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POLICY AND PRACTICE REVIEWS
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Light and Shade in Marine Conservation Across European and Contiguous Seas

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As a response to increasing human pressures on marine ecosystems, the legislation aimed at improving the conservation and management of marine coastal areas in European and Contiguous Seas (ECS) underwent crucial advances. ECS, however, still remain largely affected by increasing threats leading to biodiversity loss. Here, by using emblematic case studies and expert knowledge, we review current conservation tools, comparing their application in different areas to assess their effectiveness, potential for synergies, and contradictions. Despite regional differences in their application, the existing legislative frameworks have the potential to regulate human activities and to protect marine biodiversity. However, four challenges remain to be addressed to fully achieve environmental policy goals: (1) Lack of shared vision representing a limitation in transboundary collaboration. Although all EU countries are committed to fulfil EU Directives and other binding international legislative acts, a remarkable heterogeneity exists among countries in the compliance with the common legislation on conservation and in their degree of implementation. (2) Lack of systematic procedures for the selection of protected marine sites. Regional and national approaches in designating Natura

2000 sites and nationally designated marine protected areas (MPAs) reflect varying conservation targets and importance of conservation issues in political agendas. (3) Lack of coherent ecological networks. Natura 2000 sites and other MPAs are still far from reaching the status of effective networks in all considered case studies. (4) Hotspot of conflicts with private economic interests prevailing over conservation aims. Recommendations are given to overcome the fragmented approach still characterizing the conservation and management of coastal marine environments. Holistic, integrated, ecosystem-based, cross-cutting approaches can avoid conflicts among institutions so as to provide effective and timely solutions to current and future challenges concerning the conservation and management of marine ecosystems and associated goods and services.

Keywords: European Directives, Natura 2000 sites, marine protected areas, MSFD, MSP, fishery management, OECMs

INTRODUCTION

As a response to increasing human pressures on marine ecosystems (Claudet and Fraschetti, 2010), in the last two decades legislative frameworks aimed at improving the conservation and management of marine coastal areas in European and Contiguous Seas (ECS) underwent crucial advances. Several studies documented the positive ecological impact of marine protected areas (MPAs) (Claudet et al., 2008; García-Charton et al., 2008) and the protection of ecologically relevant habitats (e.g., spawning and nursery areas) on local and regional economies (Badalamenti et al., 2000; Guidetti, 2006). Also, other areas subjected to different forms of management or protection (i.e., fishery reserves, fisheries restricted areas (FRAs), biological protection zones, artificial reef areas, exclusive fishing zones) can increase socio-economic benefits of fisheries in southern European waters (Higgins et al., 2008; Vandeperre et al., 2011; Pipitone et al., 2014).

This evidence stimulated marine environmental legislation to fill gaps in protection and management initiatives (see also **Box 1**). The adoption of the Habitats Directive (HD), the Birds Directive (BD), and the Water Framework Directive (WFD) represented important opportunities to decrease disturbance to ecosystems. More recently, along with the WFD and the Common Fisheries Policy (CFP), the Marine Strategy Framework Directive (MSFD) aims at achieving Good Environmental Status (GES) in the 5,720,000 km^2 of European seas by 2020, using an ecosystem approach (EC, 2010).

Several European countries rapidly expanded Maritime Spatial Planning (MSP) (Depellegrin et al., 2017; Schachtner, 2017) as an application of the Maritime Spatial Planning Framework Directive (MSPFD) and of initiatives such as regional agreements or recommendations. Although the European directives (e.g., Habitat Directive, MSFD) are binding only to EU Member States, other countries outside EU tend to follow the same or similar policy measures (e.g., the Ecosystem Approach promoted by the Barcelona Convention in the entire Mediterranean Sea is largely a clone of the MSFD).

Despite these efforts, ECS still suffer the compound effects of increasing threats with clear signs of ecosystem impairment (Airoldi and Beck, 2007; Claudet and Fraschetti, 2010; Micheli et al., 2013). A recent overview of the vulnerability of marine, terrestrial, and freshwater habitats in the EU and adjacent regions showed that 19% of the evaluated habitats were *Critically Endangered*, *Endangered*, and *Vulnerable* (Gubbay et al., 2016). The highest proportion of threatened habitats occurs in the Mediterranean Sea (32%), followed by the North-East Atlantic (23%), the Black Sea (13%), and the Baltic Sea (8%). Europe is now facing the challenge of Blue Growth (EC, 2012) that, while promoting jobs and innovation, could be also conducive to new sources of disturbance without a proper indication on how to operationalize sustainability in practice, further hindering the difficult task of achieving GES across European seas (Boyes et al., 2016; Frost et al., 2016).

These analyses are further expanded here by reviewing how current tools for biodiversity protection and management in ECS can contribute to GES. We expect a "mosaic of successes" reflecting idiosyncratic outcomes in the implementation of common regulations. Selected case studies allow considering such tools in different areas to assess their effectiveness, potential for synergies, and contradictions. The addressed questions are: (1) what are the conservation/management tools at species, habitat, and ecosystem level adopted in different ECS? (2) Are there critical differences in their application among European countries? If so, (3) do these differences limit a transboundary collaboration? (4) What are the favorable (or not) socio-ecological settings for their successful application? Drivers of the observed idiosyncrasies are identified and discussed, and specific recommendations for improving coherence and effectiveness of conservation and management across ECS are proposed.

AVAILABLE CONSERVATION TOOLS

A large array of policy tools address nature conservation either as a main or an ancillary goal in ECS (**Supplementary Table S1**).

Here we focus on the establishment of Natura 2000 sites under the HD and BD, nationally designated MPAs, MSFD,

BOX 1 | Acronyms.

National and International bodies

- EC European Council
- EEA European Environmental Agency
- EU European Union
- FAO Food and Agriculture Organization of the United Nations
- JNCC Joint Nature Conservation Committee
- INPA Israel Nature and Parks Authority
- IUCN International Union for Conservation of Nature
- MCCIP Marine Climate Change Impacts Partnership
- UN United Nations
- UNEP United Nations Environment Programme

National and International regulatory frameworks and agreements

- BD EU Bird Directive (EU Parliament and Council Directive 2009/147/EC on the conservation of wild birds)
- CBD Convention of Biological Diversity
- CFP Common Fisheries Policy (EU Parliament and Council Regulation No. 1380/2013 on the Common Fisheries Policy)
- EUSAIR Union Strategy for the Adriatic and Ionian Region
- HD EU Habitat Directive (EU Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora)
- HELCOM Baltic Marine Environment Protection Commission
- MSFD EU Marine Strategy Framework Directive (EU Parliament and Council Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy)
- MSPFD EU Framework Directive on Maritime Spatial Planning (EU Parliament and Council Directive 2014/89/EC establishing a framework for maritime spatial planning)
- OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic
- WFD EU Water Framework Directive (EU Parliament and Council Directive 2000/60/EC, establishing a framework for Community action in the field of water policy)

Others

- EBA Ecosystem-based approach
- EBFM Ecosystem-Based Fishery Management
- ECS European and Contiguous Seas
- EEZ Exclusive Economic Zone
- FRA Fishery Restricted Area
- GES Good Environmental Status
- IMP Integrated Maritime Policy
- MCZ Marine Conservation Zone
- MPA Marine Protected Area
- MSP Maritime Spatial Planning
- MSY Maximum Sustainable Yield
- NTZ No-take zone
- OECM Other Effective Area-based Conservation Measures
- SAC Habitat Directive Special Areas of Conservation
- SCI Site of Community Importance
- SPA Specially Protected Area
- SSB Spawning Stock Biomass

MSPFD, fisheries management tools, and other management tools benefiting marine conservation. These measures are largely adopted across EU, with potential interactions among the different tools (e.g., ecologically coherent MPA networks as important tools for GES achievement in the framework of MSFD; nationally designated MPAs including Natura 2000 sites), leading to critical synergies when successfully applied.

