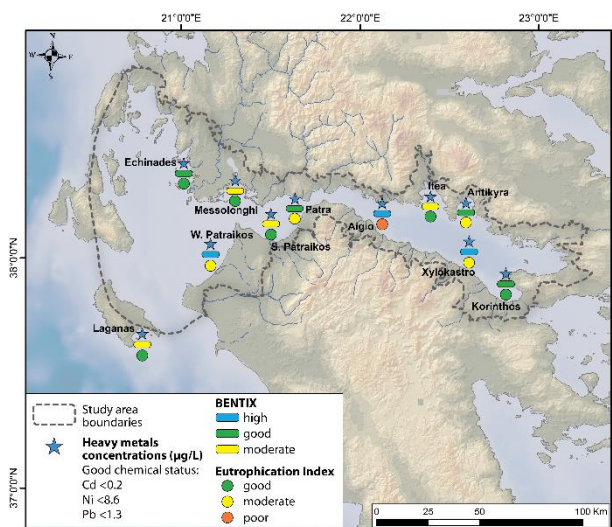


Figure 1: Human pressures on the coastal and marine environment of the Inner Ionian- Korinthiakos Gulf.

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