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POST-2020 SAP BIO

# GREECE
# CONSERVATION OF MEDITERRANEAN MARINE AND COASTAL BIODIVERSITY BY 2030 AND BEYOND

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# GREECE
# CONSERVATION OF MEDITERRANEAN MARINE AND COASTAL BIODIVERSITY BY 2030 AND BEYOND

## Ecological Status, Pressures, Impacts, their Drivers and Priority Response Fields

POST-2020
SAP BIO

**Strategic Action Programme**
for the **Conservation** of **Biodiversity**
and **Sustainable Management**
of **Natural Resources**
in the **Mediterranean Region**

# List of Acronyms

| | |
|---|---|
| **ABS** | Access and Benefit Sharing |
| **ACCOBAMS** | Agreement on the Conservation of Cetaceans in the Black Sea, the Mediterranean Sea and the contiguous Atlantic Area |
| **BBL** | Benthic Boundary Layer |
| **BHTs** | Broad Habitat Types |
| **BON** | Biodiversity Observatory Network |
| **CBD** | Convention on Biological Diversity |
| **CBZ** | Corals of the Bathyal Zone |
| **CC** | Creative Commons |
| **CFP** | Common Fisheries Policy |
| **CISE** | Common Information Sharing Environment |
| **CMBR** | Centre for the study and sustainable exploitation of Marine Biological Resources |
| **COP** | Conference of the Parties |
| **CSZ** | Corals of the Sublittoral Zone |
| **DCF** | Data Collection Framework |
| **DCR** | Data Collection Regulation |
| **DG** | Directorate-General |
| **EASIN** | European Alien Species Information Network |
| **EBQI** | Evidence-Based Quality Improvement |
| **EC** | European Commission |
| **ECAP** | Ecosystem Approach |
| **EEA** | European Economic Area |
| **EEC** | European Economic Community |
| **EIAs** | Environmental Impact Assessments |
| **ELNAIS** | Ellenic Network on Aquatic Invasive Species |
| **ELSTAT** | Hellenic Statistical Authority |
| **EMBRC** | European Marine Biological Resource Centre |
| **EMFF** | European Maritime and Fisheries Fund |
| **EMODnet** | European Marine Observation and Data Network |
| **EMSEA** | European Marine Educators Association |
| **EOSC** | European Open Science Cloud |
| **EQS** | Ecological Quality Status |
| **ERDF** | European Regional Development Fund |
| **ERIC** | e-Science European Infrastructure Consortium |
| **ESFRI** | European Strategy Forum on Research Infrastructures |
| **ETC** | European Territorial Cooperation |
| **EU** | European Union |
| **EUNIS** | European Nature Information System |
| **EuroGOOS** | European Global Ocean Observing System |
| **FAIR** | Findable, Accessible, Interoperable, Reusable |
| **FAO** | Food and Agriculture Organization |
| **FRA** | Fisheries Protected Area |
| **GBIF** | Global Biodiversity Information Facility |
| **GFCM** | General Fisheries Commission for the Mediterranean |
| **GG** | Government Gazette |
| **GIS** | Geographical Information System |
| **GM** | Greek Ministries including the Ministry of Environment and Energy, Ministry of Rural Development and Food, and the Ministry of Education and Religious Affairs |
| **GO** | Genomics Observatory |
| **GSC** | Genomics Standards Consortium |
| **GSRT** | General Secretariat for Research and Technology |
| **GTIS** | Greek Taxon Information System of LifeWatchGreece Research Infrastructure |
| **HABs** | Harmful Algal Blooms |
| **HCMR** | Hellenic Centre for Marine Research |
| **HD** | Habitats Directive |
| **HT** | Habitat Type |
| **ICCAT** | International Commission for the Conservation of Atlantic Tunas |
| **ICS-FORTH** | Institute of Computer Science – FORTH |
| **ICZM** | Integrated Coastal Zone Management |
| **IMBBC** | Institute of Marine Biology, Biotechnology and Aquaculture (HCMR) |

| | |
|---|---|
| **IMBRIW** | Institute of Marine Biological Resources and Inland Waters (HCMR) |
| **IMMA** | Important Marine Mammal Area |
| **IO** | Institute of Oceanography (HCMR) |
| **IOC-UNESCO** | Intergovernmental Oceanographic Commission-The United Nations Educational, Scientific and Cultural Organisation |
| **IUCN** | International Union for Conservation of Nature |
| **IUU** | Illegal, Unreported and Unregulated fishing |
| **JMD** | Joint Ministerial Decision |
| **MA** | Management Agencies |
| **MAP** | Mediterranean Action Plan |
| **MedPAN** | Network of Marine Protected Areas managers in the Mediterranean |
| **MEEN** | Ministry of Environment and Energy |
| **MLS** | Minimum landing Size |
| **MMEs** | Mass Mortality Events |
| **MPAs** | Marine Protected Areas |
| **MSFD** | Marine Strategy Framework Directive |
| **MSP** | Maritime Spatial Planning |
| **NBS** | National Biodiversity Strategy |
| **NECCA** | Natural Environment and Climate Change Agency |
| **NGOs** | Non-Governmental Organisations |
| **NIS** | Non-Indigenous Species |
| **NMPZ** | National Marine Park of Zakynthos |
| **NP** | National Programme |
| **OBIS** | Ocean Biodiversity Information System |
| **OL** | Ocean Literacy |
| **OP** | Operational Programmes |
| **PA** | Partnership Agreement |
| **PAP** | Priority Actions Programme |
| **PET** | Protected Endangered and Threatened species |
| **RI** | Research Infrastructures |
| **ROPs** | Regional Operational Programmes |
| **ROV** | Remotely Operated Vehicle |
| **SCA** | Special Conservation Area under the Habitats Directive |
| **SCI** | Site of Community Importance under the Habitats Directive |
| **SDGs** | Sustainable Development Goals |
| **SPA/BD** | Specially Protected Areas/Biological Diversity |
| **SPA/RAC** | Specially Protected Areas Regional Activity Centre |
| **SPA** | Special Protection Areas under the Conservation of Wild Birds Directive |
| **SSLG** | Submarine Structures of Leaking Gases |
| **SST** | Sea Surface Temperature |
| **UN** | United Nations |
| **UNEP** | United Nations Environment Programme |
| **VMEs** | Vulnerable Marine Ecosystems |
| **VRE** | Virtual Research Environment |
| **WFD** | Water Framework Directive |
| **WG** | Working Group |
| **WRiMS** | World Registered Introduced Marine Species |
| **WWF** | World Wildlife Fund |

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# List of Figures

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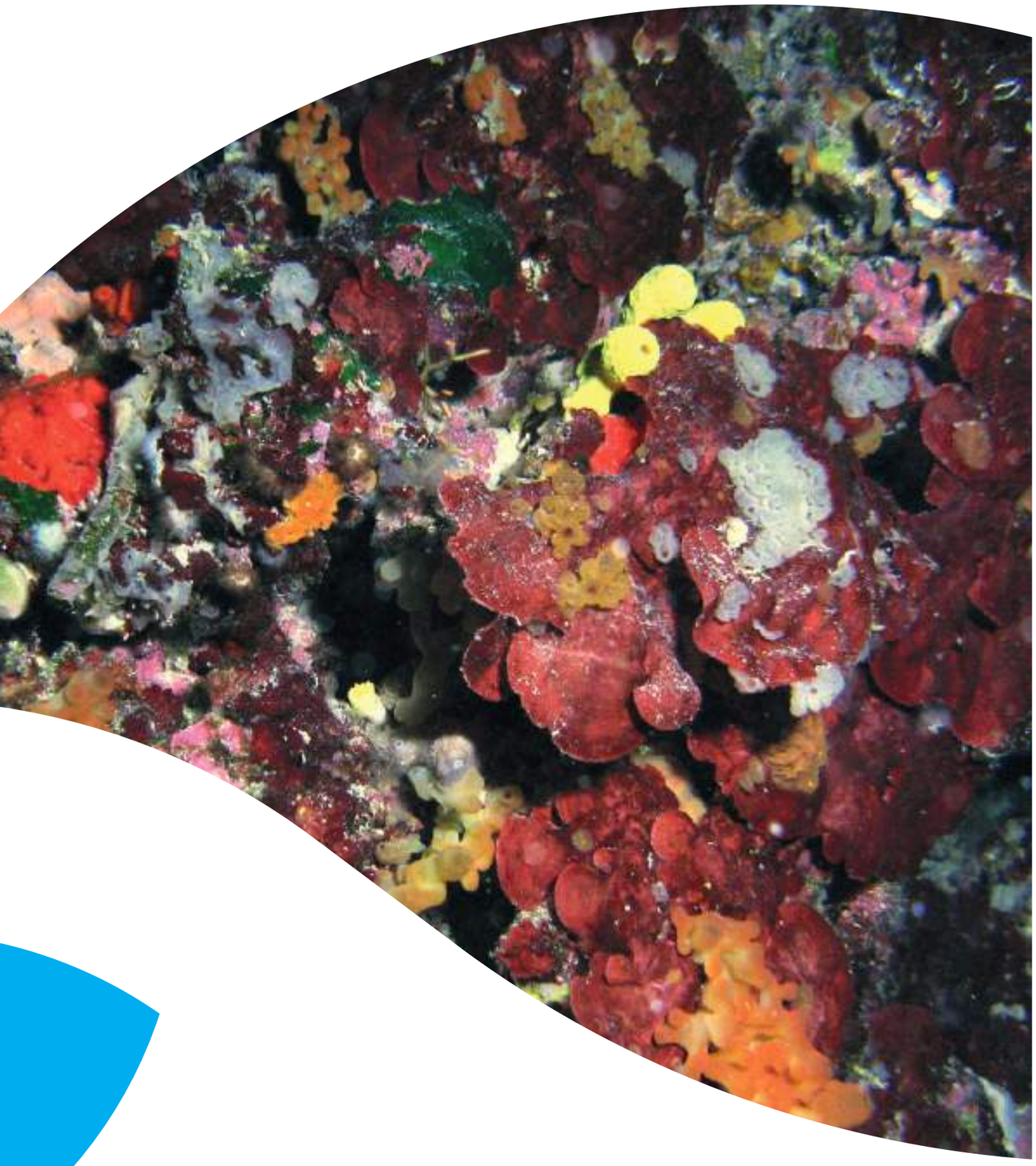

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# Executive Summary

The Greek Seas comprise a great diversity of marine life and geomorphological features, being characterized by a highly complex coastline and seascape: alternating rocky coasts and islets, sandy shores, shallow semi-enclosed gulfs, lagoons and estuaries, seagrass beds, sandy and vegetated bottoms, rocky reefs, biogenic formations (e.g. coralligenous, rhodolith/maërl beds, deep-water coral areas and sponge gardens), wide plateaus, deep canyons, seamounts and various types of extreme habitats (e.g. caves, hydrothermal vents, cold seeps, mud volcanoes, and brine pools). However, baseline knowledge about certain taxa, assemblages, habitats and geographic areas is still scarce, while these important knowledge gaps pose a significant obstacle for the conservation of key and protected marine habitats and species. In addition, a considerable part of the available data remains unpublished, difficult to access or has not been recently updated. There is also a lack of long-term projects in selected areas covering the need for assessing natural temporal trends, response to climate change and comparisons among anthropogenic impacted vs. naturally disturbed environments.

To date, Greece has responded responsibly to existing policies and initiatives relevant to natural ecosystems and biodiversity (e.g. CBD, EU Bird Directive, Habitat Directive, MSFD, WFD, CFP), Maritime Spatial Planning (MSP) and Marine Protected Areas (MPAs) with legislative acts, various measures and plans. Nevertheless, several actions are still to be taken such as: (1) to formulate an updated national marine biodiversity strategy taking into account both new legislative and governance initiatives and benefiting from bringing together insights from the regular assessments under HD, WFD and MSFD with inputs from experts and national stakeholders; (2) to adopt additional measures for the control of land based pollution sources and for the prevention and efficient management of maritime accidents and to support applied research for detection of pollutants at sea; (3) to implement benthic studies within all habitat types and intensify high-resolution habitat mapping and assessment in order to fully characterize their geographic distribution and trends in the Greek Seas; (4) to identify, map and monitor bioconstructions (e.g. coralligenous, rhodolith/mäerl beds, mesophotic reefs, deep-water corals and sponges) in order to address the current important gaps in the enforcement of existing legislation that defines their protection; (5) to further monitor species and ecosystems under threat, mass mortality events as well as the distribution and effects of invasive non-indigenous species (NIS); (6) to prioritize training options and capacity building of young researchers concerning taxonomy, and monitoring techniques of marine ecosystems and species, coupled by other disciplines; (7) to monitor marine litter and especially plastics in order to quantify negative impacts on marine life; (8) to conduct studies on the impacts of hydrocarbon (oil and gas) exploration, offshore windfarm construction and connection, as well as other anthropogenic effects on fragile deep-sea ecosystems; (9) to identify

and carry out studies required for the introduction of new areas into the NATURA 2000 Network and the national Marine Protected Areas (MPAs) network; (10) to support and improve the efficiency of existing Management Agencies of Coastal and Marine Protected Areas for the protection of the marine and coastal ecosystems and expand the existing network of protection; (11) to strengthen mechanisms for the effective control of legal and illegal construction and development in coastal areas; (12) to evaluate the magnitude and effect of the interactions between fisheries and charismatic marine megafauna (e.g. mammals, sea turtles, and seabirds) as well as to apply action plans for the minimization and management of such conflicts; (13) to apply additional appropriate measures for the sustainable use of fisheries resources; (14) to regularly assess and quantify fisheries stocks and improve commercial and recreational fisheries management planning; (15) to intensify controls and inspections in support of the sustainable use of marine biological resources and apply principles of sustainable fishing and aquaculture, (16) to develop and promote awareness raising and citizen science programmes addressing to the wider public, to selected stakeholder groups (fishers, divers, sailors, etc), as well as to school students and teachers.

Specific actions needed for critical conservation include: (1) the long-term monitoring of climate change and community changes in the Greek seas through an integrated and standardized framework; (2) the assignment of coralligenous, rhodolith/maërl beds and other bio-calcareous concretions as priority natural habitat types in the EU Habitats Directive and implement a systematic mapping and monitoring programme, which is a prerequisite for the enforcement of existing national and EU legislation for their protection; (3) establishment of an international research programme aiming at investigating the spatial distribution and population structure of the red coral in the Greek Seas in order to assess its status and implement appropriate effective management and restorative measures; (4) regular monitoring of mass mortality events for protected and threatened species (e.g. *Pinna nobilis*, sponges and red coral); (5) regular monitoring of live and dead stranding events of protected species of megafauna (e.g. marine mammals and turtles) and deposition of standardized data in existing databases.

The estimates of the Greek marine biological resources and the services which marine biodiversity and ecosystems provide to the citizens are fragmentary and based on sporadic information gathered from research projects funded mainly by national or EU sources, especially for species of commercial interest. Consequently, the available information is scarce and geographically limited. This is due to the fact that there is no long-term national marine research policy with specific strategy, goals, coordination and implementation roadmap that also involves human capital and infrastructure - reflected also in national funding opportunities both for governmental and non-governmental organisations. Moreover, baseline information concerning marine biodiversity is not usually the main target of marine research funds, while at the same time this kind of research is carried out for as long as financial support exists and therefore with questionable sustainability.

Although our knowledge concerning certain taxa may be considered satisfactory, there are still vast gaps regarding the distribution, range, population and conservation status for the majority of species and habitats. Therefore, research and systematic monitoring of Greek biodiversity and related conservation actions must be largely supported. This is particularly important in the current period with the new *EU Green Deal* including actions such as the *EU Biodiversity Strategy for 2030* aiming to put Europe's biodiversity on the path to recovery by 2030 and the 2021-2030 *UN Decade of Ocean Science for Sustainable Development* and *Decade on Ecosystem Restoration* aiming to restore degraded and destroyed ecosystems. It is also vital for the state to fulfil and fully implement its obligations stemming from European Legislation and International Treaties and Conventions. The adoption of the National Biodiversity Strategy and Action Plan and the integration of issues concerning biodiversity into sectoral policies combined with the effective operation of the NATURA 2000 European Ecological Network will be decisive for biodiversity conservation. The evolving process of institutional protection of the network's sites, the effective operation of Management Agencies and management and conservation plans for important sites and the empowerment and enforcement of environmental control institutions and mechanisms are very significant steps. The institutional protection of new sites and the support to the operation of all Management Agencies of the MPAs is expected to have a catalytic effect on the conservation of coastal and marine biodiversity of Greece.

Measures for the minimization of the adverse effects of human activities on the marine environment, such as the implementation of restrictions on waste disposal, policies for the prevention and management of maritime accidents, coupled with measures to address overfishing, illegal and unreported fishing, as well as of by-catch and discards, are required to be implemented along with effective measures for the protection and conservation of endangered marine species and important sites as well as international cooperation to deal with the phenomenon of invasion of NIS.

More specifically, key national and perspective recommendations are proposed:

- Development of a long-term national policy for marine research and marine ecosystem and resources management, with specific strategy, goals, coordination, funding and implementation roadmap.
- Activities such as: (a) coordination and harmonization of monitoring surveys (e.g. for plastic marine debris), along with intensifying the sampling effort and expanding the grid of monitoring stations (e.g. WFD and MSFD), in association with other international and regional projects (e.g. jellyfish blooms); (b) rapid assessment surveys (RAS) in understudied areas/habitats and in locations at high risk for the introduction of NIS, such as ports, marinas and aquaculture sites.
- Promotion of basic research for certain understudied habitats, such as deep sea, pelagic and interstitial habitats, benthic boundary layer, and hard substrates (especially coralligenous formations and marine caves) as the knowledge on their biodiversity is of utmost importance for ecological studies assessing ecosystem functioning, food webs, habitat conservation. Gaps in knowledge of biodiversity in unexplored geographic areas should also be addressed.
- Extending the scope of studies beyond the level of species matrices, incorporating more data on demography, size, life cycle, trophic relations, productivity, ecophysiology, and genetics.
- Support of the relevant Research Infrastructures (LifeWatchGreece, CMBR) in order for the country to produce evidence-based scientific knowledge on the state of marine biodiversity and ecosystems which, in turn, will allow for their rational management towards sustainability.
- Networking: joining forces, setting the essential questions, developing the National Strategy in compliance with EU and International Treaties and Conventions, linking with the relevant EU (e.g. EurOCEANS, EuroGOOS) or Mediterranean (e.g. MedPAN) networks.

- MPAs and Fisheries Protected Areas (FRAs) are important tools for preserving biodiversity and managing fisheries, and therefore baseline and monitoring studies are needed in order to improve the efficiency of these areas as well as increase their number and be effectively implemented, enforced and managed.
- Further development of physical facilities and infrastructure (laboratories, large-scale equipment, vessels, observatories, and platforms) with ease of access by the scientific community.
- Further development of digital facilities (e.g. databases ELNAIS, GTIS, National reporting system for marine turtles and cetaceans) employing new tools and disruptive technologies (e.g. Virtual Research Environments).
- Investment in human capital and mobility, ensuring future competence and expertise (training and career paths in marine science).
- Establishment of national working groups addressing various biodiversity issues meeting and reporting regularly including on species and habitats status assessments. Establishment of national targets for the conservation and restoration of specific marine species and habitats in line with the CBD requirements, the recent EU Biodiversity Strategy 2030 marine targets to restore degraded ecosystems and the aspirations of the UN Decade on Ecosystem Restoration 2021-2030.
- Considerable advancement and increase of Ocean Literacy (OL) in society, from education and school curricula, to decision-makers and the public at large especially focusing on marine biodiversity, considering priorities of the UN for supporting the implementation of SDG 14 of the 2030 Agenda for Sustainable Development.
- Marine species and habitats should be regularly assessed for their conservation status (e.g. IUCN Red List).



1.

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## 1.4. Quality and comprehensiveness of available information documents

This report is the outcome of a collaborative effort, which involved a multi-disciplinary group of experts on different aspects of marine and coastal biodiversity, representing different research and academic institutions. The aim of this collaborative approach was to provide a representative "big picture" of the current status of the Greek Seas and highlight gaps and problems concerning current knowledge in marine research in Greece. The report is based on an extensive review over a large number of literature sources (see section 1 and Reference List), including both peer-reviewed papers and grey literature sources (e.g. project reports, websites, online viewers/databases, and in some cases unpublished data) as well as the personal knowledge/views of the leading marine experts in Greece. During the last years, data on biodiversity-related issues have been exponentially gathered in Greek Seas in the framework of regular monitoring programmes (e.g. HD, WFD, MSFD, and DCF), dedicated research projects (e.g. DEEPEASTMED for the deep-sea environment), digital research infrastructures, databases and networks (e.g. LifeWatchGreece, ELNAIS). However, a considerable part of the existing information remains unpublished (e.g. project reports), is difficult to access (e.g. offline databases, not always in the right format) and/or has not been recently/regularly updated (e.g. lack of updated checklists on certain taxa due to the lack of experts). In addition, information about specific marine areas (e.g. Ionian Sea, offshore areas), taxonomic groups (e.g. meiofauna, sessile benthos), habitats and assemblages (e.g. bioconstructions, deep-sea assemblages), and pressures, is still scarce (see sections 2.5, 6.1 and 7 for identified gaps of knowledge, problems and needs). Moreover, long-term monitoring projects in selected areas covering the need for assessing natural temporal trends, response to climate change and comparisons among anthropogenically impacted vs. naturally disturbed environments are also missing. In conclusion, development of a long-term national marine research policy, with specific strategy, goals, coordination, funding and implementation roadmap is required.