Natura 2000 Sites and Nationally Designated MPAs

Marine protected sites in ECS are designated based on national and international legislation instruments, grouped in two main categories: Natura 2000 sites, the cornerstone of EU conservation strategies, and nationally designated MPAs (often in accordance with Regional Sea Conventions), which greatly vary among countries. Natura 2000 is relevant only to EU countries and, furthermore, its sites often overlap with nationally designated MPAs.

Natura 2000 Sites

The HD and the BD are a legally binding basis for the establishment of EU protected areas, collectively known as the Natura 2000 network. Sites are selected according to the presence of habitats and/or species of importance at the level of the EU (Annexes I and II of HD; Annex I of BD). The HD defines special areas of conservation (SACs), where habitat types and non-avian species listed within the annexes of the directive are protected. The BD defines special protection areas (SPAs) targeting threatened bird species and all migratory birds. SACs are more pan-European because of the role played by the EU and their biogeographic approach, while SPAs are essentially nationally designated areas in which the EU has some influence. The rules for the selection of Natura 2000 sites are common to all EU Member States, even though the application of the common legislation differs among countries (**Figure 1**).

Natura 2000 is the largest conservation network globally, consisting of more than 27,500 sites that cover about 789,081 km^2 (18.15%) of the terrestrial EU territory, and almost 400,000 km^2 (11.5%) of the EU territorial waters, namely <6% of the Member States' Exclusive Economic Zones (EEZ) (existing or provisional based on middle lines with neighboring countries in cases of countries that have not yet declared an EEZ) (Mazaris et al., 2018).

The 3,797 marine sites hosted by 23 Member States are either exclusively marine or have both marine and terrestrial components (**Figure 1**). Orlikowska et al. (2016) recognized important gaps in ecological research on Natura 2000 marine systems, with limited attention to social issues (Blicharska et al., 2016). Mazaris and Katsanevakis (2018) raise concerns on the operational capacity of the network, supporting an inadequate and insufficient reporting of threats in marine sites (e.g., invasive species). Mazaris et al. (2018), given the lack of systematic procedures for the selection of Natura 2000 marine sites (Giakoumi et al., 2012), questioned its effectiveness and representativeness. The current network under-represents offshore and deep habitats (Mazaris et al., 2018), and offers limited protection to many threatened marine species (Olsen et al., 2013).

Issues related to the spatial properties of the network and its efficiency to support connectivity have also been identified in the Atlantic Ocean (Johnson et al., 2008) and the Baltic Sea (Sundblad et al., 2011; Corell et al., 2012). The ecological coherence of the network is insufficient because the designation was driven by listed priority species and habitats and favored coastal areas

(European Environmental Agency [EEA], 2015). Differences in the establishment, representativeness, and connectivity of the network reflect national and regional differences in the capacity, organization, and collaboration across EU Member States in applying EU marine policies. In many Natura 2000 marine sites neither a management plan nor conservation measures are in place (Beal et al., 2017; **Figure 1**). This is the case in ∼40% of the 2,818 sites with a marine cover >10% of their surface: paper parks cannot deliver any benefit for marine conservation.

Nationally Designated Marine Protected Areas

In ECS, nationally designated MPAs range from fully protected (*sensu* Horta e Costa et al., 2016) to partially protected areas, some being multiple-use MPAs, with varying levels of protection (Horta e Costa et al., 2016). Fully protected areas are smaller and less numerous than partially protected areas. In southern European seas, the available space and the concentration of human uses are limiting factors (Giakoumi et al., 2017). Ecological (Claudet et al., 2008; Moland et al., 2013), fisheries (Goñi et al., 2008; Huserbråten et al., 2013), and socio-economic benefits (Roncin et al., 2008) of fully protected areas are well documented. Due to the heterogeneity of the effects of partially protected areas (Di Franco et al., 2009; Sciberras et al., 2015), their benefits are expected to be lower than those of fully protected areas (Giakoumi et al., 2017): benefits of partial protection depend on how uses are regulated (Zupan et al., 2018) and on the degree of users' engagement in management and decision-making processes (Di Franco et al., 2016).

In a report on the establishment of MPAs (EC, 2015) the EC highlighted their positive ecological effects, with regional differences in terms of total covered area, data availability, and performance assessment methods. Nationally designated MPAs reflect varying importance of conservation targets in political agendas. A spatial bias in the distribution of Mediterranean MPAs is due to limited funding for conservation and sustainability in southern countries, most MPAs being along the northern coastline (Abdulla et al., 2009; Gabrié et al., 2012).

The Marine Strategy Framework Directive

The MSFD is the environmental pillar of the integrated maritime policy (IMP) (EC, 2011), aiming to achieve the full economic potential of the seas, integrating environmental protection and sustainable use. The Directive's ultimate goal is GES of EU marine waters by 2020 and to sustain the resource upon which marine-related economic and social activities depend. The 6-year implementation cycle started in 2010 and consists of: (1) assessment of the European marine waters; (2) GES

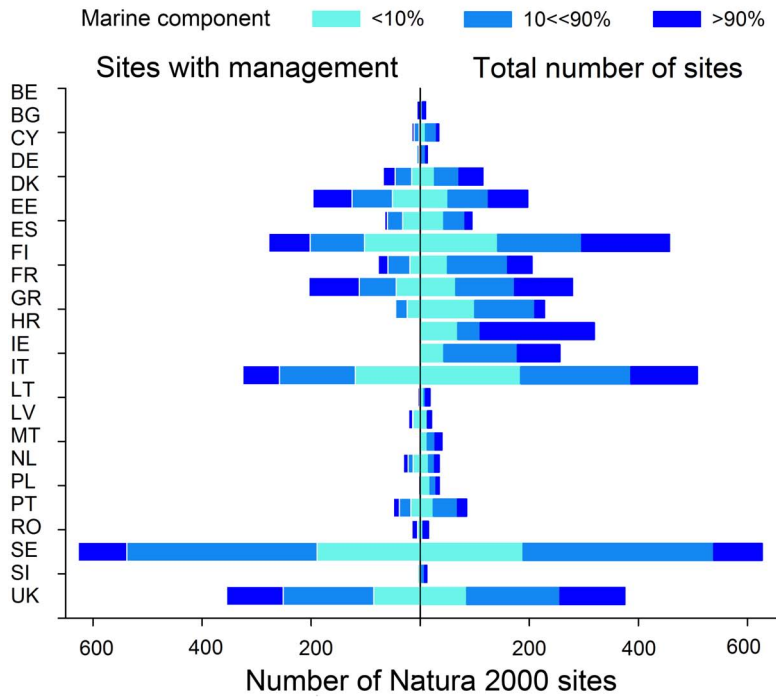


FIGURE 1 | Number of sites of the Natura 2000 network with a marine component in each country. The number of sites for which a management plan exists and/or official management and conservation measures are applied is also showed. The spatial borders of the Natura 2000 sites and information on site-based management plans and measures were retrieved from the official Natura 2000 database in the European Environmental Agency (EEA) website (accessed 27 October 2017). To identify the marine component of the sites, we used the digital terrestrial terrain of Europe, also retrieved from EEA (https://www.eea.europa.eu/data-and-maps/data/eea-coastline-for-analysis-1; accessed 27 October 2017). Country codes as follows: BE, Belgium; BG, Bulgaria; CY, Cyprus; DE, Germany; DK, Denmark; EE, Estonia; ES, Spain; FI, Finland; FR, France; GR, Greece; HR, Croatia; IE, Ireland; IT, Italy; LT, Lithuania; LV, Latvia; MT, Malta; NL, Netherlands; PL, Poland; PT, Portugal; RO, Romania; SE, Sweden; SI, Slovenia; UK, United Kingdom.

determination; (3) target setting to guide GES achievement; (4) monitoring programs; and (5) programs of measures, including networks of MPAs. GES is based on 11 *Descriptors*, in line with the Drivers-Pressures-State-Impact-Response approach (Patrício et al., 2016), relating anthropogenic impacts and pressures (non-indigenous species, fisheries, eutrophication, hydrographical alterations, contaminants, marine litter, and introduction of energy) to the state of the marine environment (biodiversity, ecosystem functioning including food-webs, and sea bottom integrity). EU Member States do not necessarily have to work on all 11 descriptors; they need to choose those who would demonstrate achievement of GES.

The position of the MSFD in marine legislation (Boyes and Elliott, 2014, 2016) requires marine management tools as a platform to harmonize assessments, monitoring programs, and environmental objectives of relevant, already in-force, legislation. The first evaluation of the MSFD, i.e., the in-depth assessment of the first phase of the implementation (EC, 2014a; Palialexis et al., 2014), appraised efforts and progresses, but also highlighted drawbacks and inconsistencies. For instance, the national definitions of descriptor 1 (*Biodiversity*) of GES were predominantly qualitative and vague: the initial assessments evaluated as adequate only 4 definitions out of 19 assessed countries, the set targets were adequate for only three countries, partially adequate or inadequate for eight countries, and not defined for two countries (EC, 2014b). A predominance of *status* targets and paucity of pressure-based targets indicated insufficient focus on key threats to biodiversity. The variables used across Europe to assess biodiversity were different in terms of development, operability, and ecological relevance of biodiversity indicators, with lack of consistent and harmonized approaches to describe and assess European marine biodiversity (Hummel et al., 2015). These findings triggered a review of the EC Decision on the criteria and the methodological standards for the determination of GES (EC, 2017), aiming to the harmonization and integration of assessments stemming from other legal obligations or regional initiatives.

The Maritime Spatial Planning Framework Directive

The MSPFD contributes to Blue Growth under the EU IMP (EC, 2012) "to support the sustainable development of seas and oceans" (EC, 2014b). Hence, MSP should apply an ecosystem-based approach (EBA) to manage human activities (EC, 2014a). The MSP, also according with the MSFD, should: (1) ensure that collective pressures remain within compatible levels with GES, (2) avoid compromising the capacity of marine ecosystems to respond to human-induced change, and (3) ensure the provision of marine ecosystem services for future generations.

Principles of the EBA are debated (Douvere, 2008), with several attempts to operationalize them (e.g., McLeod et al., 2005; Foley et al., 2010; Katsanevakis et al., 2011; Gilbert et al., 2015; Ansong et al., 2017). However, implementing these principles in the MSPFD still lacks a concrete guidance. Reviews on MSP cases (both European and international) highlighted that the implementation of EBA is limited (Ansong et al., 2017), with design, conceptual, and methodological differences in tackling it because of specific value systems and political and socio-economic context (Domínguez-Tejo et al., 2016). In Europe, MSP initiatives differ significantly among countries for multiple reasons. Belgium, Germany, Netherlands, and United Kingdom launched pioneering MSP initiatives on a voluntary basis before the MSPFD entered into force and the Portuguese MSP established the first national integrated approach to marine spatial management (Calado and Bentz, 2013).

These initiatives followed national agendas incorporating new economic activities in marine areas (Ehler and Douvere, 2009; Collie et al., 2013). Foley et al. (2010) observed that "although nearly all planning efforts outlined one goal of MSP as protecting marine ecosystem health, ecological goals and objectives were not fully incorporated into the planning process." Currently, EU Member States are implementing the MSPFD in different ways, according to administrative and planning contexts (Gissi and de Vivero, 2016). The Netherlands is at the third-generation maritime spatial plan (UNESCO-IOC, 2017), and Sweden is working on three plans covering the territorial sea and the EEZ (Skagerrak/Kattegat, Baltic Sea, and Gulf of Bothnia, source: http://www.msp-platform.eu/countries/sweden). Mediterranean Member States have not yet gone through official MSP processes.

Addressing transboundary concerns within MSP processes requires collaboration between countries (Gilbert et al., 2015; Jay et al., 2016; Gissi et al., 2018). Baltic countries already collaborate under well-established initiatives (e.g., HELCOM), while in the Mediterranean some initiatives were recently launched to foster collaboration and cooperation in achieving environmental targets (e.g., EUSAIR; EC, 2014c), with transboundary MSP as implementing tool.

Fisheries Management Tools

Fisheries management tools are part of marine biodiversity conservation and management. Fisheries impacts extend from target populations to entire ecosystems (Lotze et al., 2006; Worm et al., 2006; Coll et al., 2008a). Only 19 out of 115 recently assessed EU stocks are sustainably fished, with a significant geographical discrepancy between northern seas, where most stocks are not overfished, and the Mediterranean where overfishing affects almost all stocks (Fernandes et al., 2017). Fishing pressures, combined with other human disturbances, degraded Mediterranean food webs (Coll et al., 2008b; Halouani et al., 2015; Piroddi et al., 2017), with impacts on biodiversity and ecosystem services (Liquete et al., 2016).

Fisheries management in ECS is organized into national, regional, or international jurisdictions. Since many stocks are shared among countries, several Regional Fishery Bodies promote sustainable fisheries where international cooperation is required to manage shared stocks. Regional Fisheries Management Organizations have legal competence to adopt binding conservation and management measures on their Member States, and act partially in the high seas. Regional Fishery Bodies regulate fisheries in ECS by bilateral or multilateral agreements (**Supplementary Material**, **Supplementary Table S2**), including Regional Fisheries Management Organizations established under FAO (General

Fisheries Commission for the Mediterranean), or outside (International Commission for the Conservation of Atlantic Tunas, North Atlantic Salmon Conservation Organization, North-East Atlantic Fisheries Commission).