# 2. Marine and coastal ecosystem status

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## 2.1. Biological characteristics

### 2.1.1 Description of water column biological communities

*Phytoplankton*

Phytoplankton biomass and abundance in coastal Greek waters are characterized by high seasonal variability, revealing a clear annual cycle. Spatial differentiation has been identified in several coastal areas (e.g. Saronikos, Thermaikos and Maliakos gulfs), due to the different environmental conditions and anthropogenic effects. The Aegean, Levantine and Ionian basins have been classified as regions with a bimodal dynamic, showing low biomass during late spring-summer and higher biomass up to the maxima in late fall-winter (D'Ortenzio and Ribera d'Alcala, 2009). During spring the Aegean Sea presents high total Chlorophyll-*a* (Chl-*a*) concentration compared to the lower levels of the Ionian and Levantine seas. During summer Chl-*a* concentrations are lower than in spring in the Aegean, whereas they are similar in the Ionian and Levantine seas. The northeastern and the south Aegean, Ionian and Levantine seas present low phytoplankton abundance values. The presence of a deep chlorophyll maximum (DCM) has usually been observed below 50 m depth in the north Levantine, Aegean and Ionian seas during the summer stratification period. Large-sized diatoms dominate throughout the water column (e.g. *Chaetoceros costatus, C. curvisetus, C. decipiens*) while small-sized diatoms (*Hemiaulus hauckii, Thalassionema nitzschioides, Leptocylindrus minimus, Thalassiotrix longissima,* and *Dactyliosolen fragilissimus),* dinoflagellates (*Amphidinium spp.* and *Gymnodinium sp.)* and autotrophic nanoflagellates account for the bulk of phytoplankton abundance and biomass in offshore waters. HABs frequently occur in coastal areas of Greece, characterized by high pollution levels, restricted water mass circulation and riverine inflows, mostly related to eutrophication caused by intensive agriculture, partially treated domestic and industrial sewage, mariculture activities (Pavlidou *et al*., 2015; Dimitriou *et al*., 2015). In Thermaikos Gulf, toxic microalgal species of the "*Dinophysis acuminata* complex" have been mostly responsible for intoxications of the *Mytilus galloprovincialis* and long harvest closures of mussel farms (Varkitzi *et al.,* 2013). In 2009, a bloom of the toxic phytoplankton species *Chattonella sp.* caused massive fish-killings in Maliakos Gulf with severe economic losses (HCMR, 2009).

*Microzooplankton and the microbial food web*

Though the spatial and vertical variability of ciliates has been shown from studies in both offshore waters and coastal waters (e.g. Pitta and Giannakourou, 2000; Pita *et al.*, 2005), the information is fragmented and geographically restricted. Recently, a few more projects have focused on open environments (e.g. Giannakourou and Pitta, 2014, Santi *et al*., 2020), or coastal ones in pristine or anthropogenically impacted areas. Table S1 (see Annex) presents all available data obtained through different research projects in various geographical areas in both coastal and offshore Greek Seas. Research on planktonic ciliates in Greek waters has revealed that: (a) in terms of ciliate abundance, the oligotrophic character, even in the coastal areas, is obvious; (b) there is high variability in terms of spatial, seasonal, vertical distributions, however the available information is still scarce (although there is some information on size classes and trophic modes); (c) very few time-series stations exist, with the exception of Saronikos and Thermaikos gulfs and the open station M3A (Cretan Sea), therefore it is risky to draw conclusions on patterns or trends; (d) in terms of ciliate diversity, a considerable number of species has been found

using microscopy. Identification of planktonic ciliates at the species level is very uncertain due to their cell fragility resulting in morphological distortion when fixed. A solution to this problem could be the implementation of molecular techniques, i.e. 18S DNA metabarcoding. Recent studies have tried to assess the role of planktonic ciliates within the microbial food web, in an attempt to draw the «big picture», in the field (Giannakourou and Pitta, 2014; Santi *et al*., 2020) and also using large-scale experiments (Pitta *et al*., 2017; Tsiola *et al*., 2018). Apart from ciliates, microbial components (e.g. nano-Eukaryotes, Prokaryotes, and Viruses) have been studied in the Greek Seas in the framework of the same projects as for ciliates and similar findings may be drawn regarding the trophic status or the variability in terms of spatial, seasonal, vertical distributions of these groups.

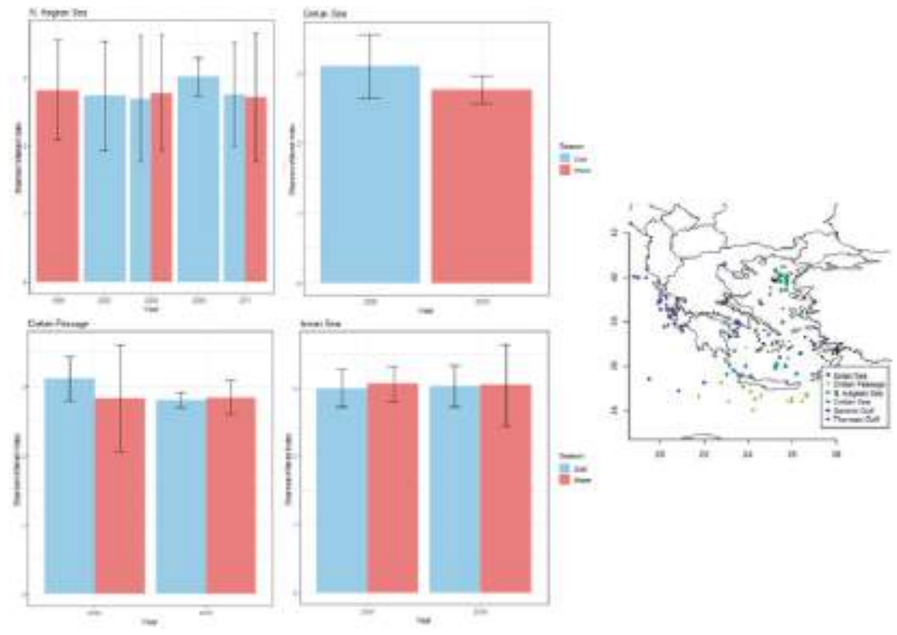
### *Mesozooplankton*

The Greek Seas, because of their diversified topography and bathymetry are characterized by a great variety of habitats, thus supporting high mesozooplankton diversity. Based on the available information collected from coastal and offshore waters (Figure 1), more than 200 species have been recorded, distributed among several taxonomic groups. In coastal areas, the abundance of mesozooplankton is characterized by high seasonal variability. In general, the highest values of abundance have been observed in spring. Strong spatial differentiation has been identified in several coastal areas (e.g. Saronikos, Thermaikos and Maliakos gulfs), due to the different environmental conditions and anthropogenic effects. Generally, copepods dominate the mesozooplankton but their contribution varies markedly between areas and seasons, with high values in the cold season and low values in the warm season (Zervoudaki *et al*., 2006; Protopapa *et al*., 2019). In coastal waters small-sized calanoid (*Acartia, Centropages, Paracalanus* and *Clausocalanus*) and cyclopoid copepods (*Oithona* and *Oncaea*) together with cladocerans (e.g. *Penilia, Pleopis* and *Pseudoevadne*) dominate in the mesozooplankton community. Mesozooplankton biomass and abundance are generally lower in offshore waters when compared to coastal areas. A distinct pattern of decreasing mesozooplankton abundance is observed along the north-south axis in the Aegean Sea during both warm and cold seasons. The Ionian and northwestern Levantine seas reveal similar values to those of the south Aegean Sea. Epipelagic mesozooplankton communities in offshore waters are highly diversified in terms of taxonomic composition, but copepods represent the major group both in terms of abundance and biomass. Species-rich genera of the calanoids (*Clausocalanus, Calocalanus*, *Mecynocera, Haloptilus* and *Ctenocalanus*) and cyclopoids (*Oithona*, *Oncaea*, *Corycaeus,* and *Farranula*) account for the bulk of copepod abundance and biomass in epipelagic layers of the offshore waters.



**Figure 1.**

Aggregated mean values of the mesozooplankton Shannon Wiener diversity for the warm and cold periods with error bars indicating the 95% confidence interval in several offshore waters. The map shows coastal and offshore stations sampled for plankton abundance and diversity.



It should be noted that taxonomic uncertainties still remain for some copepod species of the Greek Seas. A recent molecular study revealed that *Paracalanus quasimodo* and not *P. parvus* is the dominant coastal species of the *Paracalanus* species complex in the Mediterranean and the Greek Seas (Kasapidis *et al*., 2018), while taxonomic uncertainties still remain for certain taxa.

### *Other zooplankton groups*

Considerable densities of zooplanktonic organisms have also been found residing on or just a few centimetres above the sediment surface (near-bottom zooplankton), but are still poorly studied (Koulouri *et al*., 2009). Finally, medusae blooms are normal and recurring events, a biological expression of the pelagic ecosystem in response to the fluctuations of the environmental parameters. Distribution gaps are filled lately by new records, while outbreak events are more frequent due to climate change.

## 2.1.2. Information on invertebrate bottom fauna, macro-algae and angiosperms including species composition, biomass and annual/seasonal variability

Despite the oligotrophic conditions of the eastern Mediterranean Sea, the Greek Seas are among the richest Mediterranean marine regions in terms of benthic biodiversity, with the Aegean Sea ranking second in macrofaunal species (>3,200, considering both soft and hard substrate benthos), after the well-studied north-western basin (SoHelME, 2005).

Greek Seas host over 600 macrophyte species (Simboura *et al*., 2019) and four species of marine angiosperms (*Posidonia oceanica*, *Cymodocea nodosa*, *Zostera noltii* and the NIS *Halophila stipulacea*).

The Greek Seas harbour more than half of the total Mediterranean diversity of several invertebrate groups, such as the anthozoans, polychaetes, molluscs, crustaceans, echinoderms, and brachiopods (Table 1). However, it is estimated that the actual species number of the Greek Seas is much higher, given that several small-sized taxa (e.g. meiofauna), sessile taxa (e.g. Hydrozoa, Bryozoa) and habitat types which either harbour exclusive species (e.g. extreme habitats) or their accessibility is not easy (e.g. Benthic Boundary Layer - BBL) have not been adequately studied due to lack of expertise, sampling inefficiencies, difficult access or inadequate funding.

Following the landmark publication of SoHelME in 2005, during the last years several species checklists were published either by individual researchers or within research initiatives (e.g. GTIS: Greek Taxonomic Information System of LifeWatchGreece and ELNAIS), with the aim to assemble, store, update, analyze and disseminate existing information on the biodiversity of Greece. Specifically, a series of taxonomic checklists were published for Ulvophyceae (96 *spp.* – Tsiamis *et al*., 2014), Phaeophyceae (107 *spp.* Tsiamis *et al*., 2013), Rhodophyta (262 *spp.* – Tsiamis and Panayotidis, 2016, 2019), Porifera (215 *spp.* – Voultsiadou *et al*., 2016), Polychaeta (836 *spp.* – Faulwetter *et al*., 2016), Cumacea (62 *spp.* – Koulouri *et al*., 2016a), Mysida and Lophogastrida (49 *spp.* Koulouri *et al*., 2016b), Tanaidacea (20 *spp.* – Koulouri *et al*., 2020a), Stomatopoda (9 *spp.* – Koulouri *et al*., 2020b), Bryozoa (237 *spp.* – Gerovasileiou and Rosso, 2016), Brachiopoda (12 *spp.* – Gerovasileiou and Bailly, 2016), and Ascidiacea (75 *spp.* – Antoniadou *et al*., 2016). In addition, thematic checklists concerning NIS (e.g. Zenetos *et al*., 2018) or biotas of specific habitats (e.g. marine caves – Gerovasileiou *et al*., 2015) are continuously updated.

The above taxonomic studies highlight that several species were first discovered in the Greek Seas, including species of sponges (12 *spp.*), anthozoans (2 *spp.*), polychaetes (18 *spp.*), and bryozoans (6 *spp.*). Many of these species are endemic to a specific type locality (e.g. extreme habitats), the regional sea or the eastern Mediterranean. Among the endemics, the anemone *Paranemonia vouliagmeniensis* and the sea pen *Crassophyllum thessalonicae*, known exclusively from Vouliagmeni Lake and Thermaikos Gulf, respectively, were recently assessed as endangered by the IUCN Red List of Threatened Species.



**Table 1.**

**Summary table showing the numbers of the currently valid benthic taxa occurring in Greek waters based on data from the GTIS initiative (Bailly et al., 2016), SoHelME (2005) and updates from recent studies. The proportion of species number in the Greek Seas against the total Mediterranean diversity for each taxonomic group was calculated based on Coll et al. (2010).**

** taxa for which updated checklists have been recently published (for Crustacea, updated checklists have been published only for specific taxa).*

| Taxonomic group | Species in Greek waters | Percentage of Mediterranean diversity |
|---|---|---|
| Porifera * | 220 | 32% |
| Anthozoa | 88 | 54% |
| Polychaeta * | 836 | 75% |
| Sipuncula | 17 | 50% |
| Mollusca | 1,202 | 57% |
| Crustacea (benthic) * | 674 | 57% |
| Echinodermata | 108 | 70% |
| Bryozoa * | 237 | 43% |
| Brachiopoda * | 12 | 85% |
| Ascidiacea * | 75 | 33% |

The high biodiversity of the Greek Seas is not only the result of focused research effort (e.g. taxonomic competence for specific taxa, which however continuously decreases), but is also related to the complexity of the Greek coastline and seascape. The Greek Seas comprise a great variety of habitats and geomorphological features (see sections 2.2 and 2.3): alternating rocky coasts and islets, sandy shores, shallow semi-enclosed gulfs, lagoons, estuaries, seagrass beds, rocky reefs, biogenic formations (e.g. coralligenous, rhodolith/maërl beds, deep-water coral areas and sponge gardens), wide plateaus, deep canyons, seamounts and various types of extreme habitats (Voultsiadou *et al*., 2013).

Spatial variability patterns can be observed in the area with the most striking one being the decrease in species number, abundance and biomass (considering both motile and sessile taxa) along a N-NW to S-SE gradient, following the parallel increase in oligotrophy and sea water temperature (SoHelME, 2005; Voultsiadou, 2005). Due to oligotrophy (e.g. Heraklion Gulf), for instance, BBL macrofaunal organisms are mostly concentrated very close to the seabed instead of the overlying water column (Koulouri *et al*., 2013). Furthermore, different numbers of species have been recorded in different regional seas, with the Aegean harbouring a much higher diversity than the Ionian Sea. Nevertheless, the latter observation might be affected to a certain degree by research effort, which has been traditionally more intensive in the Aegean Sea.

### 2.1.3 Information on vertebrates other than fish

#### *Marine mammals*

The Greek Seas constitute a hot spot area for marine mammals at the Mediterranean scale (Coll *et al*., 2010). To date, 13 species of cetaceans have been sighted in the Greek Seas (Frantzis, 2009; 2018), of which 12 are included in the list of endangered or threatened species (Annex II) of the SPA/BD Protocol. The striped dolphin (*Stenella coeruleoalba*),

common bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*), Cuvier's beaked whale (*Ziphius cavirostris*), sperm whale (*Physeter macrocephalus*), Risso's dolphin (*Grampus griseus*), and fin whale (*Balaenoptera physalus*) are commonly observed in Greek waters. The Black Sea harbour porpoise (*Phocoena phocoena relicta*) is restricted to the Thracian Sea (north Aegean Sea). The NIS humpback dolphin (*Sousa plumbea*) was recently sighted in the north coasts of Crete (Frantzis, 2018). In South Crete and Ionian Seas, the observation frequency of Cuvier's beaked whale is higher compared to the rest of the Mediterranean (Frantzis and Alexiadou, 2003). Greek Seas also constitute an important habitat for sperm whales as the species is present year-round along the Hellenic Trench, most sightings being recorded from south-west Kefalonia Island south to west Peloponnese, west and south Crete. A permanent small population of common dolphin is known to inhabit Korinthiakos Gulf (subpopulation recently listed as Critically Endangered by the IUCN Red List), forming mixed-species groups with striped dolphin and showing a preference for pelagic habitats and deep water (Bearzi *et al*., 2011) instead of a typical coastal behaviour. Amvrakikos Gulf, where fishing is restricted for purse seiners and bottom trawlers, also hosts a resident population of bottlenose dolphins (Gonzalvo *et al*., 2015). In addition, Greek waters host a total of seven Important Marine Mammal Areas (IMMAs) and several areas where more research is required to better assess their importance to marine mammal populations (https://www.marinemammalhabitat.org/imma-eatlas/).

Stranding events can be a source of information about the causes of deaths and provide baseline data for management and conservation actions. The causes of death among others are related to natural factors like diseases, climatic events, and anthropogenic causes, such as boat collisions, noise pollution and entanglement in fishing gears (Mytilineou *et al*., 2019). A total of 1,160 individuals have been stranded in the Greek Seas between 2010 and 2019 mostly of common dolphins, striped dolphins, bottlenose dolphins, sperm whales and Cuvier's beaked whales (HCMR unpublished data).

The population size of the endangered monk seal (*Monachus monachus*) in Greece is currently estimated at ~300 individuals, representing 43% of its global population (Karamanlidis *et al*., 2016). The major factor favouring the survival of the monk seal in the Greek seas is the presence of suitable habitats (i.e. marine caves with internal beaches) both for resting and pupping, due to the specific geomorphology of the area (Voultsiadou *et al*., 2013). Nowadays, monk seal sightings are widely distributed throughout the Aegean and the Ionian seas and several important monk seal pupping areas have been identified (Sini *et al*., 2017). The northern Sporades Islands (including the National Marine Park of Alonissos Northern Sporades) is estimated to host a population of more than 50 individuals. The Kimolos-Polyaigos island complex (Cyclades) has a breeding colony of 50 animals. The areas of north Karpathos and Saria (Dodecanese Islands) have a population of ~25 individuals, while a breeding colony of ~60 individuals has been discovered at Gyaros Island (Cyclades). Since 1991, although ~40% of the entire Greek coastline has been surveyed by the Hellenic Society for the Study and Protection of the Monk Seal (MOm), large areas which remain unexplored may host important breeding sites. Despite applied management measures (e.g. guarding and regulations in MPAs) which have led to an increase in the species' birth rate, 195 individuals have been recorded stranded along the Greek coastline during the period 2011-2019 (HCMR unpublished data).



### *Marine turtles*

Three species of marine turtles inhabit the Greek Seas, also listed in Annex II of the SPA/BD Protocol: the loggerhead turtle *Caretta caretta*, being the only marine turtle reproducing in Greece (Margaritoulis, 2009); the green turtle *Chelonia mydas* and the leatherback turtle *Dermochelys coriacea*. The monitored nesting areas in Greece host about 45% of the total Mediterranean nests, 39% of which are laid in Laganas Bay (National Marine Park of Zakynthos) and 28.5% in southern Kyparissia Bay, western Peloponnese, comprising the two largest nesting aggregations of *C. caretta* in the Mediterranean (Casale *et al*., 2018). Long-term studies have shown negative trends in nesting activities in most studied Greek areas, except for southern Kyparissia Bay likely due to intense conservation efforts by ARCHELON (Casale *et al*., 2018). A long-term sea turtle monitoring program at sea has shown that Amvrakikos Gulf is a major foraging area of *C. caretta* (Rees *et al*., 2013). Despite the encouraging findings for the Mediterranean loggerhead sea turtle population recovery (recently upgraded from endangered to vulnerable) the overall conservation status has been deemed as unfavourable – bad (Article 11 of HD for Annex II, IV and V) species at national level therefore calling for further conservation actions. The presence of small juvenile green turtles in Lakonikos Bay suggests its importance for the development of *C. mydas* (Casale *et al*., 2018 and references therein). A total of approximately 6,000 strandings of sea turtles have been recorded in the Greek Seas between 2010 and 2019. Almost 90% of these strandings concern loggerhead turtles, followed by 7% of green turtles.

### *Marine birds*

Many species of marine birds are facing increased challenges in the form of invasive predators on their breeding sites, by-catch mortality by fisheries gear as well as disruption of their migratory pathways due to global climate change. Furthermore, they reflect shifts in environmental conditions in a marine environment, including those occurring due to pollution pressures by toxic chemical residues and plastics. The Greek Seas host a significant network of breeding and foraging sites for marine birds (Fric *et al*., 2012; Karris *et al*., 2018). The main marine birds of the Greek territorial waters are Scopoli's shearwater (*Calonectris diomedea*), Yelkouan shearwater (*Puffinus yelkouan*) and Mediterranean Storm petrel (*Hydrobates pelagicus melitensis*), all classified as seabirds (according to BirdLife International and the Ramsar Convention), while the main waterbirds are the Mediterranean Shag (*Phalacrocorax aristotelis desmarestii*) and Audouin's Gull (*Larus audouinii*). These species of marine birds are listed in Annex II of the SPA/BD Protocol.

Scopoli's shearwater - recently recognised as endemic in the Mediterranean Sea - is a colonial long-lived migrant species, well-known for nest site tenacity, mate fidelity and its pelagic and wide-ranging distribution. The Strofades Island group (National Marine Park of Zakynthos) in the Ionian Sea hosts the largest colony in Greece (ca. 5,550 pairs), although no complete national population census has ever been carried out. The total breeding population of Greece is estimated at ca. 8,000-11,000 pairs (Karris *et al*., 2017). The Yelkouan Shearwater is strictly endemic to the Mediterranean with outposts in the Black Sea. The species is known to breed in Greece on Aegean islands and islets and the national population is estimated at 4,000-7,000 breeding pairs (Fric *et al*., 2012). Nevertheless, data on key sites and long-term regular monitoring at the major breeding colonies are scarce and patchy except for Gyaros Island which hosts one of the most important colonies. The European Storm-petrel is one of the smallest long-lived seabirds. Populations of its

Mediterranean subspecies are confined to sites without presence of terrestrial predators (e.g. invasive rats). The species occurs in Greek waters and the breeding population is estimated at 90 breeding pairs (BirdLife International, 2020), although this is probably an underestimation. The Mediterranean Shag is a coastal diving species and has been poorly studied in the eastern Mediterranean, although the coast of Greece is regarded as a stronghold for its population, as significant breeding colonies are located in the north and central Aegean Sea. In the 1990s, the Greek population was estimated at 600-1,000 individuals, although a recent survey found that >1,500 breeding pairs reside in Greek waters, probably as a result of better monitoring rather than a real population increase (Bazin and Imbert, 2012). The Audouin's Gull is endemic to the Mediterranean Sea and the Atlantic coast of Morocco and breeds on rocky coasts on uninhabited islets but rarely on non-accessible coastlines of larger inhabited islands. Greece hosts some of the most significant colonies of the species in Aegean Sea and the national population is estimated at 350-500 breeding pairs (Fric *et al*., 2012) which represents a decline of approximately 30% compared to the previous national estimate (Portolou and Papaconstantinou, 1999).