The consequences of fisheries led to the Ecosystem-based Fisheries Management (EBFM), integrating fisheries management and marine conservation (Pikitch et al., 2004; Garcia-Rubies et al., 2017), acknowledging the need for sustaining healthy marine ecosystems and the fisheries they support and implementing a precautionary approach where information is scarce. The introduction of EBFM changed international and regional policy instruments (Bianchi and Skjoldal, 2008). FAO provided guidance on EBFM (FAO, 2003, 2009) in many Regional Fisheries Management Organizations agreements (**Supplementary Material**, **Supplementary Table S2**). EBFM calls for minimizing the impacts of fisheries on marine ecosystems and for mitigating undesirable interactions between fisheries and marine ecosystems by using tools as fishery reserves, FRAs, no-take zones (NTZs), MPAs, and other spatial and temporal closures (Pipitone et al., 2014). In synergy with stakeholders and other conservation-aimed directives like MSFD, the EBFM is an integral part of a larger vision of the ecosystem-based MSP (Katsanevakis et al., 2011). Still, the key issue in obtaining healthy marine ecosystems is bridging the gap and reaching common objectives of conservation and fisheries (Salomon et al., 2011).

Member States delegated fisheries-related measures to the EU, whose initial approach to fisheries management was criticized for centralized decisions and for failing to reduce overfishing (Daw and Gray, 2005). The new, revised CFP (EC, 2013) implemented EBFM, including avoidance/limitation of environmental impacts of fishing activities and unwanted catches, in coherence with the fisheries targets by the Conference of the Parties to the Convention on Biological Diversity on the Strategic Plan for Biodiversity 2011–20, and with the biodiversity targets adopted by the Council of Europe. The CFP integrates in other EU "conservation" directives (HD, BD, MSFD), particularly through Article 11, contributing to the protection of the European marine environment and the achievement of GES by 2020. It introduces a limited decentralization in fisheries management, with a regionalization process through the establishment of stakeholders' Advisory Councils. However, the goal of "all European fish stocks producing at maximum sustainable yield (MSY) by 2020" could be labored by complexity in setting the MSY (e.g., more than 100 species landed in the Mediterranean) (Lleonart and Maynou, 2003), lack of active participation of stakeholders to Advisory Councils (Raicevich et al., 2018), or failure to understand and implement substantial reforms (Salomon et al., 2014). Even if EBFM is complex, difficult to operationalize and with limited achievements, the progress is visible (Link and Browman, 2017).

Other Management Tools Benefiting Marine Conservation

In addition to explicit conservation tools, such as MPAs and the Natura 2000 network, a number of legislative tools not necessarily mentioning biodiversity among their objectives, act as biodiversity conservation measures. These Other Effective area-based Conservation Measures (OECMs) are referenced in the Aichi Biodiversity Target 11 (UNEP-CBD, 2010), which calls for "at least [...] 10% of coastal and marine areas" to be conserved through "well-connected systems of protected areas and OECMs": an *ad hoc* task force has been created to guide countries and management bodies in discriminating which areas should be included under this label (Jonas et al., 2014; Watson et al., 2016; IUCN-WCPA, 2017; Laffoley et al., 2017).

Potential OECMs in European waters include historic wrecks, war graves, military waters, archeological sites and no-shipping areas (e.g., for the presence of extraction platforms, pipelines, or cables) among others, which are generally enforced but whose conservation effects are not clear. OECMs are not explicitly considered in EU Member States' conservation policies, making their inclusion in any conservation plan difficult.

ZOOMING INTO EUROPE: REGIONAL CASE STUDIES

Natura 2000 Sites

Baltic Sea

In the Baltic Sea, 893 Natura 2000 sites cover 18.9% of the total marine surface. More than one-third of them (342) extend over <1 km^2 and 130 sites over >100 km^2. Approximately 725 sites are extensions of terrestrial sites, and are restricted to territorial waters. Insufficient extension into open sea areas was noticed in recent coherence assessments of the Baltic MPA network (HELCOM, 2010, 2016), although progresses were made recently by designating larger areas (e.g., the Hoburgs and Midsjö Bank extending over 10,578 km^2) to protect the breeding habitat of harbor porpoise.

Most of the Baltic Natura 2000 network was designed for protection of marine birds, seals, and habitat types listed in the Annex 1 of the HD. The distribution of most habitats in the Baltic remains unknown, therefore the representativeness of the network cannot be quantified even for reefs and sandbanks included into the existing network. On the landscape scale, a quarter of benthic landscapes does not meet the minimum target of 20% areal protection set by Baltic Marine Environment Protection Commission (HELCOM, 2016). Therefore, the Baltic Natura 2000 network partly meets representativeness criteria: half of landscapes, especially in the aphotic zone, need improved replication and percent coverage. This demonstrates a limit but also the opportunity for using the MSFD framework to extend the Natura 2000 network to unprotected features.

Baltic countries committed themselves to develop and apply management plans for all existing Natura 2000 sites by 2015. The Natura 2000 database contains 695 management plans for 893 inspected sites (78%). Baltic countries have different formats for content and adoption procedures of management plans. While most countries have management plans for individual Natura 2000 sites, others (e.g., Denmark, see the section "Denmark" below) approve management plans for conservation features

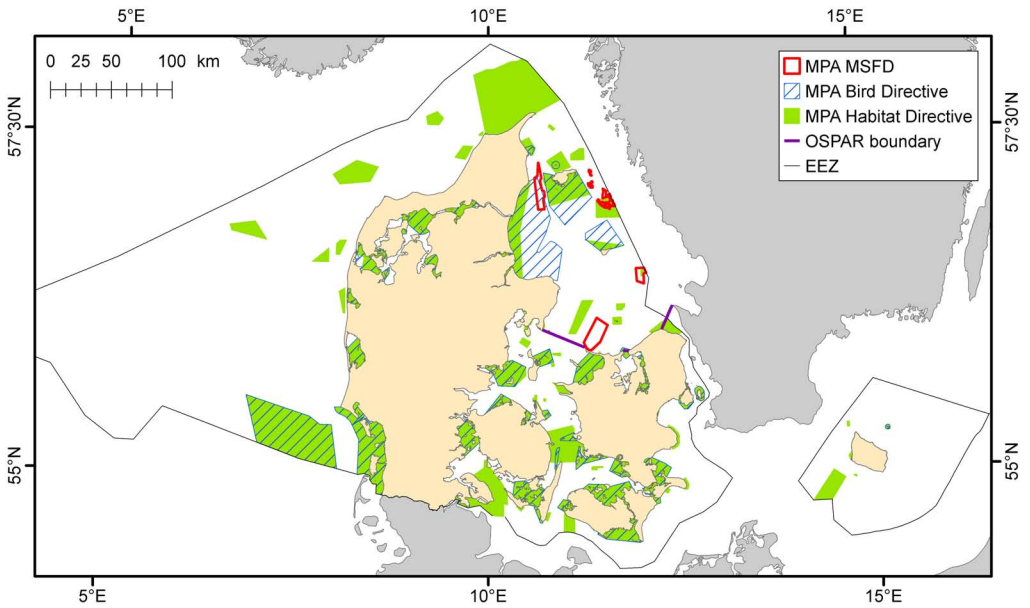


FIGURE 2 | Areas appointed according to the BD (hatched), the HD (green) together make up the Natura 2000 sites. MPAs appointed according to the MSFD (see the section "Denmark") are marked with red.

(e.g., reefs) irrespective of individual sites, better reflecting the "network" concept. Designated sites with management plans increased during the last years, but it remains unknown how conservation targets are implemented within the network, and how many managed sites have reached conservation aims. Only 81 (62%) out of 131 Natura 2000 sites with the presence of at least a single critically endangered Baltic species according to the Red List assessment (HELCOM, 2013) have approved management plans. Management plans are present for 40 out of 74 reviewed Natura 2000 sites covering the critically endangered habitat type *Estuary*, with a clear mismatch between needed protection efforts and the actual state of threatened species and habitats.