Besides marine birds, a bird species of great importance for Greece listed in Annex II of the SPA/BD Protocol is the Eleonora's falcon (*Falco eleonorae*). It is a medium-sized raptor and a long-distance migrant that overwinters mainly in Madagascar and breeds colonially on steep sea cliffs of uninhabited islets and large islands (e.g. Skyros) over the Mediterranean region and the eastern Atlantic. More than 85% of the global population is concentrated on the Aegean archipelago in Greece. The species is an aerial predator, feeding on insects in its wintering quarters and its breeding grounds till the egg-laying period and then upon bird migrants caught over the sea close to its colonies (Xirouchakis *et al*., 2019).

### 2.1.4 Inventory of the temporal occurrence, abundance and spatial distribution of non-indigenous, including invasive, species

A total of 232 marine NIS has been recorded in Greek waters up to December 2019. The taxonomic groups with the highest number of NIS are the molluscs and fishes (45 species each), followed by crustaceans (44), annelids (33) and macroalgae (26) (Zenetos *et al*., 2018 and unpublished ELNAIS data). In addition, an increase in the number of NIS Bryozoa (8) and Ascidiacea (7), mostly reported from boat hulls and marinas, was observed within the last decade.

The spatial distribution of NIS varies between the different marine subnational areas of Greece (according to the MSFD scheme), with the highest NIS number reaching 186 species in the South Aegean Sea, followed by the Levantine (113), North Aegean (96) and Ionian Seas (75). Approximately half of the NIS are found in at least two MSFD subnational areas, while 86 species occur exclusively in one MSFD subnational area (>30 of them are established).

The main pathways of NIS introductions in the Greek Seas are (Zenetos *et al*., 2018): (a) unaided, which correspond mainly to the Lessepsian immigrants, i.e. natural dispersal of Lessepsian NIS already introduced in the Southeast Levantine basin (57.5%), and (b) transport-stowaway, e.g. ship/boat ballast water and hull fouling, (36.7%). The number of NIS introduced through the above pathways shows an increasing trend from the 1970s to 2017, especially in the South Aegean and Levantine areas (unpublished ELNAIS data).



However, these trends are highly affected by monitoring bias and time lags in the reporting of new introductions. Dedicated monitoring of NIS, constant in space, time and across taxonomic groups, is necessary in order to assess spatial and temporal trends with higher certainty.

It is expected that systematic research in locations at high risk for the introduction of NIS scheduled within the framework of the Descriptor D2 of the MSFD (e.g. Dodecanese Islands, ports, marinas and aquaculture sites), understudied habitats (e.g. sublittoral hard substrates and cryptic habitats) and overlooked taxa (e.g. microalgae, foraminiferans and small-sized sessile invertebrates), coupled with the development of citizen science networks will significantly raise the number of NIS species in Greek waters.

### 2.1.5 Information on species of commercial interest for fishing (fish, molluscs and shellfish)

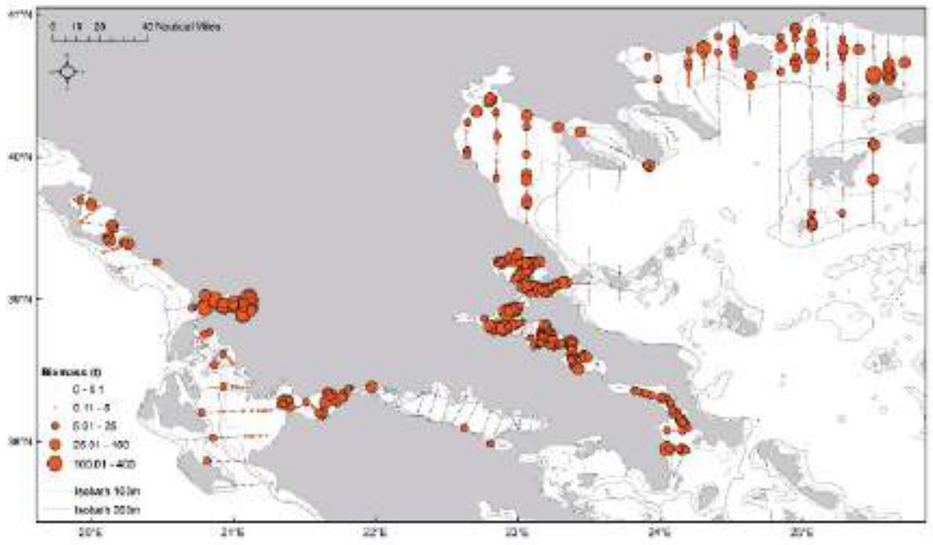
Greek marine fisheries are characterized by a large number of species caught per main fishing gear (i.e. multi-species fisheries) as well as by a variety of species that are exploited concurrently by different fishing gears (i.e. multi-gear fisheries). According to the latest available census, 510 fish species (including elasmobranchs) have been recorded from the Greek Seas (Papaconstantinou, 2015) half of which are used as food resources. According to the Hellenic Statistical Authority (ELSTAT) the species with the highest quantities of landings (in tons, based on 2016-2018 data for all gear types, i.e. trawls, purse seines, artisanal) are the fish *Engraulis encrasicolus*, *Sardina pilchardus*, *Merluccius merluccius*, and *Boops boops*, followed by the invertebrates *Melicertus kerathurus* and *Octopus vulgaris*. In terms of average price per kg for 2018 catches (fish-wharves and auctions), the five main species with the highest prices are *Palinurus elephas*, *Nephrops norvegicus*, *Mullus surmuletus*, *Octopus vulgaris* and *Loligo vulgaris*.

#### *Pelagic species*

Abundance of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) - the two most important small-sized pelagic species in terms of catch - presents high inter-decadal variability linked to climatic cycles and successful recruitment. They also present specific life history traits, for example, short-life span and high relative fecundity. In the Mediterranean and Greek Seas, small pelagic fish populations are characterized by truncated size- and age-structure (GFCM, 2019) making them sensitive to environmental forcing. Anchovies and sardines do not perform long migrations between feeding, spawning and juvenile grounds (Giannoulaki *et al*., 2011, 2013) reflecting that favourable habitats are associated with the existence of local point sources of nutrients that enhance productivity (e.g. river runoffs or upwellings), and isolated from one another due to complex oceanographic and topographic characteristics. Both anchovy and sardine are gregarious species forming schools and clusters of schools, an effective behaviour to escape from predators. Landings of small pelagics can remain more or less stable although the stock might decline and are often biased towards large specimens thus not representative of the age structure of the population at sea. Therefore, *in year* monitoring of landings is essential to be coupled with data from concurrent fisheries' independent surveys (e.g. hydroacoustics; ichthyoplankton surveys) and hydrographic sampling. Hydroacoustics surveys, carried out within the framework of the EU DCF International Mediterranean Acoustic Surveys (MEDIAS) on an annual basis in the eastern Ionian and

northern Aegean Seas (Figure 2) have allowed the identification of anchovy and sardine spawning and nursery grounds and hotspot distribution areas in the Greek Seas. Major anchovy spawning grounds are found in the north Aegean Sea (Somarakis *et al*., 2006a, Schismenou *et al*., 2008), while smaller spawning grounds exist in the central Ionian and Aegean Seas (Somarakis *et al*., 2006a). Suitable juvenile grounds are mainly located over the continental shelf, at sites presenting enrichment processes such as in the vicinity of river mouths. In the north Aegean Sea, anchovy nursery areas are largely associated with the more productive coastal waters, gulfs and closed basins (Giannoulaki *et al*., 2013). Sardine spawns during the winter (e.g. Somarakis *et al*., 2006b), mainly in inshore waters at depths between 40 and 90 m. Ichthyoplankton surveys have also verified the presence of spawning grounds of sardine in Patraikos Gulf and the inner part of Ionian Sea between the islands and the mainland but with higher concentrations close to the mainland (Somarakis *et al*., 2006b). The highest concentrations and abundances of sardine juveniles in the Aegean Sea during early summer have been identified in the coastal areas of the gulfs (e.g. Thermaikos Gulf, Strymonikos Gulf, North Evoikos Gulf), as well as in shallow areas (<70 m bottom depth) of the north part of the Thracian Sea plateau, often associated with waters of high productivity in the vicinity of river runoffs (Giannoulaki *et al*., 2011). Based on acoustic surveys, anchovy biomass during the last decade was on average 18,000 tons and 39,000 tons, in the eastern Ionian and north Aegean Seas, respectively. Sardine biomass was lower, being on average around 5,500 tons and 25,000 tons in the eastern Ionian and north Aegean, respectively.

**Figure 2.**
Spatial distribution of small pelagic fish biomass in the eastern Ionian and north Aegean Seas based on hydroacoustic surveys results in 2019.



### *Demersal species*

Species abundance and structure of the demersal megafauna community in the Greek territorial waters are monitored within the MEDITS survey which is carried out annually to date from 1996, following a standardized protocol, in 185 fixed sampling stations, distributed from 20 to 800 m depth. For all fish, crustaceans, and cephalopods species the total number and total weight are recorded for each haul, while more information (age, maturity, etc.) is collected for a set list of target species. Differences in the species diversity–depth patterns have been reported, depending on the faunal group or subarea studied. For instance, published data from three highly oligotrophic areas with relatively elevated SST values (Cyclades, the Dodecanese and Crete) revealed a high number of taxa (245) from 244 hauls. In particular, the recorded numbers of Osteichthyes (147), elasmobranch (33) and cephalopod (30) species were higher than the corresponding numbers of species in other central and western Mediterranean areas, despite that species richness is assumed to be negatively influenced by low primary production and higher SST values. Analysis of survey data on a fine spatial scale indicated that the median species richness by haul was higher for fish and lower for crustaceans (Peristeraki *et al*., 2017). Findings also suggest that the importance of depth-related factors in communities' structuring was more important for cephalopods and less important for fishes, owing to the species' trophic strategies and foraging abilities. Differences were higher between Crete and the other two study areas than between the Cyclades and Dodecanese islands, a fact that could be attributed to the specific geographical and oceanographic characteristics of this particular subarea. A total of 41 demersal chondrichthyan species were recorded from 1,159 hauls in the Aegean and eastern Ionian seas (all species were found in the Aegean, while only 28 of them were found in the Ionian Sea). A substantially higher total number and a higher number of chondrichthyan species by haul was also observed in the Aegean Sea, indicating the higher diversity of chondrichthyan species in this area, probably due to higher niche diversity. Patterns and trends from these regional areas indicated that biomass declines with increasing fishing effort (Peristeraki *et al*., 2019). However, certain chondrichthyans can withstand fishing pressure and it is likely that discard survival rates, depth preferences and fisheries exploitation strategies, are the main drivers explaining variations regarding the impact of fishing on the different chondrichthyan stocks. In the Aegean Sea, higher biomass rates were observed, in general, at longitudes and latitudes that correspond to insular areas of its central and eastern part and could be related either to the particular hydrology and geomorphology and/or to spatial differences in bottom-trawl fishing strategies. Of the species whose exploitation is regulated and included in Annex III of SPA/BD protocol only the fishes/elasmobranchs *Anguilla anguilla*, *Centrophorus granulosus*, *Heptranchias perlo*, *Mustelus mustelus* and *Squalus acanthias* and the crustaceans *Maja squinado* and *Palinurus elephas* have been found during the MEDITS survey.

## 2.1.6. Others

Among other species exploited as marine biological resources, sponges and the red coral are the most prominent in the Greek Seas.

Four sponge species are commercially harvested in the Mediterranean and the Greek Seas as 'bath sponges': predominantly *Hippospongia communis* and *Spongia officinalis* and - to a lesser degree - *S. lamella* and *S. zimmocca*. These species naturally occur in most coastal benthic habitats down to 100 m depth approximately. Their exploitation has been extensive in the eastern Mediterranean (Voultsiadou *et al*., 2011). A gradual decline of the Greek sponge stocks started after the heyday of sponge fishing throughout the first half of the 20th century and culminated with a major disease incident occurring

in the late 1980s (Voultsiadou *et al*., 2013). This has resulted in particularly small and fragmented bath sponge populations that are remnants of a past-time widespread distribution and still undergo local mortality events (Voultsiadou *et al*., 2011). Currently, the sponge fishery remains active as a small-scale artisanal fishery, strongly anchored in certain insular communities as that of Kalymnos, since bath sponges are still on global demand as luxury natural products, retaining a high market value. Despite its artisanal nature, this fishery imposes a persisting impact on the remaining sponge stocks, owing to a nomadic approach of a limited number of vessels and crews to actively harvest sponges over the whole extent of the Greek seas. Apart from harvesting pressure, bath sponge stocks still undergo local mortality events that are attributed to global change. The extant populations of *S. officinalis* have been genetically assessed in the Greek Seas (Dailianis *et al*., 2011), suggesting adequate genetic diversity and showing signs of connectivity, thus implying the necessity and potential effectiveness of sound conservation measures; however, similar data are pending for the remaining three bath sponge species, which are currently more limited regarding abundance. In a recent assessment of the conservation status combining landing data with current observations, all four bath sponges were characterized as Endangered (EN), following the IUCN Red List criteria (Gerovasileiou *et al*., 2018). Within the last years, along with commercial bath sponges, sponge fisheries have started targeting other species, such as *Chondrosia reniformis* and *Dysidea avara*, which are being intensively collected and traded for biotechnological use in some parts of the Aegean Sea. No data on the population status of these species are available to date and their exploitation is not being reported or regulated.

In Greece, the most abundant populations of the red coral *Corallium rubrum* are found in the north Aegean Sea, as illustrated by the total landings from this area, which are twice as high as those recorded from the Cretan and Ionian Seas taken together (Dounas *et al*., 2010). According to the available Greek fisheries data, shallow water stocks (down to 60 m) are almost depleted, and thus professional divers are forced to harvest in greater depths (up to 130 m). Observed evidence for the decline of stocks in areas only recently opened up to exploitation is an indication that fishing was carried out in these areas throughout the closed period, possibly by using illegal dragging gears (Dounas *et al*., 2010). Since 1994, red coral stocks have been regulated in the Greek Seas on a 5-year rotational basis in five large geographic areas (Presidential Decree 174/1994; Ministry Decision 240102/1995). Each coral harvesting zone in Greece is harvested for a maximum of 5 years followed by a 20-years closure. Last official landings as reported in 2019 to GFCM are from 2005. The north Aegean Sea has been harvested in the past and there was interest from practitioners, which is not the case for the latest zone to open (up to 2020). Previously four zones for exploitation opened with minimum interest from practitioners due to deep red coral distribution in these regions, resulting in a temporary paucity of harvesting activity. Harvesting is permitted only by means of scuba or surface-supplied air, at depths not shallower than 50 m and with a minimum harvesting legal size of 7 mm basal diameter (in line with GFCM advice) along with other technical and management measures. Significant knowledge gaps remain and an urgent need for scientific research targeting the red coral in the Greek Seas is apparent, aiming at a detailed investigation of the ecology, size and structure of coral populations assessing its conservation status and updating and/or implementing appropriate management and restoration measures. Detailed mapping and effective protection of the coralligenous and marine cave habitats of the species is of great importance in order to safeguard its future potential sustainable exploitation and the species' conservation.



## 2.2. Main Habitat types

Due to its highly heterogeneous coastline, complex geomorphology, active tectonics, and a notable eutrophication gradient between its north and south latitudes, Greece is home to a large diversity of marine habitats, comprising most Marine and Coastal Habitat Types classified under the Updated Classification of Benthic Marine Habitat Types for the Mediterranean Region (SPA/RAC–UN Environment/MAP, 2019).

Seabed-wise, marine conservation efforts in Greece have primarily focused on the Habitats Directive priority habitat types (Annex 1, 92/43/EC), namely coastal lagoons (HT 1150) and *Posidonia* seagrass beds (HT 1120). As of today, most coastal lagoons, and an estimated 20% of the total cover of *Posidonia* meadows along the Greek coastline have been included in the national Natura 2000 network as Sites of Community Importance, or Special Areas for Conservation. Most other habitat types, however, have benefited from partial, incidental or no protection. The main habitat types are presented below according to the Annex 1 inventory:

### *Habitat Type 1110: Sandbanks which are slightly covered by seawater all the time*

At the initial establishment of the Greek Natura 2000 Network (1999-2001), this habitat type was strictly interpreted as shallow wave-exposed sandy beds, mostly corresponding to well sorted fine sands with or without associations of angiosperms, i.e. *Cymodocea* and *Halophila stipulacea* for the Greek case. *C. nodosa* in particular is characteristic of several coastal areas in Greece, in many cases forming extensive meadows from the sea surface down to 10 m depth.

Later on, the "Interpretation Manual of European Union Habitats - EUR28" (2013) extended its use to include deeper sands under the influence of waves or currents, and particularly maërl or rhodoliths beds, as well as various associations and facies of coastal detritic bottoms. This flexibility allowed for a significant deeper marine expansion of the national Natura 2000 Network in 2016, to actively encompass some of these sensitive habitat types (*sensu* the Mediterranean Fisheries Regulation), which largely remain understudied and underrepresented in the National Monitoring Network (less than 15% of the total stations, while 1/3 was found to be under risk) and protection schemes.

### *Habitat type 1120: Posidonia beds*

*Posidonia oceanica* beds cover an estimated total of (2,300-2,600 km$^2$) in the Greek infralittoral zone of which ~700 km$^2$ within an SCI/SCA designation. *Posidonia* beds mostly thrive in well-oxygenated sandy bays unaffected by terrestrial runoff, a rather common feature along the Greek coastline. Depending on latitude and local conditions, their depth range may vary significantly (0-45 m). *Posidonia* beds commonly co-occur with *Cymodocea nodosa*, especially at the upper and lower limits of their distribution. Increased cover of dead *Posidonia* mattes is a typical finding in human-impacted areas, also with associations of *Caulerpa* and *Halophila spp.* Although particular ecomorphoses (i.e. *Posidonia* stripped meadows, fringing reefs, barrier reefs and atolls) occasionally occur, they have not been considered for conservation purposes due to their rather limited extent (V. Gerakaris, pers. observ.). Banks of beached *Posidonia* leaves forming extensive banquettes are typical to be found along Greek sandy or rocky shores in the proximity of *Posidonia* meadows.

### *Habitat Type 1130: Estuaries*

Habitats of transitional waters (estuaries) occur where major, year-round flowing rivers meet the sea in semi-enclosed coasts. Depending on sea- or freshwater influence, several marine angiosperms or halophytes may predominate in these systems, as is the case of *Ruppia maritima* and *Zannichellia* that form well-developed meadows in Evros Delta. Remarkable canopies of *Cystoseira spp.* (mostly *C. compressa* and *C. barbata*) occasionally thrive in such sheltered highly productive environments.

### *Habitat Type 1140: Mudflats and sandflats not covered by seawater at low tide*

This habitat mostly occurs in tidal environments with littoral sands and muds, as is the case of north Evoikos Gulf and the Strait of Oreoi but may also occur in lagoonal and estuarine environments.

### *Habitat Type 1150: Coastal lagoons*

Several angiosperms have been recorded in Greek coastal lagoons, mainly of the genera *Ruppia*, *Zostera*, *Cymodocea* and *Zannichellia*. Ruppia is rather characteristic of coastal brackish waters and inland salt-water habitats in Greece. *R. cirrhosa* and *R. maritima* have been recorded to form dense submerged meadows in many Greek lagoons. *Cymodocea nodosa* was reported in Messolonghi and other lagoons with increased water salinity. *Zostera noltei* has a relatively restricted distribution and is mostly found in the lagoons of Amvrakikos Gulf. Occasionally, well developed reefs formed by the serpulid *Ficopomatus enigmaticus* are recorded (i.e. Prokopos lagoon) enhancing environmental heterogeneity and forming new microhabitats for associated organisms.

### *Habitat type 1160: Large shallow inlets and bays*

This habitat is described as "shallow and sheltered indentations of the coast where, in contrast to estuaries, the influence of freshwater is generally limited", it is a quite complex geomorphological entity, ranging from coastal lagoons and estuaries, to reefs and seagrass meadows. These ecosystems are typically highly productive and may occasionally host exceptional formations, notably oyster reefs, *Cladocora* reefs or multi-specific biogenic reefs. *Pinna nobilis* exceptional aggregations were typical in these environments before the mass mortality outbreak of the species in 2018.

### *Habitat Type 1170: Reefs*

Although not a priority habitat type, reefs - corresponding to nearly all UNEP/MED Habitat Type categories across littoral to infralittoral rocks - make an important component of the national Natura 2000 network, as also the wider Greek coastline.

According to local physicochemical conditions, littoral and infralittoral rocks may present a large variety in their prevailing biotic features. In well-lit pristine environments, these associations are characterized by rich canopies of Fucales (i.e. *Cystoseira* and *Sargassum spp.*), while articulated corallines (e.g. *Corallina-Haliptilon*) abound in more shaded and/or mesotrophic environments. Encrusting belt-forming Corallinales (e.g. *Lithophyllum spp.*, *Neogoniolithon spp.*, *Titanoderma trochanter*, *Tenarea tortuosa*) or vermetid reefs are not uncommon, but extensively developed only in well-exposed and moderately shaded littoral rocks. Facies with endolithic species (e.g. *Lithophaga lithophaga*, *Cliona spp.*) are rather ubiquitous along the extensive calcareous shores, but conspicuously prevail in degraded, canopy-devoid zones. Here, facies of *Cladocora caespitosa* are also typical, but generally appear to be in ongoing recession. Facies of *Oculina patagonica* also occur, rather restricted in central latitudes. Within the last decade, Greek infralittoral rocks (*esp.* depths of ~2-10 m) have been shown to suffer a severe loss of canopy algae, under increasing herbivore pressure by native sea-urchins and/or invasive siganid fish. This is an intricate and rapidly progressing phenomenon, synergistically triggered by overfishing, disruption of coastal food webs and climate change.