Denmark

A part of Danish waters belongs to the HELCOM convention area, a part belongs to the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) area, and a part belongs to both. Danish waters belong to two biogeographic zones according to the HD, equal to the southern OSPAR boundary. The Natura 2000 network represented the main conservation instrument until additional protection was established in Kattegat in 2016 according to the MSFD (see the section "Denmark").

In Danish waters, 97 Natura 2000 sites with marine components have been designated, covering 19% of the sea (**Figure 2**). Most sites are strictly marine, but some are both terrestrial and marine. Site selection followed three strategies: (1) essential coastal habitats for seabirds and seals became Natura 2000 sites in the 1990s and all habitats listed in the Annex I of the HD were included as part of the designation of those sites; (2) selection based on inventories and existing data was used for most sites appointed due to presence of reef (1170) and "bubbling reef" (1180); (3) offshore areas were appointed due to the presence of sandbanks, reefs, and harbor porpoise. The careful selection of many sites, also supported by habitat mapping, each with a high cover of the protected habitat, enhances the idea of a coherent network, setting replicability, representativeness, and connectivity high on the agenda.

Danish MPAs focusing on reefs and "bubbling reefs" are often small. Management plans within the Natura 2000 sites target the habitats and species that are part of the designation. This implies that human uses, e.g., fishery and sand or gravel extraction, may take place if they do not affect area, structure, and function of the designated habitats or species. Regulation of blue mussel dredging is still discussed in relation to the definition of biogenic reef areas within Natura 2000 sites, but in some areas the overall catch of blue mussels is regulated in accordance to needed food supply for birds. Most reefs and bubbling reefs are managed. In a few sites with international fishing rights the process of forbidding trawling on reefs sites and all commercial fishing on bubbling reefs is still underway but is planned to be finalized in 2018. In some Natura 2000 sites, fishery restrictions and the associated buffer zones are extended outside the border of the site to protect the whole reef structure. Monitoring takes place within Natura 2000 sites but the coverage of specific indicators for protected habitats is not complete. Enforcement takes place using tracking devices on fishing vessels >12 m and on sand and gravel extraction vessels and a warning system is activated if signals indicate risk of trawling within Natura 2000 sites.

United Kingdom

The United Kingdom has a raft of legislation relating to the protection and management of marine biodiversity and a large number of designation mechanisms for MPAs (Frost

et al., 2016), including SACs, SPAs (107 of them with marine components), Nature Conservation MPAs, and Marine Conservation Zones (MCZs), Sites of Special Scientific Interest with marine components and Ramsar sites (JNCC, 2017). The various types of protected areas form the "UK MPA network," which the UK Government considers an "ecologically coherent network" (Lieberknech and Jones, 2016). This ambition is in line with the aims stated in OSPAR, despite much uncertainty over what "ecologically coherent" means and whether coherence can be measured (Ardron, 2008; Foster et al., 2017). As a signatory to the Convention of Biological Diversity (CBD), the United Kingdom is also committed to the Aichi targets, including target 11 for "*10% of coastal and marine areas*" to be conserved and managed effectively as part of an "*ecologically representative and well connected system of protected areas*."

The HD has been very efficient in establishing MPAs, with 105 SACs with marine components, covering approximately 14% of the UK's marine area (JNCC, 2017). Of these SACs, 80 are located in inshore waters (within 12 nautical miles of the coast). Originally SACs were only established in inshore waters but in 1999 the UK High Court ruled that the HD applied "*from the 12-nautical mile (nm) boundary of its territorial sea out to the limit of its 200 nm Exclusive Fisheries Zone*" (De Santo and Jones, 2007). Sixteen SACs are in offshore waters (beyond 12 nautical miles) and nine straddle both inshore and offshore waters. The UK SACs include 13 Annex I marine habitats and 8 Annex II marine species with 3 of the Annex I habitats being also found offshore (Sandbanks which are slightly covered by seawater all the time; Reefs; submarine structures made by leaking gases). The UK government considers that "*the SAC network for marine habitats is now substantially complete*" although the EC asked to explore the option for further SACs for gray seal (*Halichoerus grypus*), common seal (*Phoca vitulina*), bottlenose dolphin (*Tursiops truncatus*), and harbor porpoise (*Phocoena phocoena*) (JNCC, 2017).

Although the implementation of the Natura 2000 network has been achieved there are still conflicts due to the complexities of the legal situation whereby most UK fisheries come under the direct regulation of the EC under the CFP (De Santo and Jones, 2007; Jones, 2012). Numerous studies show that marine biodiversity protection only works when there is a mixture of bottom-up and top-down governance and strong "on-the ground" leadership in monitoring and enforcing measures (Morris et al., 2014). The management of marine Natura 2000 sites is also complex with various bodies responsible for management and conservation objectives, depending on location (intertidal, subtidal, offshore) and devolved responsibilities (JNCC, 2018; Mackenzie et al., 2018).

Future legislative mechanisms after Brexit are unclear. The UK Secretary of State for the Environment stated in the "25 Year Environment Plan" that the United Kingdom "*must do more to protect the seas around us and marine wildlife*" (HM Government, 2018), "*reversing the loss of marine biodiversity*" and completing "*our ecologically coherent network of well-managed MPAs*". This ambition is generally supported although there is concern over the timeframe, lack of detail on how this will be achieved and the risks around weakening environmental regulation (Burns et al., 2018).

Belgium

In the Belgian part of the North Sea (BPNS), five Natura 2000 sites have been designated covering 35% of the marine surface. The red-throated diver (*Gavia stellata*), the little gull (*Hydrocoleus minutus*), the sandwich tern (*Thalasseus sandvicensis*), the common tern (*Sterna hurundo*), and the little tern (*Sterna albifrons*) are protected by being included in Appendix I of the BD.

The BPNS has two habitats of Community importance: shallow sandbanks and reefs. In addition, the harbor porpoise (*P. phocoena*), the gray seal (*H. grypus*), and the common seal (*P. vitulina*) are included in Appendix II as species of Community interest.

Two fully marine SACs protect shallow sandbanks and gullies hosting a diverse benthic community, with limits to activities impacting the sea floor integrity (Degraer et al., 2010). The first SAC "Vlakte van de Raan" (designated in 2005, covered only 0.5% of the BPNS) was challenged in court, with the revocation of the designation by the Council of State (Cliquet et al., 2012). In 2012, a second SAC, "Vlaamse Banken" was designated to cover about 1,100 km^2 (the 30.5% of the BPNS), adjoining the French "Bancs des Flandres" SAC. It was designated for protecting reefs, gravel beds, and biogenic *Lanice conchilega* aggregations, the latter listed as potential habitat due to lack of information on its recent condition and distribution (Degraer et al., 2009). Restrictions to recreational and professional fisheries were foreseen in the "Vlaamse Banken" SAC (Belgisch, 2014), but were challenged in court and are currently not enforced. Three fully marine SPAs, overlapping in part with the "Vlaamse Banken" SAC (∼172 km^2), were designated over about 8.5% of the BPNS for protecting important foraging and wintering areas of the red-throated diver (*G. stellata*) and common scoter (*Melanitta nigra*). Only for *S. albifrons* the coverage by the SACs in the BPNS reaches >60% EC target (Degraer et al., 2010).