In regard to deeper (circalittoral and bathyal) rocks, these remain significantly less studied and therefore scarcely considered in national monitoring and protection schemes. Still, they appear to be rather common across the Greek seas, depending on substrate availability and depth (e.g. Martin *et al*., 2013; DEEPEASTMED report, EMODNET). As typical for the Mediterranean, coralligenous communities are also the natural climax in the Greek circalittoral zone. Depending on light availability, various associations of Fucales may characterize the upper limit of this zone (30-60 m), succeeded by variable facies of sponges and scleractinians (low to moderate hydrodynamic energy), or gorgonians and antipatharians (current-swept circalittoral rocks). *Dendrophyllia cornigera* banks and facies of bathyal corals also occur in deeper horizons, but lack of basic research and seabed mapping has not yet allowed for a representative inclusion of their diversity and extent in national conservation schemes.

### *Habitat Type 8330: Submerged or partially submerged sea caves*

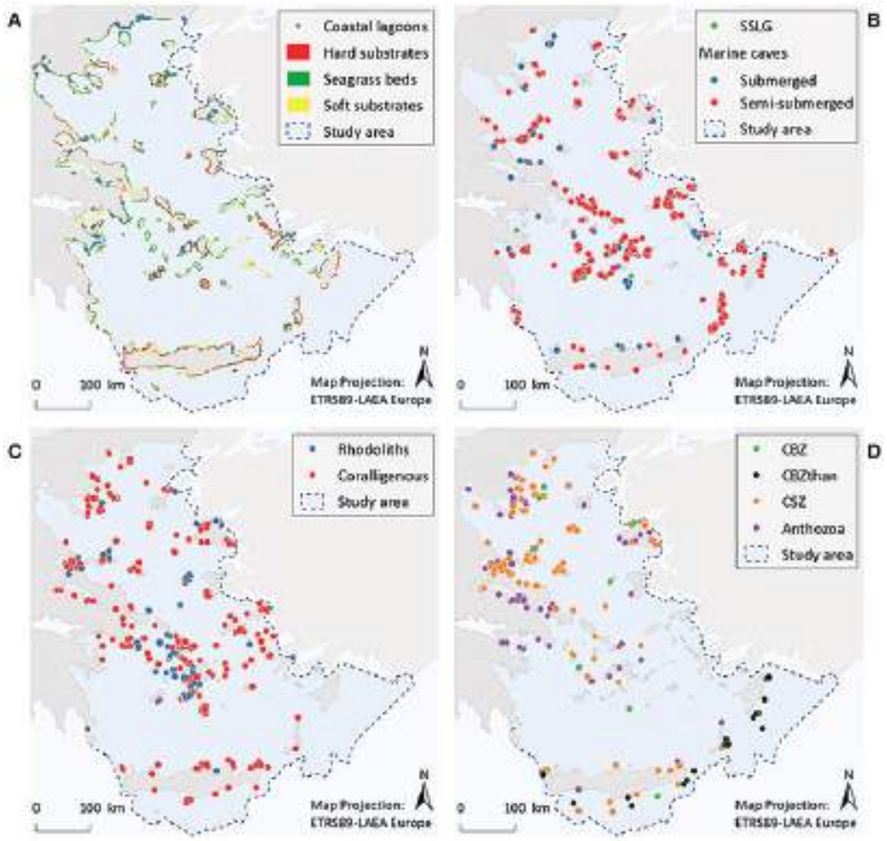
Marine caves are among the most iconic features of the Greek rocky coasts. To date, approximately 1,000 marine caves, mostly semi-submerged, are known from the Greek coasts (ca. 700 in the Aegean and ca. 300 in the Eastern Ionian Sea) (Giakoumi *et al*., 2013; Sini *et al*., 2017 and unpublished data by V. Gerovasileiou). Nevertheless, given the high complexity of the Greek coastline and the continuous abrasive and geodynamic processes, the actual number of caves in the country is assumed to be much higher. Most caves are located in the island-dominated South Aegean Sea (Cyclades and Dodecanese Islands) and the northern Sporades and Ionian islands, where limestone coasts prevail (Figure 3B). Existing information mainly concerns shallow semi-submerged and intertidal caves while lesser spatial data exist regarding submerged caves. The recent study of ca. 40 marine caves in the Greek Seas has shown that they constitute biodiversity hotspots, harbouring more than 400 species, including rare, protected, and new endemic taxa, as well as unique communities and bioconstructions (Gerovasileiou *et al*., 2015 and unpublished data).

*Habitat Type 1180: Submarine Structures made by leaking gases*

Although non strictly methane-related, several sites along the Aegean volcanic arc known to comprise submarine structures presenting exceptional chemosynthetic bacterial communities and other important fauna, have been proposed for inclusion under this category in the Greek Natura 2000 Network (see section 2.3).

**Figure 3.**

Maps depicting the distribution of (A) Coastal lagoons, hard substrates, seagrass beds, and soft substrates, (B) Submarine structures made by leaking gases (SSLG) and marine caves, (C) Rhodolith beds and coralligenous formations, (D) Corals of the bathyal zone (CBZ), Corals of the bathyal zone thanatocoenoses (CBZ), Corals of the sublittoral zone (CSZ), and protected anthozoans in the Aegean Sea (from Sini et al., 2017 reported up to 2016 within MARISCA project). Points on the map show positive presence and lack of points does not imply verified absence.

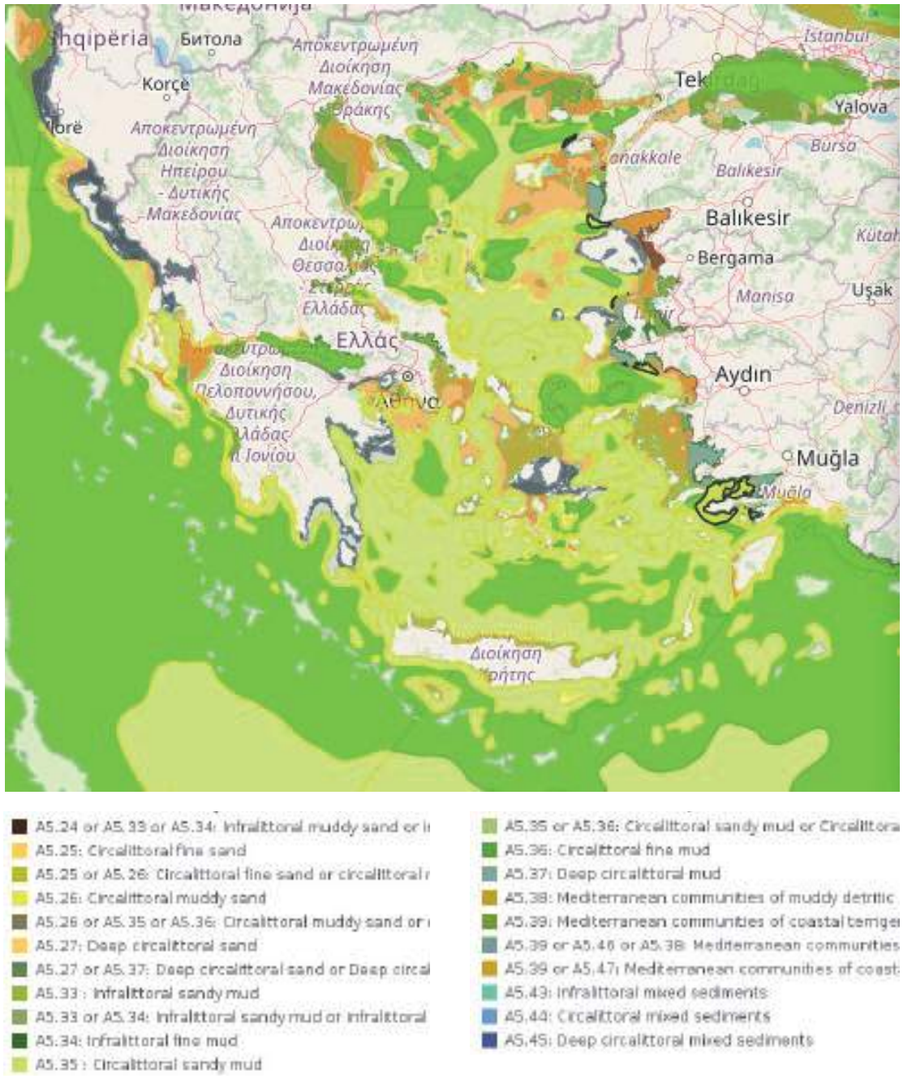



The "European Marine Observation and Data Network" (EMODnet) has produced a broad scale habitat online map viewer (Figure 4) by assembling point datasets and habitat distribution models from different sources (www.emodnet.eu/seabed-habitats). Its usefulness lies in its total coverage for the European Seas and the standardisation of habitat classification, which is in accordance with the European Nature Information System (EUNIS) (Gerovasileiou *et al.*, 2019). EMODNET also displays information and maps of the MSFD broad habitat types (BHT), i.e. soft, hard and biogenic substrate types spanning from littoral to abyssal depths, for the needs of the assessment of the Good Environmental Status (GES) of the benthic habitats under the MSFD. These habitats include threatened and protected EUNIS level 4+ habitats that require additional targeted assessments and conservation and restoration measures, for example mapping the *Pinna nobilis* habitats status and planning the necessary research and conservation actions (see also below the red coral case).



**Figure 4.**

Modelled distribution of seabed habitats according to the EUNIS classification system on the EMODnet Seabed Habitats map viewer (from https://www.emodnet.eu/seabed-habitats)




## 2.3 Singular habitats in the country

The Greek Seas encompass several types of "extreme" habitats which harbour unique assemblages and forms of life, including hydrothermal vents, cold seeps, pockmarks, mud volcanoes, brine pools, seamounts, submarine canyons, marine and anchialine caves. Most of the above habitats fall under the category of "dark habitats" which are protected under the Mediterranean Dark Habitats Action Plan (UNEP-MAP-RAC/SPA, 2015), except for vents in the shallow photic zone, and often support extensive mats of extremophile

microbes, mono-specific invertebrate communities (e.g. sponges, anthozoans and ascidians) and endemic species (e.g. cave-exclusives). The Hellenic volcanic arc, extending from Methana to Nisyros Island, hosts several unique habitats and assemblages. Typical examples include the extensive microbial mats in Kolumbo volcano (Christakis *et al*., 2018). Shallow marine and anchialine caves, which are one the most distinctive features of the Greek rocky coasts, harbour several endemic, rare and protected taxa (Gerovasileiou *et al*., 2015). In addition, deep-sea faunal elements can survive under dark cave conditions in the shallow littoral zone, providing "natural laboratories" that can be directly accessed by diving researchers. Nevertheless, our knowledge and understanding of these unique habitats and their biodiversity is still incomplete and they deserve further research and conservation actions.

## 2.4. Transboundary issues

Important areas (e.g. feeding, spawning, nesting, and nursery grounds) for charismatic marine megafauna (e.g. cetaceans, turtles, and birds), pelagic and deep-water species often extend beyond the Greek territorial waters and coasts. For instance, loggerhead turtles cover long distances (up to 800 km) from their neritic foraging grounds (e.g. in the Libyan/Tunisian shelf and the Adriatic Sea) to their breeding sites in Zakynthos and Crete (Casale et al., 2018). Both coastal and offshore pelagic waters represent density and residency hotspots and ecological corridors connecting distant population units for cetaceans (Sini et al., 2017). Migratory marine birds, including long-distance migrants, face severe challenges such as the disruption of their pathways due to global climate change (Mesquita et al., 2015). Nursery and spawning areas for some commercial fishes (e.g. *Merluccius merluccius*) and shrimps (e.g. *Aristaeomorpha foliacea, Aristeus antennatus, Parapenaeus longirostris*) are located in international deep-water areas (MediSeH, 2013; Mytilineou et al., 2019), which host Vulnerable Marine Ecosystems (VMEs – see section 3.2). Therefore, important areas, corridors and migratory pathways in adjacent countries and international waters must be considered in the framework of population assessments, management actions and conservation initiatives for the above-mentioned taxa.

Several human activities and pressures which affect marine and coastal biodiversity in Greece, both directly and indirectly, may originate from or impact on broader/adjacent geographical regions (e.g. marine litter and pollution from ships) or are linked to global climate change phenomena (e.g. seawater warming and ocean acidification) (see sections 3.3 and 5.2). Thus, monitoring, management, and mitigation actions for the protection of marine and coastal biodiversity from negative impacts caused by human activities and pressures require transboundary collaboration at broad geographical scales (e.g. EU strategy for the Adriatic and Ionian region) and implementation actions within regional, international and European frameworks (see sections 4.2 and 4.3).

One of the most typical examples of biodiversity issues that need to be monitored and managed at a broad transboundary level is that of non-indigenous species, since their main pathways of introduction in the Greek Seas are unaided dispersal of Lessepsian immigrants already introduced in the south-eastern Mediterranean Sea (i.e. Egypt, Israel, Lebanon, Syria, Cyprus and Turkey) and introductions related with ballast water and hull fouling from maritime transport (see section 2.1.4).



## 2.5. Identification of the country's marine and coastal biodiversity gaps needed for scientifically sound based conservation

There are numerous studies addressing taxonomic issues and species composition of benthic communities in transitional, coastal and offshore waters, but they are mostly related to soft substrate biota and are concentrated in specific areas such as the Cretan Sea, the north-eastern Aegean and some gulfs (e.g. Saronikos, Thermaikos, Heraklion and Evoikos). However, extended transition zones (ecotones) as well as BBL macrofaunal communities of the soft substrates have been little studied. Despite the availability of taxonomic studies and species checklists (e.g. GTIS), there is a notable absence of information and expertise regarding the small-sized (e.g. microalgae, meiofauna), sessile (e.g. Hydrozoa, Ascidiacea) and planktonic taxa and types of habitats which often harbour rare, unknown and exclusive species (i.e. pelagic systems, interstitial habitats, rhodolith beds, sciaphilic and coralligenous formations and caves, special and extreme marine habitats such as salt marshes, hydrothermal vents, deep sea assemblages, etc. Moreover, there is no balanced sampling effort among the different habitat types resulting in little information relevant to their distribution. Studies concerning time-series are also scarce and urgently needed in order to investigate temporal variability of biological communities of the Greek Seas. Little is known on the ecology of deep-sea benthic fauna in the eastern Mediterranean. Molecular approaches in combination with classical methods for cryptic and questionable species are needed. Available literature for several taxa refers almost exclusively to the Aegean Sea. Consequently, there are knowledge gaps in the biodiversity of unexplored geographic areas in order to investigate spatial variability of Greek Seas. More specifically, there is a critical necessity for further research on the biodiversity of the Ionian and Levantine waters of Greece. The role of zooplankton as a link between the lower trophic levels (phytoplankton, microbes) and the higher trophic level (fish) needs to be investigated both in coastal and offshore waters. The role of the macrofauna related to the sediment-water processes is also underestimated, especially in studies of benthic-pelagic coupling related to energy fluxes and also in holistic approaches of the marine ecosystem (Koulouri *et al*., 2015). Further research on gelatinous zooplankton diversity of the Greek Seas is required in order to investigate distribution patterns and monitor potential outbreak events. Studies directly investigating the impact of NIS on the diversity of native biota, as well as the socio-economic impact of invasive alien species, are missing. Monitoring of NIS and their impact in hotspot areas for biological introductions, such as ports and aquaculture sites, is necessary. New information should be in the right format to match currently available information. Only in the MedOBIS virtual laboratory of LifeWatchGreece can one find information on taxa distribution and composition, which is duly annotated and according to international standards (Darwin Core), in order to be machine-to-machine readable and, therefore, to allow global aggregators, such as GBIF and OBIS, to harvest these data or information. Consequently, the large gaps in acquiring information are mirrored also in properly managed and stored information by national platforms, such as LifeWatchGreece.

# 3.

# Pressures and impacts

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## 3.1. Biological disturbance

### *Non-indigenous species*

To date the most notable negative environmental impact in Greek Seas from NIS has been documented mainly for grazing herbivore fish (e.g. *Siganus luridus* and *S. rivulatus*) depleting canopy-forming macroalgae (Salomidi *et al*., 2016). In addition, two predators, the cornetfish *Fistularia commersonii* and the lionfish *Pterois miles*, which have established large populations in the South Aegean and Levantine waters of Greece, prey on small benthic and newly hatched fish. The macroalgae *Caulerpa cylindracea*, *Asparagopsis taxiformis*, and *Codium fragile* exhibit invasive behaviour by causing reduction of the diversity and abundance of native macroalgae and macro-invertebrates but only in some degraded areas. Other invasive species such as the bivalves *Pinctada imbricata radiata*, *Dendostrea cf. folium*, and *Fulvia fragilis* as well as the crab *Percnon gibbesi* are locally abundant but their impact has not been studied. Apart from the puffer fish *Lagocephalus sceleratus* which is extremely toxic and dangerous for human health (its marketing has been banned), a number of NIS fishes (e.g. *Siganus rivulatus*, *S. luridus*, *Fistularia commersonii*, *Pterois miles*), crustaceans (e.g. *Callinectes sapidus*) and mollusks (e.g. *Conomurex persicus*) have attained commercial value.

### *Microbial pathogens and mortality events*

The first evidence of mass mortality events (MMEs) in the Greek Seas date back to the 80's, having severely affected harvested commercial sponges (see section 2.1.6). In addition, many other sessile invertebrate groups were locally affected by such events, including gorgonians, bivalves, and bryozoans (Voultsiadou *et al*., 2013; Gerovasileiou *et al*., 2018; Garrabou *et al*., 2019). Nevertheless, information is scarce since in most cases such events remain unnoticed. Since 2016, an ongoing MME has caused the severe decline of the endemic fan mussel *Pinna nobilis* populations in the entire Mediterranean. As most populations of the species have collapsed it has been assessed as critically endangered by the IUCN Red List. The infection was most probably caused by the cryptogenic protozoan *Haplosporidium pinnae*, although the effect of a mycobacterium was reported (Carella *et al*., 2020). The infection was first reported in Greece in 2018 (Katsanevakis *et al*., 2019) and since then it gradually affected all Greek populations. Both *Haplosporidium pinnae* and *Mycobacterium sp.* were detected in Greek fan mussel populations (Lattos *et al*., 2020). By June 2020, most fan mussel populations in Greece had collapsed; important surviving populations have been reported only from Kalloni Gulf (Zotou *et al*., 2020). A mass mortality outbreak was also recorded in 2013 within the National Marine Park of Zakynthos (NMPZ), concerning groupers (*Epinephelus spp.*) due to nodavirus causing Viral Nervous Necrosis (VNN)/Viral Encephalopathy and Retinopathy (VER) (NMPZ unpublished data).

### *Impact of aquaculture*

Aquaculture affects the marine environment through the release of dissolved nutrients, particulate material as well as chemotherapeutants and antifouling chemicals. In the framework of the MERAMED project, benthic impacts were observed at a distance of 25 to 50 m from the farm cages, based on observations of low-flux in sediment traps (Cromey *et al*., 2012). Different indices used as indicators of the seabed environmental conditions revealed an acceptable environmental quality beyond 50 m of the fish farms,

while conditions were usually unacceptable up to 10 m from the fish cages (Karakassis *et al*., 2013). The presence of antibiotics in sediments below fish farm cages in Greece is sparse (Van den Brink *et al*., 2020). In the framework of the TAPAS project, results revealed negative effects of fish farming on patches of the seagrass *Posidonia oceanica* in shallow water by significantly reducing the seagrass morphology and productivity. Decrease of the horizontal rhizome production of the seagrass *Cymodocea nodosa* with the proximity to the fish farm was also found. An increase of the eco-physiological indicators (e.g. rhizome nitrogen, leaf carbon and leaf $\delta^{13}C$), and of metabolites involved with stress-response, and a decrease of growth promoting metabolites were observed close to the fish farm. Zooplankton functional community structures were strongly related to aquaculture-associated abiotic factors which were increased close to the fish cages (Van den Brink *et al*., 2020). The content of benthic organisms in elements increases with increasing sediment metal content and with sedimentary grain size, organic matter and chlorophyll-*a*. In Greece, the annual fish escapes from fish farms were estimated to be 303,066 seabream and 21,700 seabass, based on questionnaires (Jackson *et al*., 2015). These escapes are associated with genetic interactions and risk of competition with wild stocks thus having further negative impacts in the marine environment. Environmental sustainability of European aquaculture by developing tools, approaches and frameworks for monitoring and management of aquaculture sites have been investigated within the framework of TAPAS project (http://tapas-h2020.eu) and spatial and socio-economic constraints on the expansion of aquaculture in Europe and globally, within the framework of AQUASPACE project (http://www.aquaspace-h2020.eu).

### *Impact of fisheries on target species*

The Greek fishing fleet consists of a large number of fishing vessels (14,123 vessels as of 31 December 2018) with small overall tonnage and engine power, mostly engaged in fishing coastal stocks. The largest segment of the fleet (96.54%) is made up of vessels fishing multiple species near the coast with static gears. Only 1.69% of the fleet target pelagic species with purse seine, and 1.77% target benthic species with bottom otter trawls. The Greek fisheries are managed through control effort regimes accompanied by various technical measures. Direct effort is controlled through limitations in the number of fishing licenses, as well as through seasonal and spatial fishery closures. The applied technical measures include minimum landing size (MLS) regulations for several commercial species and control of gear characteristics (e.g. mesh-size). From 2019 all species with Minimum Conservation Reference Sizes in the Mediterranean are subject to the landing obligation, requiring all catches of regulated commercial species on-board to be landed and counted. Undersized fish cannot be marketed for direct human consumption purposes whilst prohibited species (e.g. basking shark) cannot be retained on board and must be returned to the sea. Management plans have been endorsed by the Greek legislation regarding bottom trawls and purse seines. *Mullus barbatus* is mainly fished by bottom trawlers and is one of the most important target species of the gear. Minor catches are also reported from artisanal fleets using various gillnet types. *M. surmuletus* is equally fished by bottom trawlers and artisanal fleets. Assessment results demonstrated that their stocks are at a healthy state and their exploitation rates are at safe levels. The progressive implementation of increases in the trawl codend mesh-size and the prohibition of bottom trawling in depths <50m had positively affected the state of their stocks. The species *Merluccius merluccius* (hake) is fished by bottom trawlers and various artisanal fleets that use gillnets and longlines. Assessment results have demonstrated that its stocks are overfished, and fishing effort reductions or nursery grounds protection have been recommended to rebuild stock biomass at levels ensuring maximum sustainable yield. Pink shrimp (*Parapeneus longirostris*) is fished by bottom trawlers and it is one of the main target species of the gear. Assessment results suggest that its stocks are at safe levels, but there is high uncertainty in the relevant estimates. Hence, management based on precautionary principles has been suggested. Intense exploitation of the prawn *Melicertus kerathurus*, has also resulted in a severe reduction in catches. Thus, existing stocks of this species should be considered as potentially endangered, and species-specific initiatives towards sustainable management of this resource should be implemented (Kevrekidis and Legaki, 2011). Anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) stocks are predominantly fished within the continental shelf by purse seiners, as the main target species of the gear. There is a closed period for the fishery from mid-December till the first of March, each year. Latest assessment results (GFCM, 2019) showed that anchovy stock in the Aegean Sea is sustainably exploited whereas the sardine stock is overfished.

### *Impact of fisheries on non-target species*

Fisheries impact non-target species either directly, by imposing capture-related mortality, or indirectly through altering trophic interactions. Regarding direct mortality, most studies focus on discards while knowledge on mortality-at-sea, i.e. of organisms escaping from fishing gears, is generally very limited. Bottom trawling produces the highest volume of discards (Tsagarakis *et al*., 2014), accounting for 26-35% of total catch in the Aegean Sea bottom trawl fishery in the period 2004-2014 (Damalas *et al*., 2018). Fish comprise the majority of discards, followed by crustaceans (Damalas *et al*., 2018), while approximately 60-70% of the discarded catch is attributed to numerous non-commercial species and the rest consists of undersized commercial species. The discard ratios of the small scale and purse seine fisheries are much lower (<10%, Tzanatos *et al*., 2007 and <4.6%, Tsagarakis *et al*., 2012, respectively) however the discarded amounts may be still considerable due to the high overall catches of these fishing sectors. Survival of discarded species shows clear seasonal patterns and is low or zero for most species but can be high for certain species or groups (e.g. invertebrates, elasmobranchs), especially during the cold season (Tsagarakis *et al*., 2018).

Until now, there is little quantitative information concerning the incidental capture of Protected Endangered and Threatened (PET) species in the fishing gears (e.g. turtles: Panagopoulou *et al*., 2017, turtles and sharks: Touloupaki *et al*., 2020; elasmobranchs: Damalas and Vassilopoulou, 2011; seabirds: Karris *et al*., 2013; dolphins: Pardalou and Tsikliras, 2018) showing interactions especially with small scale fisheries. However, there are ongoing efforts to collect more and up-to-date information in order to better evaluate the magnitude of incidental catches and the effects on the populations of these long-lived, slow-growing PET species.

The main indirect impact of fisheries is related to discarding; discards constitute a food source for many scavenging species including seabirds (Karris *et al*., 2018), fish and crustaceans, which may be favoured by this fishing practice. As far as small invertebrates living close to the sediment-water interface is concerned, there is scarce information indicating that these animals can be exposed by the passage of a trawl and that this may lead to increased opportunistic feeding by other invertebrate and fish predators (e.g. Koulouri *et al*., 2005). In parallel, fisheries may compete for resources with other predatory

species increasing the risk of population decline due to shortage of food. Overfishing of small pelagic fish in the Ionian Sea has been proposed as the cause of decline for the short-beaked common dolphin population (Bearzi *et al*., 2008). In contrast, in the north Aegean Sea, trophic interactions due to fishing small pelagic fish do not seem to adversely affect dolphin populations, at least under the current fishing pressure levels.

### *Impact of fisheries on habitats*

Besides the removal of targeted catch and bycatch, bottom contacting fishing gears can have degrading impacts on the seabed. Different parts of fishing gears contact, cut, scrape and plough the seabed, including trawls on sedimentary or mixed bottoms, whilst traps, nets and longlines fish on all types of seabeds The largest impacting gears are bottom trawls used throughout most Greek waters during the main trawling season (traditionally, beginning of October to the end of May). Trawlers can operate deeper than 50 m (or further than 1.5 nm from shore). A few Greek trawlers operate deeper than 500 m depth, although there is a number of Italian vessels targeting red shrimp from 6 nm offshore at depths of 300-700 m around Greek islands and the Ionian mainland. In the trawl path the gear can flatten topographical features as well as ploughing, that can remove, damage, bury and kill both epifauna and infauna, as well as changing the sediment fabric and related processes contributing to the degradation or destruction of habitats. More specifically, illegal, unreported and unregulated (IUU) fisheries practices by trawling cause significant and frequently irreversible impact to protected marine habitats, such as *Posidonia* seagrass meadows, coralligenous and rhodolith/maërl beds. Away from the trawl path, resuspended sediments can settle, smothering biota and algal/plant communities. Trawling impacts in Greek waters fauna have been studied by Smith *et al*. (2000, 2003, 2007), Dounas *et al*. (2007) and Petihakis *et al*. (2007).

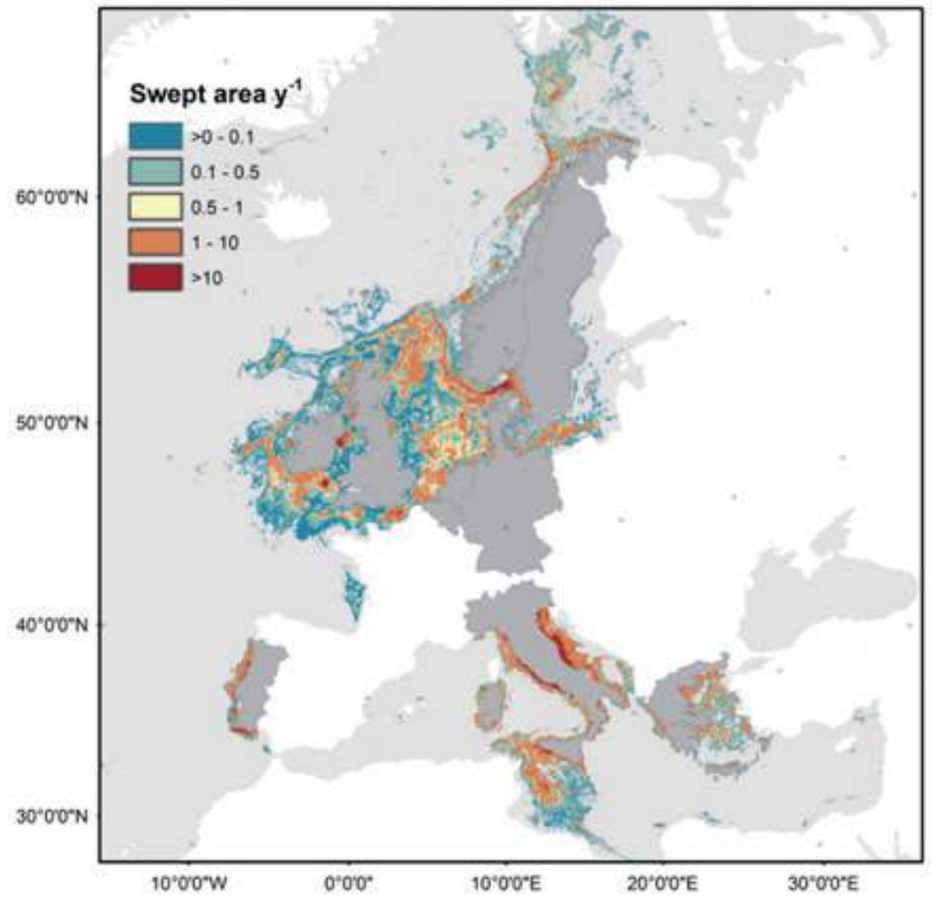
Gear impacts have been estimated in Eigaard *et al*. (2016) and used to estimate swept areas trawling intensities across Europe including Greek waters (Eigaard *et al*., 2016), see Figure 5. Data from this study indicated that for the Aegean Sea 0-200 m depth, 52,000 $km^2$ has a trawling intensity of 1.65 times per year and a trawling footprint of 74.8% within this zone, whilst for the 201-1000 m depth zone, 205,000 $km^2$ has a trawling intensity of 0.25 times per year and a 24.3 % footprint. All sedimentary habitats are trawled including a significant proportion (e.g. 40%) of macrophyte-dominated sediments and biogenic habitats in Mediterranean areas (e.g. Aegean and Adriatic) with some impacts documented recently by Bevilacqua *et al*. (2020) although mapping for many habitats is still incomplete (Sini *et al*., 2017). In terms of fisheries landings, for the 0-200 m depth zone, 19.4 $km^2$ of seabed has to be fished to land 1 ton of fish while for 201-1000 m zone, this area is 10.8 $km^2$.

The artisanal fishing fleet is much larger than the trawl fleet, operating mostly in shallow waters (<200 m), although some longlining and netting is carried out in deeper waters particularly if they are in proximity to shore (e.g. off Kefalonia, Mytilineou *et al*., 2014). These gears also remove, scrape and entangle on the seabed but with a much smaller footprint than trawling.

Lost fishing gears can be classified as litter, but traps and nets may continue to ghost fish for some time after loss. They will eventually collapse or foul on the seabed and become a local hard substrate for colonisation.



**Figure 5.**
Mean annual trawling intensity (total swept area) in the period 2010-2012 at the sediment surface for European countries marked in dark grey (from Eigaard et al., 2017)




## 3.2. Vulnerable marine ecosystems

Vulnerable Marine Ecosystems (VMEs) include groups of species, communities or habitats/features that are rare, endangered and/or physically fragile and vulnerable to damage by human activities with slow recovery rates. According to FAO, VMEs are defined by their vulnerability to fishing activities (GFCM, 2017). The term has been widely used for deep sea habitats (>200 m), which host long-lived emergent fauna of low turnover rates or fragile biogenic structures, thus being particularly vulnerable to numerous human activities (e.g. deep-sea fisheries, seabed extraction and mining).

In the frame of the recent DEEPEASTMED project (HCMR and IUCN funded), aiming to identify and map VMEs in the Eastern Mediterranean, archive video (from ROV, towed video systems and manned submarine) and photographic material (on-board and laboratory deep-water experimental fishing catches), collected by HCMR within the last two decades

within numerous research projects and expeditions, was assessed for the presence and abundance of vulnerable benthic taxa. In addition, a detailed review of published and grey literature was performed, for the collection of available records of deep-sea sessile benthos and relevant metadata.

A considerable number of "hotspot" sites (related to higher vulnerable species number and/or abundance) were identified, particularly on either side of the island of Crete and particular locations of the Eastern Ionian Sea. The majority of the surveyed seabed was sedimentary with few species recorded and, with the exceptions of sea pens, bamboo corals, cerianthid anemones and crinoids, the vulnerable species were mostly associated with geological features (e.g. rock outcrops, crusts, stones and chimneys) or anthropogenic features (e.g. amphorae, marine litter). Underwater volcanic areas (Santorini caldera, Kolumbo and Pafsanias volcanoes) often harboured monospecific habitats, such as beds/fields of cerianthids, ascidians or lollipop sponges. Vulnerable species in the studied sites included 16 sponge taxa, 5 pennatulid and anemone taxa, 18 cold water coral species and 5 other taxa (2 Crinoidea, 1 Brachiopoda, and 2 Ascidiacea). Several of these taxa are protected and/or listed in the IUCN Red List endangered categories, including rare and new records for the Eastern Mediterranean Sea (Gerovasileiou *et al*., 2019; Mytilineou *et al*., 2019).

The literature review clearly revealed the widespread presence of vulnerable deep-sea benthos across the study area. Among the most characteristic taxa, in terms of occurrence records, are: the bamboo coral *Isidella elongata*, the crinoid *Leptometra phalangium*, the scleractinians *Caryophyllia smithii* and *Desmophyllum dianthus*, the sea-pen *Funiculina quadrangularis*, and the demosponge *Rhizaxinella spp.* Large living structural scleractinians have not been observed in Greek waters but are present in adjacent Ionian Sea waters off Italy.

Nevertheless, much of the available data is outdated with almost half of the literature records dating before the year 2000, while most of the video/photographic material was recorded over a wide chronological scale (23 years). Thus, the current status, particularly of observed fields of bamboo corals, pennatulids or crinoids in recently opened trawl areas is unknown.

In any case, the wide presence of protected and vulnerable species and habitats in the Greek Seas calls for more systematic assessments (identification and enumeration), dedicated surveys and collection missions for the molecular characterization of deep-sea biological resources and implementation of effective fisheries management, as well as other conservation actions in the light of current activities (deep-water red shrimp fishery) and future plans for offshore oil and gas exploration, and wind farm installation in the deep eastern Mediterranean Sea.



## 3.3. Emerging issues such as climatic change effects and open sea including deep-sea ecosystem concerns

Anthropogenic activities and pressures (e.g. marine litter and especially plastic pollution, oil and gas extraction, mining, underwater cables and pipes, maritime accidents, waste disposal, land-based activities) impact directly or indirectly vulnerable ecosystems and habitats (UNEP, 2007). Indirect effects of human pressures are related more with climate change, ocean acidification and ozone depletion (UNEP, 2007). Information concerning the anthropogenic impacts on deep Mediterranean environments is still limited especially for the eastern and southern regions of the Mediterranean basin (Coll *et al*., 2010). In further work in the DEEPEASTMED project, scientific research data on marine litter/human effects collected within several research projects and expeditions and a detailed review of published and grey literature was carried out in order to identify anthropogenic impacts in the deep eastern Mediterranean.

Plastics are the dominant litter category on the seafloor of Greek seas (Mytilineou *et al*., 2019), particularly in the deep waters. Litter density in the eastern Ionian Sea ranged between 11 and 2,475 items/km$^2$; in the north Aegean Sea between 8 and 766 items/km$^2$, whereas in the south Aegean Sea, between 8 and 3,057 items/km$^2$. Areas of highest plastic pollution (>1,000 items/km$^2$), were observed on the seafloor around some islands of the Ionian Sea and Saronikos Gulf. Though there is lack of extensive monitoring programs but also different sampling schemes, it could be suggested that plastic density was higher close to highly urbanised gulfs/areas and shipping lanes. In some cases, the presence of marine litter on the deep seafloor as well as lost fishing gears entangled on corals or rocks was documented by videos obtained by ROV transects. The negative impacts of litter on the marine life have not been studied in detail, but effects such as suffocation, entanglement, physical damage, ghost fishing of discarded/lost nets and chemical pollution from decomposing materials (e.g. plastics additives, microplastics, paints) are considered among the major threats of marine biodiversity and have been suggested as major issues requiring further investigation. To date, information on the ingestion of litter by marine organisms has been documented from deep-sea fish (Anastasopoulou *et al*., 2013), invertebrates (Bordbar *et al*., 2018) and mammals (Alexiadou *et al*., 2019). The impact of ghost fishing on mammals and fish has been reported in the north Aegean Sea (SoHelFi, 2007).

To date, Greece has a number of local submarine communication cables and local pipelines in place, but their impact has not yet been studied. Hydrocarbon, oil and gas exploration and production operations have a variety of potential impacts on the ecosystem (Piante and Ody, 2015). Offshore blocks put on tender for hydrocarbons exploration are located off Crete and in the Ionian Sea. Both areas are of exceptional biodiversity significance (e.g. marine turtles, cetaceans, cold water corals, vulnerable marine ecosystems, Natura 2000 sites). No specific studies related to impact from the hydrocarbon, oil and gas exploration and production operations have been conducted in the Greek waters, although mammals strandings have been related with seismic surveys for oil and gas explorations (ACCOBAMS, 2011).

Information collected so far emphasizes how little is known on the anthropogenic effects on the deep-sea fragile ecosystems, particularly in the Greek waters. As a result, any protection or management measure is difficult to be developed.

# 4.

# Current response measures

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## 4.1. Marine protected areas and other area-based conservation measures

Natura 2000 is a network of nature protection areas to protect the most seriously threatened habitat and species within the EU. It stretches across all 27 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive.

The Natura 2000 network in Greece consists of a total of 446 areas (GG 4432 B/2017). 265 of the aforementioned areas have been defined as Sites of Community Importance (SCIs) according to Council Directive 92/43/EEC on "The conservation of natural habitats and of wild fauna and flora" and 207 have been characterized as Special Protection Areas (SPAs) for Birds (Directive 79/409/EEC amended with Directive 2009/147/EC). These 2 area categories overlap. The land area of the Natura 2000 network in Greece is 36,000 $km^2$ covering 27.3% of the Greek land area. Natura 2000 sea area in Greece is approximately 23,000 $km^2$ covering 20% of the total sea area.

Greece assumes responsibility for the maintenance of its marine biodiversity. Two National Marine Protected Areas (National Parks) are in operation (National Marine Park of Alonissos and Northern Sporades, and National Marine Park of Zakynthos) while there are insular or coastal protected areas such as Karpathos, Amvrakikos Gulf and Messolonghi-Aetoliko lagoons, Acheloos, Evinos estuaries and Echinades islands which include significant marine areas. The National Marine Park of Zakynthos was the first Protected Area in Greece with a Management Agency (established in 1999), being one of the major areas in the Mediterranean for the reproduction and nesting activities of the loggerhead sea turtle *Caretta caretta*. Kyparissiakos Gulf was also recently designated as an MPA for the presence of this species. The National Marine Park of Alonissos and Northern Sporades is the largest marine park in Greece (2,180 $km^2$ of total surface area). Apart from a high diversity in priority species and habitats, the area is mostly renowned for hosting the large majority of the Mediterranean monk seal (*Monachus monachus*) population. Recent research has shown that many Mediterranean Monk Seals live and reproduce in Gyaros island (Cyclades) and in the surrounding marine area. Moreover, this area is a habitat for other significant sea species including a colony of Yelkouan/Levantine shearwater (*Puffinus yelkouan*). The Ministry of Environment and Energy (MEEN) has enacted legislation in order to determine terms and restrictions for the protection, conservation and management of the island Gyaros land and sea areas (GG 389 D/2019).

Yet, MPAs in Greece are still exposed to various anthropogenic threats, mainly overfishing, pollution, coastal development and other recreational activities. Conservation measures and management effectiveness have been repeatedly failed due to lack of funding, insufficient human resources and training, conflicts of land and sea users. New MPAs should be established, allowing the creation of ecologically coherent networks into a spatial framework sustained by common processes of biodiversity conservation, both within and outside the MPAs.

## 4.2. Legal and institutional frameworks governing the conservation and sustainable use of marine and coastal biodiversity

### *Natural ecosystems and biodiversity*

Although Greece has a long-standing conservation policy (the legislation on nature conservation dates back to the 1930s, with the laws providing for protection of mainland national parks and forests), it was not until recently that special concern has been given to the impacts of climate change on biodiversity and to the adaptation potential/procedures of the latter. Greece has recently extended the marine protected areas network from almost 6% of the total NATURA 2000 sites to more than 20% of national waters (GG 4432/B/15-12-2017), holding a large variety of Mediterranean habitats included in the reference list of the Natura 2000 initiative (EU Bird Directive 79/409/EEC and Habitat Directive 92/43/EEC). Law 1650/1986 provides for the key categories of protected areas and the process for their designation and establishment of conservation measures/objectives, while Law 3937/2011 (GG 60 A/2011) regards the conservation of Biodiversity. This law identifies national priorities, sets out the framework for the national system of protected areas and defines the main tools for biodiversity management. Both laws were amended by Law 4685/2020 (see below). In line with the COP 10 Decision X/2 of the Convention on Biological Diversity (CBD), a National Biodiversity Strategy (NBS) was endorsed in 2014 (GG 2383B/2014) which is due for updating since its time-frame was 2014-2019. The NBS comprises 13 targets, including prevention and minimisation of the impacts of climate change on biodiversity (Target 7).

### *Marine environment*

The conservation of the marine environment is governed by Law 743/1977, as codified by Presidential Decree 55/1998 on the "protection of the marine environment" and Law 1269/1982 on "the prevention of marine pollution from ships" and its amendments, which ratified the international treaty MARPOL. The legal framework also includes Laws 2252/1994, 3100/2003 and Presidential Decree 11/2002 for issues of preparedness and cooperation in dealing with oil pollution in the sea, hazardous and dangerous substances.

Regarding the protection of marine environment, the Marine Strategy Framework Directive (2008/56/EC) was incorporated into Greek legislation by Law 3983/2011 (GG 144 A/2011). The aim of Directive 2008/56/EC as well as the Greek corresponding Law is to achieve or maintain the marine environment in good environmental status, which is determined on the basis of the qualitative descriptors listed in Annex I of the Directive. These descriptors include the maintenance of biological diversity, control of NIS, sustainable management of fisheries, conservation of marine food webs and sea-floor integrity. All these descriptors are directly or indirectly related to the conservation of biodiversity.

In 2011, The Ministry of Environment and Energy (MEEN) approved the operation of the National Committee of Marine Environmental Strategy (through Ministerial Decision 160182/2011) and the Committee was officially created in 2012 (Ministerial Decision 110428/2012). In 2016, MEEN approved the monitoring programmes for the continuous evaluation of the status of marine waters (Ministerial Decision 126635/2016, GG 3799 B/2016), and in 2017 the competent authorities and their roles on the monitoring of the status of marine waters have been defined (GG 11 B/2017).

The Law on the National Marine Strategy was complemented with the Ministerial Decision 142569/2017 (GG 4728B/2017) "Approval of Programme of measures for the achievement of good environmental status in marine waters, based on paragraph 9 of article 12 of law 3983/2011", which approves sets of measures for the achievement or maintenance of good environmental status of marine waters. The Ministerial Decision includes measures for biodiversity and alien species, among others. The amended Marine Strategy Directive (Directive 2017/845/EU) has been transposed into national law with Joint Ministerial Decision (JMD) 50529/2779 (GG 5728 B/2018).

Regarding fishing, Regulation 1967/2006 concerns the sustainable exploitation of fishery resources in the Mediterranean Sea. In addition, according to Greek Law 3937/2011, destructive fishing (e.g. by trawling) over mäerl beds and coralligenous habitats is prohibited. Furthermore, the establishment and operation of aquaculture units over *Posidonia* meadows is also prohibited.