The management plans for Belgian marine Natura 2000 sites for 2018–2023 were finalized in 2018 to achieve GES (Belgische, 2018). Legal challenges have thus far prevented the enforcement of restrictions to recreational and professional fisheries in existing MPAs. However, all fisheries are prohibited in the concession areas of offshore wind farms which currently cover 7% of the BPNS.

Portugal

Portugal recently made significant national efforts leading to a set of protected areas spanning several types of legal status and various degrees of spatial protection (European Environmental Agency [EEA], 2015). Currently, Portuguese protected areas overall cover a surface area of about 134,000 km^2 in the North-East Atlantic Ocean, with the marine Natura 2000 sites covering 38,062 km^2. Protected areas correspond to 3.5% of Portuguese marine waters overall, with the idea to further expand it via the Portuguese MSFD Program of Measures, to meet the CBD 10% coverage target for MPAs. Only 20–30% of Natura 2000 sites

that are not nationally designated MPAs have management plans, most of which are not implemented.

In line with the extension of Natura 2000 toward the inclusion of oceanic areas, Portugal made an important effort to establish an MPA network in the Azores Archipelago. Over 110,000 km^2 of marine space including a suite of coastal habitats, offshore areas, seamounts, hydrothermal vents, and large parcels of mid-ocean ridge presently benefit from some form of protection (Costa-Abecasis et al., 2015). The resulting MPA network stands as the cornerstone of Azorean marine conservation policies. With this solution the protection of such an important and management-wise complex ecosystem like the seamounts outside of the EEZ would be shared between Portugal for the seabed and sub-seabed and OSPAR for the water column. This has made Portugal, and particularly the Azores, a pioneer in the protection of offshore marine biodiversity at an international level, contributing to progress the ground-breaking OSPAR high seas MPAs process. Despite the limits (implementation of management plans, appropriate enforcement and monitoring, and bridging gaps in scientific knowledge), the envisioned full-scale MPA is intended to provide a comprehensive, adequate, and representative offshore MPA network for the Azores that will protect all major ecosystems in relation to habitats and species, at an appropriate scale, within and across each bioregion.

Aegean Sea

The Natura 2000 network represents the main conservation instrument in the Greek territorial and international waters of the Aegean Sea (**Figure 3**). 186 Natura 2000 sites with a marine component have been designated, covering 2.3% of Greece's marine surface. Only 128 of them exceed 1 km^2, and only 6 cover areas >100 km^2. Few sites are predominantly marine (i.e., 25 and 15 sites with more than 50% and 75% of marine portion), most being simple expansions of terrestrial sites (as is evident in **Figure 3**): most marine sites were not selected based on conservation plans, and certainly not because of their high importance for marine biodiversity. The average depth of the Natura 2000 sites is 56 (±78) m, which is far from representing the bathymetric heterogeneity of the region.

The national targets for habitats or species listed in Annexes I and II of the HD should be >60% for priority features and between 20 and 60% for non-priority features according to European guidelines (ETC/BD, 2010). The actual coverage of habitat types and species of community importance was in accordance with these targets for only four of the nine features of community importance that are present in the Aegean Sea (**Table 1**). For some species, such as the harbor porpoise *P. phocoena relicta*, the coverage is only 3% (Sini et al., 2017), although according to the IUCN Red List, this species is endangered and in decline (Birkun and Frantzis, 2008): the last Mediterranean population inhabits the northern Aegean Sea (**Figure 3**) and is unprotected. Even for the priority habitat *Posidonia oceanica* meadows, the coverage by the Natura 2000 network in the Aegean Sea is 27%, much lower than the >60% EC target.

Sini et al. (2017) evaluated the distribution of 68 ecological features (habitats and species) protected by international conventions and European or national legislation in the Aegean Sea, and found that 20 features were absent in Natura 2000 sites, while the coverage of 19 features was <20%. Only a small fraction of the "protected" features was sufficiently represented in Natura 2000 sites. Many targeted species have high mobility and large home ranges (e.g., *P. phocoena relicta*, *T. truncatus*, *Monachus monachus*), and thus the small average size of Natura 2000 sites is ineffective for their conservation. Forty-one sites (only four with a marine component >50% of their total area) have a management plan, with a general lack of monitoring and surveillance.

TABLE 1 | Percent coverage of marine habitat types and species of community interest by the Natura 2000 network in the Aegean Sea by the end of 2017.

	% in Natura 2000	Target	Target reached
Marine habitat			
Posidonia oceanica beds (1120)*	27	>60%	NO
Coastal lagoons (1150)*	53	>60%	NO
Reefs (1170)	22	20–60%	YES
Submarine structures made by leaking gases (1180)	2	20–60%	NO
Submarine or partially submerged sea caves (8330)	49	20–60%	YES
Animals of community interest (Annex II)			
*Monachus monachus**	93	>60%	YES
Phocoena phocoena	3	20–60%	NO
Tursiops truncatus	9	20–60%	NO
*Caretta caretta**,**	60	>60%	YES

*For sea turtles only the distribution of their nesting beaches was included in the analysis, while for marine mammals their most important habitats. Targets follow the European guidelines as in ETC/BD (2010). Data retrieved from Sini et al. (2017). * denotes priority species or habitats. ** only nesting sites.*

Black Sea: Bulgaria

With EU accession (2007), the HD and BD created an opportunity to enhance marine conservation in Bulgaria. In 2007, Sites of Conservation Interest (SCI) were monitored, assessed, and proposed in Bulgarian waters of the Black Sea, initiating the procedure for the establishment of SACs. Bulgaria was invited to propose additional marine sites and/or extend the marine area of already proposed sites to encompass a larger proportion of the national range of sandbanks and reefs, and the habitats for small cetaceans and shad. A fourfold overall extension of the marine area included in SCIs was accepted in 2013. Thus, proportions between 20% (*Alosa* spp.) and 60% (reefs) of the national area of the marine features of conservation interest were covered by the Natura 2000 network. However, until 2017 only 2 out of 16 SCIs with marine range were designated as SAC, while management plans were not developed and implemented yet.

Delays in the designation of coastal Natura 2000 sites are linked to terrestrial economic sectors (wind power generation and tourism) that oppose conservation goals. In 2016, the EU Court of Justice ruled against Bulgaria over its failure to protect unique terrestrial habitats and bird species in the Kaliakra site (which is both a SPA and a SCI) at the Black Sea coast due to the cumulative impact by wind turbines and a golf course authorized