EU Regulation 1380/2013 on the Common Fisheries Policy (CFP) declares that the CFP should ensure coherence with the fisheries targets laid down in the Decision by the Conference of the Parties to the Convention on Biological Diversity on the Strategic Plan for Biodiversity 2011-2020, and with the biodiversity targets adopted by the European Council of 25 and 26 March 2010. Moreover, this Regulation explicitly states that "the CFP should ensure that fishing and aquaculture activities contribute to long-term environmental, economic, and social sustainability". There is also Council Regulation (EC) 708/2007 "Concerning the use of alien and locally absent species in aquaculture", along with its amendments and revisions (Regulations 506/2008, 535/2008, 304/2011). For the incorporation of these Regulations into Greek Law, there is the Decision of the Minister of Rural Development and Food (165837/2009) and its amendment Ministerial Decision (GG1639 B/2013).

### *Maritime spatial planning*

It is necessary to regulate human activities not only inside but also outside protected marine areas, according to the principles of maritime spatial planning. Maritime spatial planning is about planning the time and the place that human activities take place so that their effectiveness and sustainability is safeguarded. Maritime spatial planning additional value derives from the acknowledgment of the necessity to maintain the biodiversity in the ecosystems.

Directive 2014/89/EU of the European Parliament and the Council established a framework for maritime spatial planning incorporated in Greek Legislation with Law 4546/2018. This Law sets the framework for maritime spatial planning in Greece, aiming at promoting sustainable growth of maritime economies, sustainable growth of marine areas and sustainable use of marine resources. The framework also clearly sets "resilience to climate change impacts" as a strategic objective.

### *Management Agencies concerning Marine Protected Areas*

Since 2018 and up until recently, Law 4519/2018 (GG 25 A/2018) assigned 36 Management Agencies across the Greek Natura 2000 network (445 out of 446 Natura 2000 SCI and

SPA sites) to safeguard habitats and species protected under the Habitats (92/43/EEC) and Birds (2009/147/EC) Directive. The following Management Agencies (MA) also encompass marine areas:

- MA of National Marine Park of Zakynthos
- MA of Thermaikos Gulf Protected Areas
- MA of National Marine Park of Alonissos - Northern Sporades
- MA of Nestos Delta- Vistonidas- Ismaridas and Thassos
- MA of Amvrakikos Gulf - Lefkada
- MA of Kotychi and Strofylia Wetlands and Kyparissiakos Gulf
- MA of National Forest of Ainos - Kefalonia
- Manage MA of National Park of Samaria - West Crete
- MA of National Park Oitis - Sperchios Valley and Maliakos Gulf
- MA of Protected Areas Kalamas - Axerontas - Corfu
- MA of Protected Areas Dodekanisou
- MA of Carla - Mavrovounio - Kefalovriso - Velestino - Pinios Delta
- MA of National Park of Schinias - Marathonas, Imittos and Southeastern Attica
- MA of Korinthiakos Gulf
- MA of Evia Protected Areas
- MA of S. Peloponnisos - Kithira Protected Areas
- MA of Cyclades Protected Areas
- MA of N. Aegean Protected Areas
- MA of Central and East Crete Protected Areas
- MA of Evros Delta and Samothraki Protected Areas

More recently, Law 4695/2020 (GG 92 A/2020) introduced a new centralised scheme, designating 24 "Management Units" across the Greek Natura 2000 Network, governed and supervised by the *ad hoc* established Natural Environment and Climate Change Agency (NECCA). Greece is currently under a transitional phase between these two schemes.

### *Environmental Agencies concerning Marine Ecosystems*

There are also a number of non-governmental organisations (NGOs) which take action in Greece and are involved in research, raising awareness, advocacy for the protection of marine ecosystems and *in situ* conservation. These organisations include:

- ARCHELON, the Sea Turtle Protection Society of Greece
- Archipelagos - Institute of Marine Conservation
- Arion - Marine mammal professional assistance and veterinary care - Cetacean and marine environment conservation
- Greenpeace Greece
- Hellenic Ornithological Society
- Hellenic Society for the Protection of Nature
- HELMEPA - Hellenic Marine Environment Protection Association
- iSEA-Environmental Organisation for the Preservation of the Aquatic Ecosystems
- MEDASSET - Mediterranean Association to Save the Sea Turtles
- MIO-ECSDE The Mediterranean Information Office for Environment, Culture and Sustainable Development
- MOm / The Hellenic Society for the Study and Protection of the Monk seal
- MEDITERRANEAN SOS Network
- Pelagos - Cetacean Research Institute
- WWF Greece

## 4.3. Transboundary issues and existing, planned or needed coordination / harmonisation at subregional or regional level

There is a cross border, transnational and interregional cooperation of Greece with other countries in the framework of European Territorial Cooperation (ETC). Regarding MPAs, the project "AMARe - Actions for Marine Protected Areas" has been implemented in Greece, France, Italy and Spain aiming to scale up strategies and recommendations at the transnational level, adopting an ecosystem-based approach considering the goals of the MSFD across MPAs. Two additional relevant projects are MPA NETWORKS and Plastic Busters MPAs. Moreover, in the ETC framework, the ACT4LITTER project was implemented in 10 European countries, including among others Greece, Italy, France and Spain with the aim to address the huge problem of litter in Mediterranean Sea including MPAs of this sea. In addition, MEDSEALITTER project aims at developing Mediterranean specific protocols to protect biodiversity from litter impact at local level and MPAs scales. Yet there are several initiatives and groups of experts working at regional level under the coordination of MedPAN (group of experts on sea turtles, highly mobile species etc.) or other foundations. There are also projects regarding Marine Spatial Planning such as CoCoNeT, MEDtrends, MARISCA and PROTOMEDEA.



# 5.

# Asessment of the marine and coastal status and pressures on marine and coastal areas

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## 5.1. Marine and coastal status and pressures relevant for national marine and coastal areas

The European Water Framework Directive (WFD) (2000/60/EU) has established

the concept of Ecological Quality Status (EQS) to assess the levels of anthropogenic disturbance on surface waters. Since 2012, 82 coastal and 30 transitional stations (estuaries and lagoons) are monitored through the National Monitoring Network for the WFD. From these, 60 stations are in areas with high human activity and are monitored frequently (annually or biannually), while 22 are in more remote areas and are monitored once per 5-year cycle. In each station, the Ecological Quality is estimated based on 4 biotic (benthic macro-invertebrates and macro-algae, angiosperms, chlorophyll) and three abiotic parameters (nutrients, dissolved oxygen and priority substances). Since these parameters, or Quality Elements, originate from a variety of ecosystem compartments and are affected by different types of human pressures, the EQS is a representative environmental overview. Table 2 lists all indices used to monitor each Quality Element. The monitoring stations are distributed in 90 separate water bodies, which are units of similar ecological natural variability in each administrating area and are classified based on the worst EQS recorded among the local stations (One-Out-All-Out principle).

**Table 2.**
The specific indices which are applied to monitor each Quality Element used in the Ecological Quality Status.

| Quality Element | Benthic Macroinvertebrates | Macroalgae | Angiosperms | Chlorophyll | Eutrophication |
|---|---|---|---|---|---|
| **Index** | Bentix (Coastal)<br>M-AMBI (Transitional) | EEI | PREI<br>Cymoskew | TIII E Chl-a | PCQI |

Based on the most recently recorded EQS (majority of data collected in 2018 and 2019), 53% of water bodies have none or low human impacts (HIGH and GOOD status), while 47% show significant human pressures (MODERATE, POOR and BAD status). However, transitional water bodies, acting as buffer-zones of several land human activities, are significantly more degraded (13% in GOOD status and 87% in MODERATE, POOR, BAD status) than the coastal water bodies (67% in HIGH/GOOD and 33% in MODERATE, POOR, BAD status). In addition, the map of the most recent EQS (Figure 6) shows that the degraded water bodies are mostly located in mainland Greece and Crete, while the majority of the islands' coastline are in HIGH and GOOD status.

During the last decade, EQS has been found to fluctuate between bordering ecological classes in a few water bodies, due to unstable environmental conditions, rather than clear degradation. Therefore, the worst EQS recorded in the period 2012-2020 depicted in Figure 7 highlights all the areas under risk of degradation. The major human pressures affecting EQS in these coastal areas have been identified in Pavlidou *et al.* (2015). In the gulfs of Saronikos, Thermaikos and Patraikos, where the major Greek metropolitan areas are located, the environment is threatened by several human activities, such as industrial effluents (shipyards, refineries, chemical and metal plants etc.), treated sewage, port activities (oil pollution, sediment dredging/dumping) and mariculture. Other industrial hot

spots are found in Evoikos Gulf and the shallow substrata of Korinthiakos Gulf (metal mining and smelting plant discharges), as well as east Kavala Gulf (chemical industry). Agriculture and/or mariculture affect areas such as Lakonikos and Argolikos gulfs, major rivers estuaries (Spercheios, Axios, Evros) and especially areas with low water circulation such as Amvrakikos Gulf. Semi-enclosed gulfs with low water circulation are also perhaps among the few areas under risk along insular coastlines (Moudros, Geras, Souda and Argostoli gulfs).

The benthic habitats that are monitored in the National Monitoring Network are mainly infralittoral and circalittoral muds, sands and detritic bottoms (in a few cases associated with rhodolith beds), upper infralittoral rocks and other hard substrata, *Posidonia oceanica* and *Cymodocea nodosa* beds.

A recent assessment of the ecological status of subtidal rocky reefs (HT 1170) using the ecosystem-based index reef-EBQI and covering an extensive network of stations (n=26) across the entire Aegean Sea, showed that the majority of areas were characterized by POOR/BAD conditions (Bevilacqua *et al*., 2020). The most likely causes of degradation for this habitat type were suggested to be the disappearance of structurally complex macroalgal stands (e.g. *Cystoseira spp.*) in favour of barren grounds or turf assemblages, increased herbivory by sea urchins and/or invasive fish (e.g. *Siganus spp.*), climate change, and decline of predator fish populations (Sala *et al*., 2012; Bevilacqua *et al*., 2020 and references therein). These findings are also in agreement with the Unfavourable-Bad conservation status reported for HT 1170 in the 3rd National Report on the implementation of the HD (period: 2013-2018).

**Figure 6.**
EQS per waterbody in Greek Coastal and Transitional Waters (2018-2019).

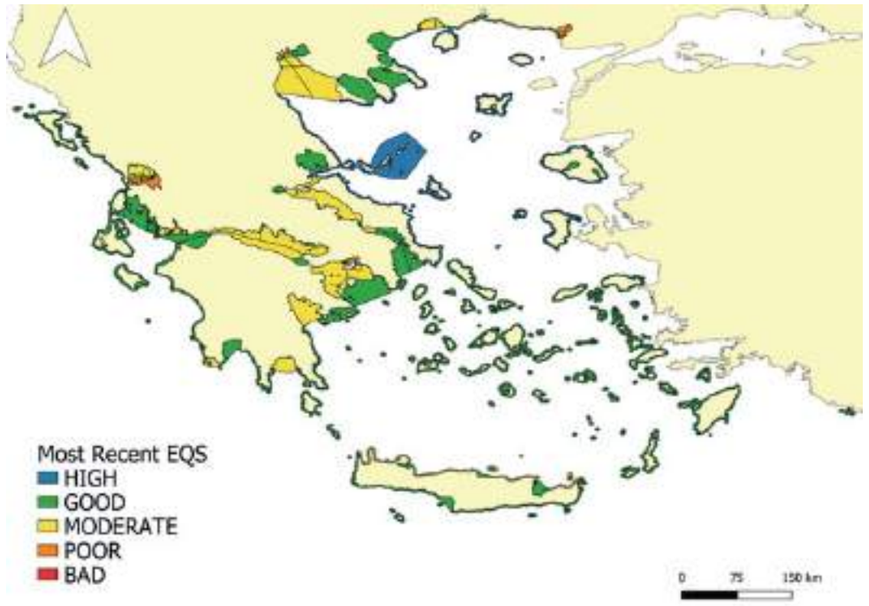
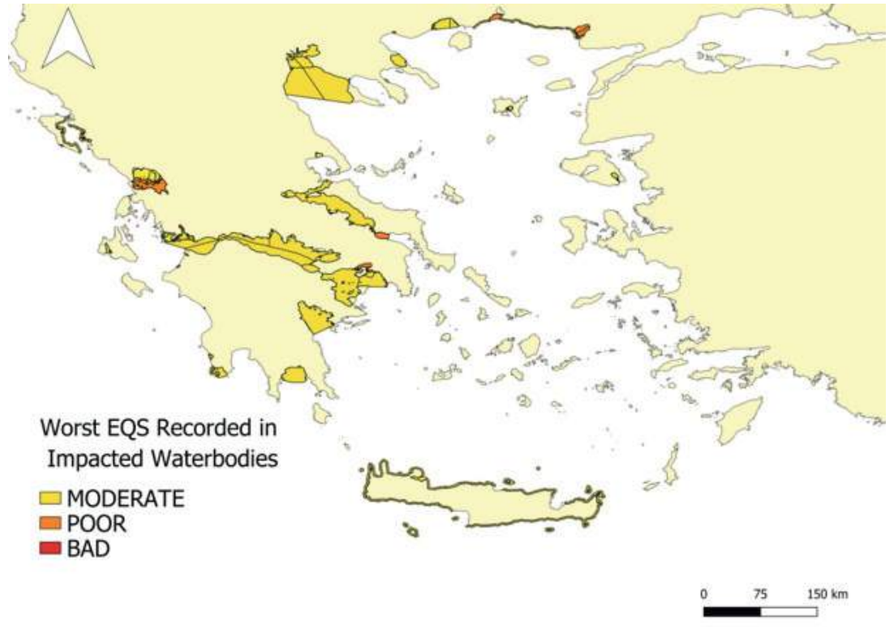



**Figure 7.**
Coastal and Transitional waterbodies at-risk, with the lowest EQS recorded in the last decade (2012-2020).




Overall, the assessment of the EQS of the coastal and transitional water bodies in Greece showed that a proportion of coastal waters, particularly in regions with intensive agriculture and high population density, have a moderate ecological status. The transitional waters are reported to have worse ecological status as they are more vulnerable ecosystems due to their limited communication with the sea.

The data collected in the National Monitoring Network should be used to urgently address all the environmental risks in the managerial plans, prioritizing habitats most important for biodiversity conservation, such as biogenic habitats and the fragile transitional areas. Although the current Network could up to a certain degree direct towards the managerial priorities, several waterbodies in the extensive Greek coastline need significantly better screening, which can be achieved by increasing the monitoring stations in the upcoming decade. Moreover, the biological and supportive physicochemical and hydro-morphological elements of the WFD address many of the MSFD indicators and descriptors. Indeed, the ongoing monitoring network related to WFD also constitutes the basis for the monitoring for MSFD in Greece although the MSFD network of stations needs to be expanded to include and to adequately cover more of the MSFD broad habitat types (BHTs) over a much wider depth range.

## 5.2. Critical impacts and effects on marine and coastal biodiversity

The degree to which anthropogenic activities impact the marine environment is a function of: (i) the pressures associated with an activity, (ii) the sensitivity of a specific habitat, community or species to the pressures, and (iii) the intensity and duration of the pressures and the spatial and temporal footprint over which they occur (Dailianis *et al*., 2018). An individual pressure can come from many activities, but an individual activity can cause many pressures (Smith *et al*., 2016). Whilst pressure lists have been well categorised (the current MSFD list includes three categories (biological, physical, and introduction of substances, litter and energy) of 16 individual pressures), they are difficult to individually assess with respect to spatial extent, intensity, duration, frequency, and consequently individual activities are often used as a proxy for pressures, accepting that the footprint of the pressure may not be the same as the footprint of the related activity. A widespread activity with a large footprint is not always an indication of critical impacts but the overlap of the proxy of a pressure with a particular species or a critical habitat or life stage of a species is always a very important consideration.

A number of projects have worked on identifying major pressures at the regional and national level (e.g. ODEMM, DEVOTES, MERCES, AFRIMED, WWF MEDTrends, DEEPEASTMED, IUCN Deep Sea, WFD and Greek MSFD) and have produced useful map outputs showing areas of hotspots, critical overlaps of ecological components and threats, and single and cumulative impacts. Cumulative impacts based on various activities (land and sea based: shipping, extraction of resources, etc.) have been mapped at the Mediterranean level (Coll *et al.*, 2012; Micheli *et al*., 2013). More specific Mediterranean impact/pressure mapping has been undertaken by Katsanevakis *et al*. (2016) on the impacts of NIS and Trujillo *et al*. (2012) for the presence of fish farms. Recently Piante and Ody (2015) have published an extensive Mediterranean review with basin-wide mapped sector activities. This report facilitated through MEDtrends project was supported by individual country reports including one for Greece (WWF Greece, 2015), which has been partially updated by Simboura *et al*. (2019). In addition to static reports and publications, there are a number of online resources with map viewers where activities and impacts can be viewed, that benefit from updated data, e.g. EMODnet Human Activities (https://www.emodnet.eu/human-activities) and WISEMARINE (https://water.europa.eu/marine/countries-and-regional-seas/country-profiles/greece) and Oikoskopio (http://short.oikoskopio.gr/31f).

Simboura *et al*. (2019) indicated in Greece the overall major sectors, trends and related pressures (some smaller scale sectors are not covered e.g. extraction of water, military, research and conservation activities). This has been adapted in Table 3 to include MSFD activity classification, relative importance and extent. It is accepted that there will be differences in impacts depending on, for example, distribution of activities, local intensity, sensitivity of habitats, north vs. south and shallow vs. deep areas, also for some activities operational aspects are assessed, not construction phases. Two sectors, marine mining and renewable energy are listed (from the parent report of Piante and Ody, 2015), although they are not currently commercially practised in Greece but, may increase in the future (wind turbine farms are currently located on islet/islands rather than offshore seabed anchored systems as found in northern European waters). Oil and gas exploitation present in small areas is also expected to expand greatly in the future. Three sectors have more important interactions with the environment, including professional fishing, tourism and leisure, and coastal and marine infrastructures, with the common pressure of physical loss/damage primarily to the seabed. The importance of these pressures, generated by activities, is also related to which habitats they impact. The majority of trawl fishing, for example, is seen to take place in less sensitive habitats of sedimentary seabeds, although it has interacted in previous decades with seagrass beds in shallower waters and rhodolith/maërl beds in slightly deeper waters, both sensitive and protected habitats. The impacts of fishing are described in more detail in Section 3.1.

In most regions a wider array of activities is present closer to the coast (e.g. coastal and marine infrastructure such as ports, see Figure 5) and many activities tend to be more intense nearer the coast and at shallow depths (e.g. anchoring by passenger and pleasure boats) or be affected by land-based activities. Sensitive coastal habitats may include macroalgal forests, seagrass meadows, coralligenous or rhodolith/maërl beds, and other biogenic habitats. Fewer activities operate offshore and in deep waters (see Section 3.3) but may include cables and pipelines although they have very small footprints. Hydrocarbons are currently extracted in small footprint areas in the northern Aegean in shallow waters, but there are very large exploration blocks designated in deep waters south and west of Crete and along the whole Greek Ionian boundary area (Figure 5). Trawl fishing may occur into deep water but is regulated to less than 1000 m depth. Although fewer types of impacts might be present the severity of impacts will depend on resilience of the habitats which may be less (slower process rates, growth/longevity or connectivity issues) characterised particularly by VMEs (see Section 3.2.)

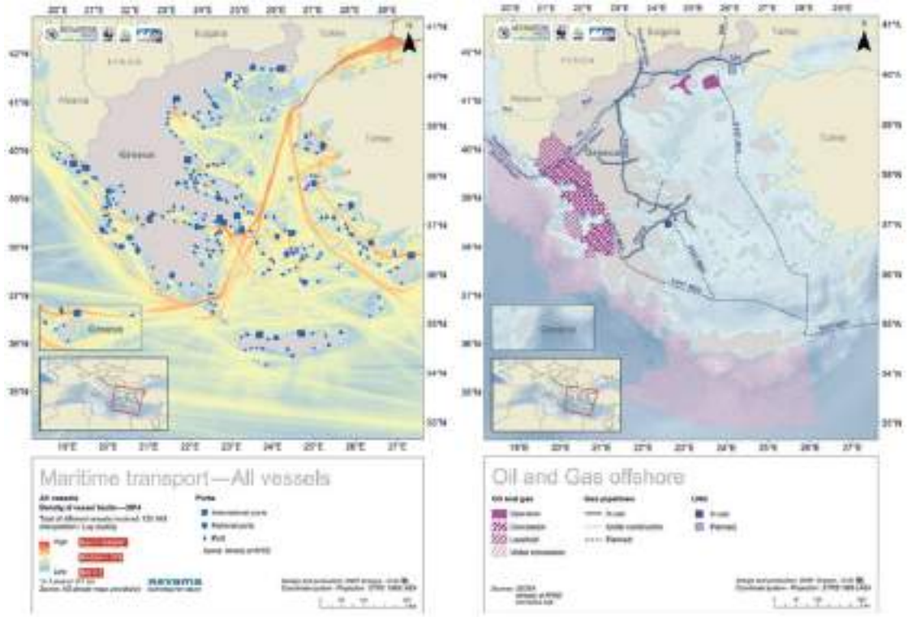
**Table 3.**

Marine sector-activities in Greek waters, future trends, related environmental pressures, importance with respect to impact and extent. Adapted from Simboura et al. (2019).

| Sector | MSFD Activity Theme | Trend | Marine Environmental Pressures | Importance, extent |
|---|---|---|---|---|
| Professional fishing | Extraction of living resources | ↘ | Selective extraction of species, physical loss and damage (changes in siltation, abrasion), marine litter, underwater noise. | High, widespread over a range of habitats and with high frequency of occurrence and intensity, severity of impacts linked to gear types. |
| Recreational fishing | Extraction of living resources | ↗ | Selective extraction of species, physical loss and damage (by anchoring), marine litter, underwater noise. | Low, locally widespread (mostly coastal) variable intensity/frequency. |
| Marine aquaculture | Cultivation of living resources | ↗ | Inputs or organic matter, introduction of non-indigenous species and translocation, selective extraction of species (juvenile capture) | Low, localised (coastal), continuous operation in licensed areas/variable intensity. |
| Tourism & leisure | Tourism and leisure | ↗ | Physical damage, introduction of synthetic and non-synthetic compounds, introduction of organic matter, underwater noise, light, introduction of non-indigenous species and translocation, introduction of microbial pathogens (ship waste disposal), marine litter. | High, widespread but locally patchy depending on activity (e.g. hotels, piers, sea sports, yachting, cruise ships), variable intensity/ frequency. |
| Maritime transport | Transport | ↗ | Underwater noise, introduction of non-indigenous species and translocation, introduction of synthetic and non-synthetic compounds, introduction of microbial pathogens (ship waste disposal), marine litter. | Medium, widespread but locally patchy, coastal anchorages, shipping concentrated across routes. |
| Dredging, disposal and aggregate extraction | 1. Physical restructuring of rivers, coastline or seabed. 2. Extraction of non-living resources | → | Physical damage and loss (abrasion, siltation, smothering, sealing), underwater noise, introduction of substances. | Medium, locally patchy to very localised in licensed sites. |
| Oil and gas exploration and extraction | Production of energy | ↗ | Physical damage and loss (smothering, sealing), underwater noise, introduction of substances whether solid, liquid or gas | Low, currently localised |
| Renewable energy | Production of energy | ↗ | Sealing, underwater noise | None, currently not present |
| Marine mining | Extraction of non-living resources | ↗ | Physical damage and loss (abrasion, changes in siltation), introduction of toxic substances, underwater noise | None, currently not present |
| Coastal & Marine Infrastructure | 1. Physical restructuring of rivers, coastline or seabed. 2. Urban and industrial uses | ↗ | Physical damage and loss (smothering, sealing), introduction of substances (including noise and light), litter. | High, widespread, coastal (e.g. (ports, marinas, shore defences, coastal roads, airports, cables and pipelines) |
| Land-pollution sources | 1. Urban and industrial uses. 2. Cultivation of living resources | ◆ | Contamination from hazardous substances, nutrient and organic enrichment, marine litter. | Medium mostly coastal, widespread and localised. |

**Figure 8.**

Major marine Infrastructure (ports) and shipping lanes (left) and hydrocarbon extraction and exploration and related pipelines (right) (from Simboura et al., 2019).