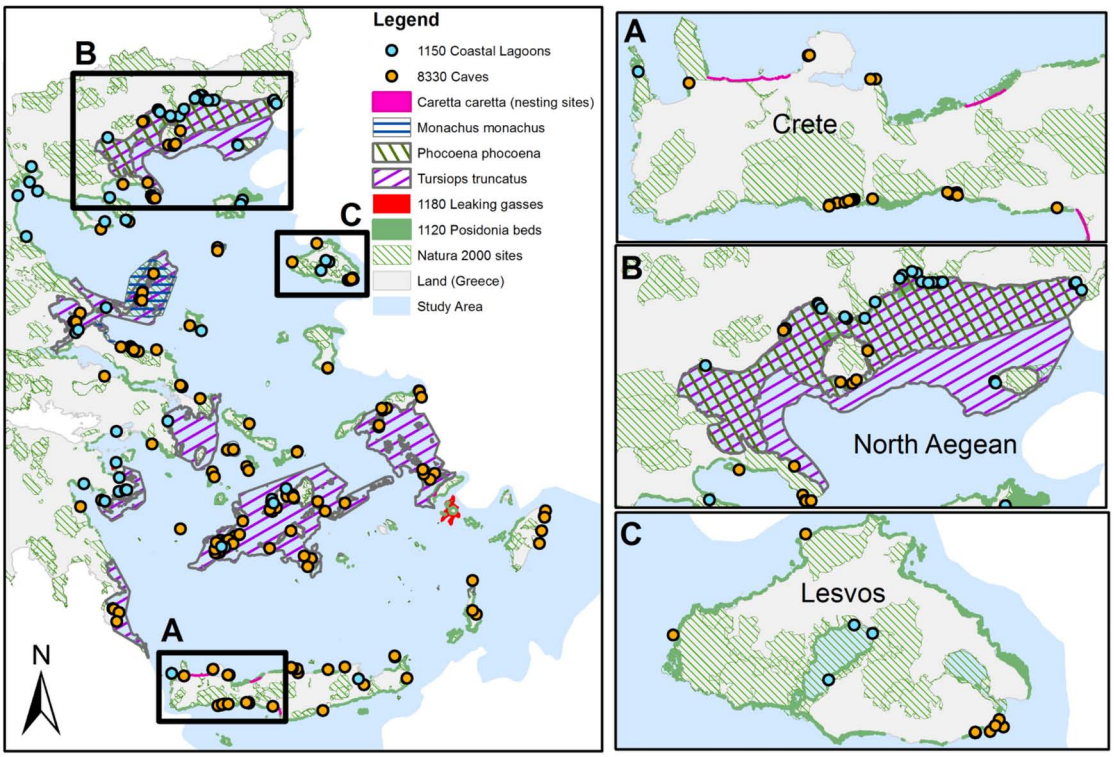


FIGURE 3 | The distribution of Natura 2000 sites in the Aegean Sea and their overlap with the distribution of habitats and species of EU importance (selected areas are highlighted in **A–C**). Distributional data from Sini et al. (2017).

without environmental impact assessment. In response to the EU Court of Justice decision, the SAC "Kaliakra Complex" was finally designated. Meanwhile, local authorities and private sectors opposed a management plan for the site due to construction and farming restrictions.

Besides conflicts about land use, specific conflicts are associated with marine uses, especially fisheries. Illegal dredging for sand clams threatens the sandbanks and poor enforcement of the dredging ban calls for introduction of additional protection measures. Meanwhile, fishers protested against the introduction of restrictions to fishing and harvesting. Natura 2000 implementation in Bulgaria is problematic due to: (1) priority given to private economic interests over conservation, resulting in designation delay; (2) lack of management plans and enforcement of conservation measures; and (3) numerous uses create hard-to-resolve conflicts.

Nationally Designated Marine Protected Areas

United Kingdom

The UK Marine and Coastal Access Act 2009 provided for the creation of MCZs in UK offshore waters and, in May 2018, 50 sites were designated. Five MCZs were designated in Northern Irish waters under the Marine Act (Northern Ireland) (2013) and the Scottish Government has designated 31 Nature Conservation MPAs as allowed by the Marine (Scotland) Act 2010. The Scottish Government used "Priority Marine Features" to identify key marine habitats and species for protection, and manages these areas as part of a wider network including 48 SACs, 45 SPAs, 61 Sites of Special Scientific Interest, 8 MPAs, and 1 demonstration and research MPA (Scottish Government, 2017). It is debatable, however, as to how to measure progress toward an ecologically coherent network can be measured when the term is vaguely understood and defined (Caveen et al., 2015).

For MCZs, the focus is on protecting "features". A recent analysis (MCCIP, 2015) revealed that these features included 105 species designated for protection 783 times throughout the network, although 75 of these were birds, others being 5 species of marine mammals, 11 species of fish, and 14 species of marine invertebrates. In terms of habitats, the same analysis showed that 74 marine habitats were designated 470 times across the network (41 broad seabed habitats, 15 biological communities dominated by specific animals, 10 biological communities dominated by plants or algae, and 8 physiographic, topographic, and oceanographic habitats).

Fifty MCZs is still a long way short of the original recommended number of 127, all UK MCZs are "multi-use" (MCCIP, 2015) and Highly Protected Marine Reserves are lacking (New Scientist, 2017). Multi-use MCZs led to label them as "Paper Parks," giving the appearance of protection with no adequate protection measures (interview with Professor Callum Roberts, The life Scientific, 2018). This resulted in calls for strict management plans although the difficulties in managing MPAs

are down to the complex legal and political framework, MPA management being often site-specific (Rodríguez-Rodríguez et al., 2015): the MSFD requires "Programmes of Measures" that contribute to "coherent and representative networks of MPAs," hence the United Kingdom should work with OSPAR partners as well as crown dependencies and Devolved Administrations to ensure coordination. With climate change, a degree of flexibility must be considered for MPA designation and management along with a strong independent evidence base to inform decisions (Frost et al., 2016, 2017).

The focus on ecosystem services and the economic and cultural valuation of protecting biodiversity in MPAs is increasing (Börger et al., 2014; Jobstvogt et al., 2014), but not yet adequately captured in the marine biodiversity protection designation process in UK waters.

Mediterranean Sea

In 2016, an assessment of the status of MPAs and OECMs highlighted the presence of 1,231 protected sites covering 7.14% of the Mediterranean Sea; these sites were established at national, regional (European or Mediterranean scale), or international level under a variety of designations (MedPAN UNEP/MAP-SPA/RAC, 2017) and are mainly located in near-coastal waters (Gabrié et al., 2012). Typically, in the Mediterranean Sea NTZs are surrounded by one or more partially protected (buffer) areas. However, among the 186 nationally designated MPAs only 76 contain at least one NTZ accounting for only 0.04% of the Mediterranean surface (202 km^2) (Giakoumi et al., 2017). NTZs are only found in nationally designated areas and at least 10 countries have designation(s) that allow their creation. Most NTZs are smaller than 5 km^2 and are less than 10 years old, only 18 MPAs have NTZs covering more than 10 km^2 and only two cover more than 100 km^2. Trends in the creation of MPAs that contain NTZs slowed down since the late 1990s and for the majority of such MPAs, little is known about the management measures and their effectiveness (D'Anna et al., 2016).

Despite the limits described in a recent MedPAN report (MedPAN UNEP/MAP-SPA/RAC, 2017), it is evident that well-managed MPAs are essential tools to preserve and restore biodiversity and increase the resilience of ocean ecosystems (Sala et al., 2012; Sala and Giakoumi, 2018). Most large-scale examples of recovery of disturbed assemblages occur inside MPAs (Lotze et al., 2011) and a recent meta-analysis carried out in the Mediterranean Sea shows that even small, well-enforced MPAs can have significant ecological effects (Giakoumi et al., 2017).