# 6.

# Assessment of national priority needs and response actions

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## 6.1. Needs

Up to now, Greece has responded responsibly to already existing policies, measures and plans relevant to natural ecosystems and biodiversity (e.g. CBD, EU Bird Directive 79/409/EEC amended with Directive 2009/147/EC, Habitat Directive 92/43/EEC), marine environment (e.g. MARPOL, MSFD 2008/56/EC, MSP Directive 2014/89/EU, WFD 2000/60/EC, CFP, GFCM, ICCAT, ACCOBAMS) with legislative acts (see section 4.2 for details). The National Species Action Plans (which are presently under consultation) for *Caretta caretta*, *Monachus monachus*, *Phocoena phocoena* and *Tursiops truncatus* are a positive step as well, provided that they will be implemented properly and on time. The recent Single-Use Plastics Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment should also be taken into account as an emerging issue. As far as the WFD and MSFD are concerned, there is a need to largely expand the grid of already existing monitoring stations (only 82 coastal and 30 transitional stations distributed in 90 separate water bodies) in order to have a more representative grid of stations over the habitats across Greece. The implementation and effectiveness of tools provided in order to protect marine ecosystems, such as maërl/rhodolith beds, coralligenous habitats, and *Posidonia* meadows, from destructive fishing and/or aquaculture impacts is hindered by the existing knowledge gaps regarding the distribution of these habitats. Therefore, ground truthed habitat mapping to improve maps that are largely based on modelling is urgently required. A great deal of additional studies on benthos within all habitats to fully characterize the geographic distribution in Greek Seas is also needed to further monitor the distribution and effects of invasive species as well as species under threat, the incidence and spread of mass mortality events and their potential recovery. Although many facets of benthic research have been accompanied by significant technological research, the technological progress on macrofauna techniques is lagging behind and it is coupled with a scarcity of ideas in technical and methodological issues not only in Greece, but worldwide (Eleftheriou, 2013). Marine biodiversity research in Greece has proved the ability to develop new and innovative techniques and methods for this purpose (Koulouri *et al*., 2003). Thus, innovative initiatives should also be supported. Training and capacity building of young researchers concerning taxonomy, coupled by other disciplines, and therefore identification of taxa by using conventional and molecular approaches should be motivated and enhanced. Research Infrastructures, initiatives, networks, open access data, reproducible analytics, databases, catalogues concerning marine biodiversity, in general, as well as specifically on NIS, threatened and rare species etc, need to be financially supported in order to secure their sustainability.

An example towards this direction is the GTIS, an initiative of the LifeWatchGreece Research Infrastructure (ERIC) that is resuming efforts to compile a complete checklist of all species reported from the Greek territory. In particular, the complete list of all species occurring in Greece is necessary for the management of biodiversity of the country, balancing both sustainable use and conservation. Such an effort is necessary as a requirement for all signatories of the CBD (Greece has been a signatory since 1994). A gap analysis combined with the collaboration of local and international scientists, could stimulate future research on understudied taxa. A strategic plan should be developed to fill the gaps including the involvement of research/academic bodies and authorities, NGOs and citizen science initiatives for updating the study of the taxonomy for all taxa

present in Greece. For this reason, the LifeWatchGreece Infrastructure plays a pivotal role by involving a wide network of research and academic institutions all over Greece. The overall GTIS initiative is open to collaboration with taxonomists from the Greek, European and World scientific community who are interested in contributing to this effort.

In addition, while multi-national networks on NIS exist in Europe (e.g. European Alien Species Information Network – EASIN: https://easin.jrc.ec.europa.eu/easin) and the world (e.g. World Register of Introduced Marine Species – WRiMS: http://www.marinespecies.org/introduced/), only a few countries have developed their own portals for covering alien species issues. ELNAIS (https://elnais.hcmr.gr/) was established in 2007 by HCMR, recognizing the need for national and international cooperation in research, scientific information exchanges and management of aquatic (marine and freshwater) NIS in Greece. According to the latest ELNAIS census, a total of 232 marine NIS has been recorded in Greek waters by December 2019 (Zenetos *et al*., 2018 and unpublished data). Detailed distributional data of marine NIS in Greece are stored in the ELNAIS database which is continuously updated with new data from published and grey literature and new observations by a network of more than 80 contributing experts from several research/academic institutes, non-governmental organizations and citizen science data.

Greece, thanks to HCMR, has been found from the very beginning to be part of international initiatives implementing marine omics biodiversity observation by integrating genomics, organismal, and environmental data to monitor biodiversity and functioning of marine ecosystems. This comprises developing standardized processes, protocols, data workflows and training, and production of FAIR data (Findable, Accessible, Interoperable, Reusable) integrating new technologies as they appear. The European research infrastructure EMBRC ERIC where Greece is member represented by IMBBC-HCMR has been committed to contribute towards a global coordination of marine biodiversity, from microbial communities to macro-organisms, by environmental genomics approaches, and integration of other forthcoming technologies. In that respect it interacts with other global initiatives such as the Genomics Observatories (GOs) network of the Genomics Standards Consortium (GSC) as well as with big research infrastructures (LifeWatch, ELIXIR, BioImaging, and EOSC). This EMBRC led GOs network purposefully contributes to the UN Decade of the Ocean, committed to produce data across European stations from the Red sea to Norway, in interaction and coordination with stations in the Atlantic and Pacific oceans. The data produced greatly enrich our understating and monitoring capacity of the oceans offering detailed views on the structure, adaptive potential, function and response to environmental change. Greece by supporting the initiative at the national level and supporting the expansion to key areas, will enhance its role in the internationally leading community, bringing knowledge at many levels and creating the conditions for internationally leveraging the initial national investment.

Greece, along with the other Mediterranean countries, has legal obligations to designate MPAs according to various agreements, policies, and laws (e.g. the Specially Protected Areas and Biological Diversity Protocol of 1995). The Convention on Biological Diversity's Aichi Target 11 calls for protecting at least 10% of the oceans and seas in MPAs by 2020. Even though Greece has recently extended the network of marine NATURA 2000 sites to more than 20% of national waters, these areas lack formally adopted management plans.

Considering the priorities of the UN for supporting the implementation of SDG 14 concerning the ocean of the 2030 Agenda for Sustainable Development and the IOC-UNESCO developing the Ocean Literacy (OL) Strategy for the UN Decade of Ocean Science for Sustainable Development, Greece needs to include considerable advancement and increase of OL in society, from education and school curricula, to decision-makers and the public at large also focusing on marine biodiversity. Within this scope, Greek researchers (a) organize educational programs for schools, universities, teachers and other stakeholders; (b) participate in international networks (e.g. EMSEA, EuroGOOS, GEOSS, GEO BON, MedPAN), conferences and fora (e.g. Ocean Literacy Summit); (c) publish scientific journals (e.g. Mogias *et al*., 2019), including marine biodiversity issues. Finally, several educational and citizen science projects (e.g. CIGESMED for Divers, COMBER, MELTEMI, PERSEUS, SEAlly), for as long as they have been carried out, identify human pressures as well as the resulting biodiversity loss and climate change and through participatory approaches provide knowledge and aim to change behaviours and attitudes of students, teachers, stakeholders, citizens.

The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization is a supplementary agreement to the CBD aiming at the fair and equitable sharing of benefits arising from the utilization of genetic resources. Thus, it protects the rights of every country on its natural resources and guarantees transparency on biodiversity exploitation, preventing biopiracy. Although Greece has ratified the Nagoya Protocol in 2019, and has a law on biodiversity (3937/2011) and a Joint Ministerial Decision (24248/598/27.3.2019) has been signed regarding compliance measures with the EU Regulation 511/2014 on Access and Benefit Sharing (ABS), there is no appropriate national regulatory framework to address access and benefit sharing issues for genetic resources in Greece. For instance, the access rules for any applicant who requests to use biodiversity in Greece has not been yet defined, which is the main role of an ABS framework. This is an urgent need, which will help policy makers, and stakeholders to understand all facets pertaining to biodiversity value, which is a much bigger gain, by contributing to better policies for the protection of biodiversity, than the possible economic income of the proper exploitation of biodiversity. ABS specifications need to be aligned with a general strategy of sustainable exploitation of resources and to also serve the UN 2030 development objectives. Without well thought ABS rules ratified by law, there are not many other tools to protect biodiversity from any citizen or visitor of the country and therefore, undetected pressure may be applied on biodiversity.

## 6.2. Urgent actions proposed

- Towards the protection and conservation of the marine environment, the prevention of its degradation and its restoration (wherever possible), the following actions are proposed:
- Adoption of measures for the control of land-based pollution sources, such as best agricultural practice in river basin catchments for the control of pollution of marine coastal areas from the use of fertilizers and pesticides. Correlation with the respective measures that are being undertaken in the framework of the implementation of the Community Water Framework Directive (2000/60/EC) and of the respective actions that have been adopted in the framework of the Barcelona Convention (Land Based Sources protocol and respective action programmes).

- Adoption of measures for the prevention and efficient management of maritime accidents, including routeing and traffic separation schemes, automated reporting systems, compulsory pilotage in precarious areas, monitoring and response systems and areas in the waters to be avoided.
- Promotion of basic research to fill the knowledge gaps concerning the status of the marine environment of Greece (e.g. expand the grid of sampling stations all over Greece) as well as adoption of applied research for the development of suitable tools for monitoring, detection of pollutants (eutrophication, oil spills etc). Support of relevant legislation and control concerning the development of cleaner and more environmentally friendly technologies and production procedures (for fisheries, aquaculture etc.).
- Promotion and support of Research Infrastructures (e.g. LifeWatchGreece, CMBR, EMSO Greece, Poseidon System, EuroArgo Greece, etc) in order for the country to achieve open access data, reproducible analytics and mobilized networks. This is one of the primary prerequisites in order for the country to produce evidence-based scientific knowledge on the state of marine biodiversity and ecosystems which, in turn, will allow for their rational management towards sustainability.
- Systematic inventorying and mapping of marine habitats at national scale at highest possible resolution, with suitable storage of the inventory data since the current knowledge gaps inhibit the enforcement of existing legislation defining their protection via targeted management measures.
- Extensive monitoring for marine litter and especially the plastics in order to investigate negative impacts on marine life such as suffocation, entanglement, physical damage, ghost fishing of discarded/lost nets and chemical pollution by decomposing materials.

Implementation of studies on the impact of hydrocarbon exploration and production operations as well as anthropogenic effects on extreme ecosystems, such as the fragile deep-sea ecosystems.

- Implementation of programmes for the systematic monitoring and collection of data to evaluate the status of threatened marine species populations, the identification and application of measures and actions for their sustainable management, development and implementation of the respective national legislation wherever this is required.

Implementation of measures to address and halt IUU fisheries practices, as well as to enforce sustainable fisheries measures and fisheries protected areas, as is defined by the EU Common Fisheries Policy.

- Systematic monitoring of the introduction of NIS into the marine environment and their effects on the natural environment and native species. Adoption of measures for prevention of transfer of NIS through maritime activity.
- Conduct studies for the introduction of new marine areas into the NATURA 2000 Network.
- Support (sufficient funding and human resources) of existing Management Agencies of Coastal and Marine Protected Areas for the effective protection and sustainable development of the marine and coastal environment, improvement of management efficiency with plans, resources and integration of policies and expansion of the existing network for protection.



- Greece needs to ratify the ICZM protocol and incorporate it into national law. Strengthening of mechanisms for the effective control of legal and illegal construction and development in the coastal zone areas.
- Evaluation of the magnitude and effect of the interactions between fisheries and marine species populations (e.g. marine mammals, sea turtles, elasmobranchs, and seabirds), development and implementation of national action plans for the minimization of interactions.
- Application of measures for sustainable use of fisheries resources in the sense of the Community Regulation for the Mediterranean (EC) 1967/2006.
- Evaluation of fisheries stocks and carrying capacity of transitional coastal ecosystems (e.g. lagoons), and planning of fisheries management, giving priority to NATURA 2000 areas.
- Intensification of controls and inspections to support the sustainable use of fisheries resources, effective protection of aquatic resources of fishery interest and application of the principles for responsible fishing and aquaculture, including the compliance with conditions for environmental use.
- Identification and mapping of all bioconstructions (e.g. *Lithophyllum* trottoir, vermetid reefs, mesophotic reefs, deep-water corals) that deserve protection.
- Taking actions aiming at increasing OL in society, from education and school curricula, to decision-makers and the public at large focusing on marine biodiversity.
- There is an urgent need to build an efficient regulatory framework to address ABS for genetic resources, as other Provider Countries have already done (Spain, France, etc.).
- Greece should ratify the SPA/BD protocol of the Barcelona Convention. Establishment of conservation objectives and adoption of effective conservation and restoration measures (including fisheries regulation) through the issuing of presidential decrees and management plans for protected areas. Coordination of the relevant authorities and Ministries to ensure consistency in the development and adoption of measures to tackle biodiversity threats. Coordination of authorities in the enforcement of these measures – ensuring that biodiversity and fisheries legislation especially with respect to enforcement actions are consistent and effectively applied.
- Greece needs to implement Directive 2014/89/EU and establish effective and functional maritime spatial plans under an ecosystem-based approach and in line with biodiversity policies and legislation (international, EU and national). Attention should be given to ecological corridors and connectivity.
- Capacity building and training of authorities (e.g. coast guard) concerning MPAs, biodiversity and fisheries legislation and enforcement measures. Use of technology in surveillance and monitoring activities.

### *Specific actions including conservation needs*

- Long-term data on climate change and on community changes in the Greek seas through an integrated framework are required. In this framework the Research Infrastructures should be actively involved.
- Assign coralligenous, rhodolith/maërl beds and other bio-calcareous concretions as priority natural habitat types in the EU Habitats Directive (92/43/EEC) and implement a systematic mapping and monitoring programme.
- Establishment of a research programme aiming at investigating the spatial distribution and population structure of red coral in the Greek Seas is urgently recommended in order to assess its status and implement appropriate effective management and restorative measures.
- Regular monitoring of mass mortality and stranding events for protected and threatened species (e.g. *Pinna nobilis*, red coral, as well as marine mammals and turtles) and deposition of standardized data in existing databases and networks (e.g. Garrabou *et al*., 2019).



7.

# Funding problems and opportunities

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The estimates of the Greek marine biological resources and the services marine biodiversity and ecosystems provide to the citizens are fragmentary and based on sporadic information gathered from research projects funded mainly by national or EU sources. Consequently, the available information is scattered, scarce and geographically limited and with no adequate time series on many occasions that would reveal trends and guide management actions and research priorities. One issue is that there is no long-term national marine research policy with specific strategy, goals, coordination, and implementation roadmap that also involves human capital and infrastructure - reflected in national funding opportunities.

## 7.1. Regular national sources, potential co-financing for international funding

Greek authorities like the Department of Nature Conservation and the Central Water Agency (Ministry of Environment and Energy), the Directorate of General Fisheries (Ministry of Rural Development and Food) and the Secretariat General for Research and Technology (Ministry of Development and Investments) provide funds for research related to the marine environment. However, baseline information concerning marine biodiversity is not usually the main target of marine research funds, while at the same time this kind of research is carried out for as long as financial support exists and therefore not being sustainable. For instance, funding was provided by the department of Nature Conservation for the first steps in the implementation of the Habitat Directive (habitat mapping on the marine NATURA sites) as well as from the Central Water Agency for the implementation of the Water Framework Directive (identification of the Greek water bodies, first ecological quality classification, and design of the national monitoring network though with no efficient number of monitoring stations). Based on the requirements of the EU Data Collection Framework (DCF), as they have been defined through a series of Commission Regulations and Decisions (199/2008, 665/2008, 2010/93, 2013/5568), the Greek National Programme (NP) has been established with the aim to monitor the Greek fishery sector. In the frame of the programme, detailed fisheries and biological data for a series of commercially important species are collected and analyzed, together with environmental and ecosystem data obtained from research surveys. The overall objective of the NP is to support the sustainable management of the marine biological resources.

Despite the above-mentioned deficiencies, LifeWatchGreece RI which is one of the seven national nodes composing LifeWatch ERIC, the e-Science European Infrastructure Consortium providing data resources, web services and Virtual Research Environments (VRE) to biodiversity and ecosystem research (Arvanitidis *et al*., 2016) is funded by GSRT and coordinated by IMBBC-HCMR, with ICS-FORTH as a partner and another 47 associated partner institutions, all over Greece. Within LifeWatchGreece a series of e-Services and virtual Labs (vLabs) have been developed which aim to support potential needs regarding the mobilisation, analysis and sharing of biodiversity datasets, not only for the scientific community, but also for the broader domain of biodiversity management and policy-making. LifeWatchGreece fulfils its vision to establish the biodiversity Centre of Excellence for south-eastern Europe by: a) allying all the Greek scientific human potential working on biodiversity data and data observatories; b) paving the way for the development of complex virtual domains through a number of background e-Services; c) developing a

number of virtual labs (vLabs); d) building capacity at the national level through a network of activities; and e) disseminating information, scientific knowledge and experience gained to the public. LIfeWatch Greece has so far delivered all the three ingredients, required for a successful policy implementation on biodiversity and ecosystem functioning: open access data, reproducible analytics and mobilized communities. It has also attracted resources from the EU and LifeWatch ERIC in order to synchronize its activity with those of the other nodes. Lately, LifeWatchGreece has received ERDF (European Regional Development Fund) resources from the Region of Andalusia in Spain. CMBR, the Greek node of EMBRC, is also producing lots of multi-disciplinary data relevant to biodiversity and ecosystems. Both RIs have developed a strong collaboration in order to avoid duplication of effort and maximize their inter-dependencies. BioImaging-GR and ELIXIR-GR are two RIs which use data, information and analytical tools developed by LifeWatchGreece and CMBR. This has paved the way for Greece to develop and provide cutting-edge technologies on biodiversity and ecosystems. Therefore, they are irreplaceable.

HCMR is responsible for the national databases, data management and final GIS products of WFD and MSFD implementation in Greece (2018-2023). Finally, the development and update of the ELNAIS database is implemented by HCMR without any financial support. The system is continually updated thanks to the input and enthusiasm of experts and aims to provide cutting-edge data and information on the topic. It has become a powerful facility to both scientists and stakeholders alike (Zenetos *et al*., 2015)

*Financing of projects for biodiversity by Partnership Agreement 2014-2020*

Projects for biodiversity are mainly financed by the Sectoral Programme for the Environment as well as by 13 Regional Operational Programmes (OPs) of the Partnership Agreement (PA) 2014-2020. They are also financed by the European Territorial Cooperation Programmes (INTERREG) that Greece is implementing with neighbour countries. The aforementioned Programmes are co-financed by EU Funds and the Greek Government. All programmes are financed by ERDF while the Sectoral Programme for the Environment is also financed by the Cohesion Fund. About 100 M€ are earmarked on biodiversity, in the Sectoral Programme and the 13 OPs of PA 2014-2020. The relevant fields are intervention categories No. 085 "Protection and enhancement of biodiversity, nature protection and green infrastructure" and No 086 "Protection, restoration and sustainable use of Nature 2000 sites". In those Programmes, projects of a total budget of about 73 M € are under implementation to date. Finally, projects of a total budget of about 34 M € are under implementation in Territorial Cooperation Programmes. However, projects funded especially targeting marine biodiversity are fragmentary and limited within this framework.

*Operational Fisheries and Maritime Programme*

The Operational Programme for support from the European Maritime and Fisheries Fund (EMFF) in Greece aims at achieving key national development priorities in line with the "Europe 2020" objectives. The OP addresses the general reform of the Common Fisheries Policy (CFP) and fully supports the priorities defined in the EMFF Regulation. The main objectives of the OP aim at enhancing the competitiveness of aquaculture and processing sectors, the viability of the sea fisheries sector and the sustainable development of traditionally fisheries dependent areas. The Programme also addresses the need for protection and rehabilitation of the marine environment and its living resources, the control of fisheries activities, the collection of fisheries data and the improvement of knowledge on the state of the marine environment.

The top priority of the OP is *"Viability and sustainable development of the Greek fisheries sector as well as at the protection of the fishing/marine resources"* (186.2 million € or 35.57% of total OP allocation). The OP foresees investments for the modernization of fishing shelters and landing sites, for better health and safety, for the promotion of innovation and partnerships between fishers and scientists, for the development of complementary activities /new forms of income for fishers and investments allowing fishers to use and add value in unwanted catches. The creation and the monitoring of artificial reefs have also been planned, aiming at the protection and the restoration of marine biodiversity and the limitation of fisheries' impact to marine environment. Permanent cessation of fishing activities and on board-investments to increase gear selectivity have also been provided.

Other priorities of the OP are a) Fostering environmentally sustainable, resource efficient, innovative and competitive and knowledge based aquaculture, b) Promoting the implementation of the CFP and c) Integrated maritime policy aiming at improving knowledge on the marine environment with particular focus on the development of part of CISE (Common Information Sharing Environment).

## 7.2. Other sources (private, public, partnership)

Private funds are allocated to projects that concern the EIAs (environmental impact assessment). Being usually local in nature (although they can cover critical/sensitive areas) they can nevertheless provide essential but limited information on marine biodiversity. EIAs have resulted in conservation actions minimising damage to keystone species by for example translocating these to nearby MPAs following harbour expansion works (Papadopoulou *et al*., 2017). In any case, they can be used as surrogate monitoring schemes when they last for a period of time. For instance, Water and Sewage Treatment Plants of Municipal Enterprises funded projects which mainly concern monitoring results that serve as tools for assessing the impact on marine ecosystems. Episodic funding may be provided from private donors or institutions at different levels from student scholarships/ awards to small scale studies to academic or research institutions, individuals and NGOs.

## 7.3. International funds, projects, programmes, national eligibility for international programmes/funds (e.g. green funds) identified

Almost all of the international programmes/projects have been funded by the EU through its various directorates (e.g. DG Environment, DG Research, DG MARE) with the GRST providing matching funds (up to 50% of the Commission's budget). With some exceptions directly related to marine biodiversity, most projects include biodiversity issues only peripherally. Furthermore, EU funded projects (being competitive in nature, diverse in topic, with a wider area in scope and with a rather limited time span) cannot be considered as a

regular source of funding. On the other hand, as the EU becomes more concerned about ECAP, more funds are expected to become available on related research topics in the Mediterranean Sea. The Greek scientific community with its established collaborations, long experience and record of success in EU projects is now well geared to participate in such funding. Obligations of the Greek authorities resulting from the needs of the ensuing EU legislation and initiatives, as well as its membership and collaboration with organisations and agencies such as UNEP/MAP and EEA, have played a significant role in determining the allocation of funds on targeted needs of marine environmental research. As in the case of EU funded projects, the local scientific capacity is more than adequate to monitor driving forces, pressures and their impact on marine biodiversity and EQS taking an ECAP approach, and to provide advice or even solutions to the problem. Examples of EU funding sources specifically focusing on biodiversity are provided below:

### *LIFE Programme*

LIFE programme is the EU's funding instrument for the environment and climate action. It has been running since 1992 and has co-financed more than 4 500 projects across the EU and in third countries, mobilising over €9 billion and contributing more than €4 billion to the protection of the environment and climate. The budget for the LIFE programme for 2014–2020 is set at €3.4 billion in current prices, with a sub-programme for environment and a sub-programme for climate action.

### *LIFE Nature and Biodiversity*

This LIFE priority area is aimed at developing, testing and demonstrating best practices, solutions and integrated approaches to contribute to the development and implementation of nature and biodiversity policy and legislation, as well as improving the related knowledge base. To date, the LIFE Nature and Biodiversity component has co-financed 73 projects in Greece. These represent a total investment of €107.5 million, of which €72.5 million was contributed by the EU. Completed LIFE Nature projects in Greece have supported actions aimed at stabilising or increasing populations of endangered species (among others *Caretta caretta* and monk seal in the Northern Cyclades and in Gyaros island), as well as rehabilitating habitats (e.g. Drana lagoon).

### *Green Fund*

The Green Fund is a Public Body funding organization, supervised by the Ministry of Environment and Energy. It was founded in 2010 with the scope: 1) to enhance development through environmental protection, 2) to support the country's environmental and energy policy, and 3) to serve public and social interests through the management of Green Fund resources. The Green Fund's resources are described in the Ministerial Decree 4503/2012 and include mostly a) the fines from environmental offences in the urban, rural and marine areas, b) other revenues, e.g. from Special Forest Entity (revenues from exploitation logging and fines, fees, leases/sales in forest areas), c) tax resources, e.g. petrol consumption and d) interest from capital. Green Fund's resources are made available through planning and implementation of Funding Programmes for the protection, enhancement and restoration of the natural and urban environment in the framework of the National Environmental Strategy priorities. Funding Programmes are structured in Priority Pillars, Measures and Actions and define the Beneficiaries, the Funding Amount and the Eligibility Criteria in order to ensure the transparency of the procedures. In particular, through the Funding Programmes "Natural Environment and Innovative Actions" and "Natural Protected Areas" the Green Fund supports both the Management Agencies of the Protected Areas of Greece and actions for the protection of marine and coastal diversity. In addition, through the "Blue Fund - Protection of the Marine Environment and Prevention of the Marine Pollution" the Green Fund supports actions of the Greek Coast Guard.

### *MedPAN small projects*

The MedPAN Network of MPAs' Managers in the Mediterranean has set up since 2011 a small projects scheme that aims to help MPAs provide a sustainable protection of biodiversity, while ensuring the sustainable economic development of human based activities. These small projects provide direct support to MPA managers for the implementation of concrete actions, which will improve management effectiveness, test pilot schemes or put in place tools that can be useful to other MPAs. Over the last 6 years MedPAN has funded three small scale biodiversity projects in Greek MPAs.

8.

# Conclusions and recommendations

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Although our knowledge concerning certain taxa may be considered satisfactory, there are still vast gaps regarding the distribution, range, population and conservation status for the majority of species and habitats. Therefore, research and systematic monitoring of Greek biodiversity must be largely supported. Greece has a rich marine biodiversity and a great variety of marine natural habitats in its territories and therefore there is a need to invest in nature and its natural capital in order to make sure that the services that biodiversity and ecosystems provide to its citizens will continue to do so in perpetuity. This is particularly important in the current period with the new EU Green Deal including actions such as the EU Biodiversity Strategy for 2030 aiming to put Europe's biodiversity on the path to recovery by 2030 and the 2021-2030 UN Decade of Ocean Science for Sustainable Development and Decade on Ecosystem Restoration aiming to restore degraded and destroyed ecosystems. In addition, the Conference of the Parties to the Convention on Biological Diversity, in its decision 14/34 adopted a comprehensive and participatory process for the preparation of the post-2020 global biodiversity framework as a stepping stone towards the 2050 Vision of ""Living in harmony with nature". It is also vital for the state to fulfil and fully implement its obligations stemming from European and international Treaties and Conventions. The adoption of the National Biodiversity Strategy and Action Plan and the integration of issues concerning biodiversity into sectoral policies, combined with the effective operation of the NATURA 2000 European Ecological Network, will be decisive for biodiversity conservation. The evolving process of institutional protection of the network's sites, the creation of Management Agencies for important sites and the enforcement of environmental control institutions and mechanisms are very significant steps. The institutional protection of new sites and the support to the operation of new Management Agencies or schemes is expected to have a catalytic effect on the conservation of biodiversity of Greece.

An overview of the existing state of marine ecosystems confirms that, with the exception of a number of marine coastal areas where the concentration of human activities has caused a long-term severe disturbance to the marine environment, such as the Saronikos Gulf and the Bay of Thessaloniki, the Greek Seas still maintain characteristics of high environmental quality as far as the planktonic, benthic invertebrate and benthic macrophyte communities are concerned.

During the last 20 years, the state of the Greek fishery resources shows negative trends, despite the reduction of the fishing capacity in accordance with EC regulations, aiming at the reduction of the fishing pressure on stocks. Moreover, the Greek fisheries' sector's viability appears to be pessimistic, since it is influenced by a variety of factors related with the capacity to produce sufficient amounts of fisheries' products and the conditions of the market. The above underline the complexity and the sensitivity of the problem and denote that the management of Greek fisheries should be based on both the sustainable use of resources and the viable development of the sector (SOHelFi, 2007).

Estimates of the Greek marine biological resources are scarce and geographically limited and are based on information gathered within research projects that are funded by national or community sources, especially for species of commercial interest. But the application of the ecosystem-based approach to fisheries' management is very complex, demanding in resources and requires the integration of solid scientific advice based on thorough research.

However, during the last decade, the construction and operation of Research Infrastructures (e.g. LifeWatchGreece, CMBR, Poseidon System) has played a pivotal role in shaping the landscape of biodiversity and ecosystems assessment and research activity in the country. In parallel, regular habitat assessments of GES under the WFD and MSFD implementation, along with the HD update on remaining gaps and areas of attention and national conservation priorities.

Measures for the minimization of the adverse effects of human activities on the marine environment, such as implementation of restrictions on solid and liquid waste disposal, and amelioration of the effects of overfishing, of illegal and unreported fishing, as well as of by-catch and discards, are required to be implemented along with effective measures for the protection and conservation of endangered marine species and important marine sites as well as international cooperation to deal with the phenomenon of invasion of NIS.

**Recommendations include**

- Development of a long-term national policy for marine research and management of marine resources, with specific strategy, goals, coordination, funding and implementation roadmap.
- Activities such as: (a) coordination and harmonization of monitoring surveys (e.g. for plastics), along with intensifying sampling effort and expanding the grid of monitoring stations (e.g. WFD and MSFD), in association with other international and regional projects (e.g. jellyfish blooms); (b) rapid assessment surveys (RASs) in understudied areas/habitats and in hotspots for NIS (locations at high risk for the introduction of NIS, such as ports, marinas and aquaculture sites) as well as for the marine environment in general (EQS); (c) supporting cutting-edge technologies on data, information and analytics of the topic; (d) contribution of validated citizen science data: development of citizen science networks and networks of taxonomic experts.
- Promotion of basic research for certain understudied habitats, such as deep sea, pelagic and interstitial habitats, BBL and hard substrates (especially coralligenous formations and marine caves). Development of innovative sampling methods and techniques. More research effort towards these habitats, as the knowledge on their biodiversity is of utmost importance for ecological studies assessing ecosystem functioning, food webs, habitat conservation and changes caused by invasions of NIS (to which Greece is particularly exposed due to its geographic location). Gaps in knowledge of biodiversity in unexplored geographic areas (e.g. Ionian Sea, eastern Aegean, south Cretan Sea). Some of these habitats are particularly fragile and their recovery time is at the scale of centuries. Yet, they are those attracting the most human interest for exploration and aesthetics through very important activities for the tourism industry, such as diving and yachting.
- Support of taxonomy experts for investigating the diversity of understudied and/or unexplored taxa such as Ascidiacea, Bryozoa, Hydrozoa, Foraminifera, meiofauna, dinoflagellates, mesozooplankton groups (other than copepoda and cladocera), macrozooplankton, microplankton, microphytobenthos. Training and capacity building concerning taxonomy by using classical and modern techniques along with international collaboration with networks of taxonomic experts.
- Extending the scope of studies beyond the level of species matrices, incorporating more data on size, life cycle, trophic relations, productivity, ecophysiology and genetics.
- Development of long-term projects in selected areas covering the need for assessing temporal trends (e.g. climate change) and comparisons among anthropogenically impacted vs. naturally disturbed environments. Suggested study areas may include Rhodes, Evoikos Gulf, the Central Aegean plateau, Lesvos and Kavala Gulf, as well as the northern and southern Cretan Sea.
- Support of the relevant Research Infrastructures (LifeWatchGreece, CMBR, Poseidon System) in order to maintain and further develop the high-quality level in open access data, reproducible analytics and mobilized communities, so far achieved.
- Networking: joining forces, setting the essential questions, developing the National Strategy in compliance with EU and International Treaties and Conventions, linking with the relevant EU networks (e.g. EurOCEANS, EuroGOOS).
- Support (sufficient funding and human resources) of the established networks of strongly protected MPAs for long-term biodiversity conservation.
- Enhance the management effectiveness of MPAs based on efficient ecological information. Scientific data obtained through ERDF Projects over the periods 2010-2015 and 2019-2023 on biodiversity conservation and management in coastal and marine protected areas, should be further supported with monitoring stations in MPAs in order to assess their ecological status and these stations should be integrated in the MSFD monitoring strategy.
- Mapping of human pressures inside and outside of the MPAs is also critically required to assess the management effectiveness, to design the management measures, priorities and decisions with respect to local, as well as national needs.
- Cooperation and coordination among the competent ministries and authorities for the development of effective conservation measures for protected areas (including mainstreaming of biodiversity and fisheries regulation). Clarification of the legal framework for enforcement of conservation measures and training of competent authorities in this respect.
- Development of robust processes for the evaluation of MPAs management plans and promotion of adaptive management.
- Estimation of population status, threats and trends for the protected and endemic species.
- Co-ordinated, cooperative multidisciplinary research is needed to understand and investigate the impact of CC on the marine ecosystem including introduced species, particularly in hot spot areas. Studies on the pelagic ecosystem presumably affected by ballast waters e.g. in Saronikos and Thermaikos gulfs as well as from ship ballasts arriving in Greek ports (Heraklion, Thessaloniki, Piraeus) are urgently needed.
- Continuation and further development of data (intensifying sampling effort and expansion of grid of stations) archiving for all ecosystems/habitat types.

- Further development of physical facilities and infrastructure (laboratories, large-scale equipment, vessels, observatories and platforms) with ease of access by the scientific community.
- Further development of digital facilities (e.g. databases ELNAIS, GTIS) employing new tools and disruptive technologies (e.g. BlockChain, Virtual Research Environments) elaborating into marine biodiversity conservation and research.
- Investment in human capital and mobility, ensuring future competence and expertise (training and career paths in marine science).
- Establishment of national working groups addressing various biodiversity issues meeting and reporting regularly on species and habitats status assessments.
- Establishment of national targets for the conservation and restoration of specific marine species and habitats in line with the CBD requirements, the recent EU Biodiversity Strategy 2030 marine targets to restore degraded ecosystems and the aspirations of the UN Decade on Ecosystem Restoration 2021–2030.
- Considerable advancement and increase of OL in society, from education and school curricula, to decision-makers and the public at large, considering priorities of the UN for supporting the implementation of SDG 14 of the 2030 Agenda for Sustainable Development.
- Particular importance should be paid for studying, understanding and protecting deep-sea ecosystems. Action plans and scientific research for sustainable management of deep-water fisheries with emphasis on the protection of highly vulnerable deep-water communities, either by immediate removal of (erect, slow growing) organisms and/or by habitat and trophic level modifications.
- Coralligenous/maërl assemblages should be granted legal protection at the same level as *Posidonia oceanica* meadows. A first step would be the inclusion of coralligenous concretions and rhodolith/maërl beds as a priority natural habitat type in the EU Habitats Directive. A second step would be the systematic mapping of their occurrence and distribution in order to define no trawling zones over these fragile protected habitats with the aim to halt the ongoing irreversible destruction.
- Investigation of spatial distribution and population structure of the red coral in the Greek Seas is urgently required in order to address proper and effective management measures.
- Marine species and habitats should be regularly assessed for their conservation status (e.g. IUCN Red List).
- Standardization and implementation of genetic approaches (DNA metabarcoding) for the assessment of marine biodiversity and for regular biomonitoring in a fast, high throughput, cost effective and taxonomically accurate way. DNA metabarcoding can be an indispensable method, especially in cases where traditional taxonomic methods are difficult to produce reliable biodiversity data. Nevertheless, it is of paramount importance the creation of curated genetic reference databases for the flora and fauna of the Greek Seas, upon which DNA metabarcoding data can be assigned to species.
- Supporting the implementation of a long-term Omics Biodiversity Observatory Network in Greece aligned with international initiatives to contribute to the European Biodiversity Strategy 2030 and to the UN Decade of the Ocean.
- Organization of workshops on Nagoya's Protocol ABS involving legal and biodiversity experts, multiple stakeholders and decision makers.
- Harmonization between the implementation of nature conservation policies (e.g. HD), environmental policies (e.g. WFD and MSFD) and economically driven policies (e.g. CFP).

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# Annex

**Table S1.**
Abundance (cells $L^{-1}$) and diversity (f: family, g: genus and sp: species number, OTUs: operational taxonomic units) examined by microscopy or metabarcoding (mBC) of ciliates, nano-Eukaryotes, Prokaryotes and Viruses. Pend: analyses in progress

| | | | | | Ciliates | | | nano-Eukaryotes | | Prokaryotes | | Viruses | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Project | Geogr. area | Period (month/year) | Depth (m) | Abundance cells $L^{-1}$ | Diversity | | Abundance cells $L^{-1}$ | Divers. mBC OTUs | Abundance cells $L^{-1}$ | Divers. mBC OTUs | Abundance cells $L^{-1}$ | Divers. mBC OTUs |
| | | | | | | microsc. g/sp Nb | mBC OTUs | | | | | | |
| Coastal | HYPOXIA | Alex/poli, Kavala, Strim/kos, N,S Evoikos, Saronikos | 06/2014 | 2-20 | 1240-6940 | 22 g | 169 | $7.0x10^5$-$1.5x10^7$ | 839 | $3.7x10^8$-$1.3x10^9$ | Pend. | $4.8x10^9$-$7.1x10^{10}$ | - |
| | HCB | Cretan Sea | 2019 monthly | 2-120 | 80-1930 | 29 g | Pend. | $1.1x10^6$-$5.9x10^7$ | Pend. | $2.7x\ 10^8$-$9.0x10^8$ | Pend. | $2.8x10^9$-$5.1x10^{10}$ | - |
| | PhD P.P. | Cretan Sea | 01-02/1992, 04-05/1993, 06-07/1993, 11-12/1993 | 2 | 10-1560 | 30 sp | - | - | - | - | - | - | - |
| | EPET | Ithaki, Cephal, Sounion | 06,11/1995, 04/1996 | 2-40 | 0-3300 | 18 sp | - | - | - | - | - | - | - |
| | AQCESS | Evia, Lesv., Chios | 05/2001, 09/2002 | 2, 10, bottom | 460-2380 | 102 sp | - | $6.8x10^5$-$1.9x10^6$ | - | $5.5x10^8$-$8.0x10^8$ | - | - | - |
| | TAPAS | Argolicos | 06,07/2017 | 2 | 2725-7970 | 18 g | Pend. | $2.3x10^6$-$3.4x10^6$ | Pend. | $4.7x10^8$-$6.1x10^8$ | Pend. | $5.3x10^9$-$1.1x10^{10}$ | Pend. |
| | WFD | Ionian, Saronikos | 03/2014, 03/2015 | 2 | - | - | - | - | - | $3.4x10^8$-$4.8x10^9$ | 406 | $7.5x10^9$-$6.1x10^{10}$ | 6 f,18 g |
| | Therm/kos | Therm/kos | 02,09/1998, 2000-02, 2004-05 monthly | 2-100 | 200-3960 | 84 sp | - | $2.1x10^5$-$1.1x10^7$ | - | $1.9x10^8$-$4.2x10^9$ | - | - | - |
| | Saronikos | Saronikos | 01-07/2001, 2003-04 monthly, 03/2007-07,09,12/2008, 2009-10, 12/2015, 02,04,06/2016 | 2-75 | 120-6260 | 122 sp | - | $2.1x10^6$-$1.3x10^7$ | - | $2.4x10^8$-$1.9x10^9$ | 296-578 | $1.9x10^9$-$2.2x10^{10}$ | - |
| Off-shore | M3A | S Aegean | 2010-13 monthly | 2-100 | 10 - 850 | Pend. | - | $2.8x10^5$-$5.8x10^6$ | - | $1.1x10^7$-$7.5x10^8$ | - | $1.2x10^8$-$8.6x10^{10}$ | - |
| | Leveco | Libyan | 04/2016 | 2-4000 | 1-740 | 39 g | 168 | $5.6x10^4$-$2.4x10^6$ | 357 | $1.7x10^7$-$4.6x10^8$ | Pend. | $1.1x10^9$-$6.6x10^9$ | 4 f |
| | MATER | N,S Aegean | 03,04/1997 | 2 -100 | 0 - 2040 | 82 sp | - | $0.6x10^6$-$4.5x10^6$ | - | $2.8x10^8$-$1.2x10^9$ | - | - | - |
| | SESAME | N,S Aegean, Ionian, Libyan | 03,04,09,10/2008 | 2-4000 | 0-1190 | 121 sp | - | $4.1x10^4$-$5.7x10^6$ | - | $1.7x10^7$-$1.1x10^9$ | | $1.2x10^8$-$9.2x10^9$ | - |
| | MEDEX | N Aegean | 12/2009, 03,04,05/2011 | 2-100 | 30 - 2360 | 101 sp | - | $9.5x10^4$-$1.1x10^7$ | - | $1.3x10^8$-$2.2x10^9$ | - | $3.2x10^9$-$1.0x10^{11}$ | - |

# SPA/RAC WORKING AREAS

*SPA/ RAC, the UNEP/ MAP **Specially Protected Areas Regional Activity Centre**, was created in 1985 to assist the Contracting Parties to the Barcelona Convention (21 Mediterranean contries and the European Union) in implementing the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol).*

POST-2020 SAPBIO

**Strategic Action Programme** for the **Conservation** of **Biodiversity** and **Sustainable Management** of **Natural Resources** in the **Mediterranean Region**

SPAMI

**Specially Protected Areas** of **Mediterranean Importance**

**Marine turtles**

**Cetaceans**

**Specially Protected Areas**

**Monitoring**

**Mediterranean Monk Seal**

**Cartilaginous fishes**
(Chondrichtyans)

**Coralligenous and other calcareous bio-concretions**

**Marine vegetation**

**Marine and coastal bird species**

Listed in Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean

**Dark Habitats**

Habitats and species associated with seamounts, underwater caves and canyons, aphotic hard beds and chemo-synthetic phenomena

**Species introduction and invasive species**

POST-2020

# SAP BIO

**Strategic Action Programme**
for the **Conservation** of **Biodiversity**
and **Sustainable Management**
of **Natural Resources**
in the **Mediterranean Region**

UN environment programme

Mediterranean Action Plan
Barcelona Convention

SPA/RAC
*The Mediterranean Biodiversity Centre*

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