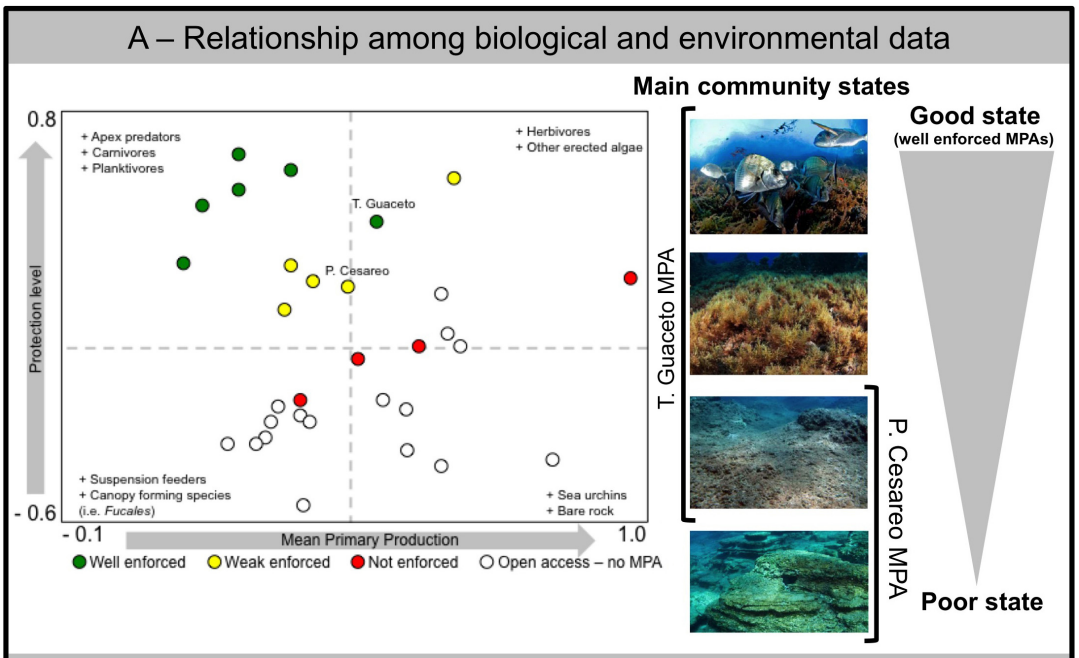
Italy

Torre Guaceto MPA (Apulia region) has been studied from both an ecological and a management point of view (Fraschetti et al., 2005; Guidetti, 2006; Claudet and Guidetti, 2010). It is a SPA of Mediterranean Importance since 2007 and includes one SCI. Located in the southern Adriatic Sea, it covers over 2,227 ha, including 187 ha of NTZ. Before MPA establishment, 10–12 small-size professional fishing boats were active in the area and the impact of recreational fishing and diving was moderate. The Torre Guaceto MPA was established in 1992 with a top-down decision and without social acceptance and political support, but it is now a successful example of adaptive co-management based on the collaboration among managers, scientists, and fishers (Guidetti et al., 2010). In 2005, a sector of the buffer zone was opened to artisanal fishing. Local fishers and the MPA authority developed a protocol to: (i) regulate the fishing effort to avoid overfishing, (ii) minimize impacts on marine habitats, (iii) protect large predators and juvenile fish, and (iv) increase fishers' income. Three years later, fish density and size increased and the catches per unit effort of all species in the buffer zone doubled those outside the MPA (Guidetti et al., 2010). Scientific investigations proved export of fish eggs and larvae to neighboring areas and cascading effects through the food web which restored key interactions among species (Guidetti and Sala, 2007; Di Franco et al., 2015) enhancing the stability of the structural components of protected marine systems, reverting or arresting threat-induced trajectories of change (Fraschetti et al., 2013). Fishers' revenues increased (Di Franco et al., 2016) and their catches received an eco-label for marketing purposes. The Torre Guaceto case highlights how co-management practices, stakeholder compliance, effective enforcement, ecological knowledge of the area, long-term monitoring programs, and incentives for users are critical for effective MPA management. Moreover, assessment and dissemination of the positive effects of MPAs on local people are also crucial to enhance social awareness (**Figure 4**).

The success of multipurpose MPAs, nevertheless, is hard to reach (**Figure 4**). In the same region, the Porto Cesareo MPA, established in 1997 on the Ionian side of Apulia, covers a surface of 16,654 ha, with a NTZ of 173 ha. Three SCIs of 7,169 ha are included in the MPA that is also a SPA of Mediterranean Importance since 2011. A recent analysis (Guarnieri et al., 2016) showed that this MPA is a paradigmatic example of critical socio-ecological interactions, where several human uses and conservation measures collide: despite the presence of the MPA, human disturbance affects all areas and ecological features in this stretch of coast. Pressures that originate outside MPA boundaries such as pollution, sediment load, climate change add to inside pressures. In addition, a medium level of enforcement in the MPA can be considered a critical driver for limiting ecological effects on biological components such as fish biomass (Giakoumi et al., 2017). Despite the ecological knowledge of the area, the long-term monitoring programs and the presence of co-management practices between the MPA authority, scientists, and fishers, a substantial lack of effective enforcement, the presence of hot spots of human uses, and poor stakeholder's compliance hampered an effective protection of the area (**Figure 4**).

Israel

Although not an EU country, Israel is committed to many international agreements (like the Barcelona Convention and specifically the Program for the Assessment and Control of Marine Pollution in the Mediterranean), and research institutions are carrying out monitoring conforming to the



B – MPA context background

List of threats and relative ranking impact for both MPAs		T. Guaceto	P. Cesareo
Extractive threats	Recreational fishing: hook and line	No Impact	Medium impact
	Recreational fishing: spearfishing	No Impact	Medium impact
	Artisanal fishing	Low impact	High Impact
	Illegal fishing	No Impact	High Impact
Non extractive threats	Bathing, trampling	Low impact	High Impact
	Private and commercial boating	No Impact	Medium impact
	Scuba diving	No Impact	Low impact
Other threats	Sedimentation	High Impact	Medium impact
	Invasive Species	High Impact	Low impact
	Coastal anthropization	No Impact	High Impact
	Chemical pollution (e.g. from ships, ports, spills)	Low impact	Medium impact
	Organic enrichment (e.g. from agriculture, outfall)	Low impact	Medium impact
General features of the MPA	Total surface (ha)	2227	16654
	No-take surface (ha)	187	173
	% No-take of the total surface	8.40	1.04
	Year established	1991	1997
	Level of enforcement	High	Low/Medium
	Level of compliance	High	Low

FIGURE 4 | (A) Synthesis of the relationships between the structure of Mediterranean rocky reef ecosystems across a gradient of protection, with a focus on the Torre Guaceto and Porto Cesareo MPAs. **(B)** Information about the context for the two MPAs is reported. Data were extracted from Sala et al. (2012) and Giakoumi et al. (2017).

European MSFD. Accordingly, in the past few years the existing environmental monitoring program was expanded along the Mediterranean coast as well as the extent of MPAs, along with a better enforcement of protection. A recent governmental initiative, motivated by an "aggressive" push by the Israel Society for Nature Protection NGO, updates and improved the implementation of fishing regulations aimed to reduce fishing pressure.

Between the 1960s and the early 2000s, the Israel Nature and Parks Authority (INPA) operating under the Ministry of Environmental Protection declared six tiny coastal reserves (total area of 10.4 km^2) along the 190 km of the Israeli Mediterranean coast. All but one - the Rosh Hanikra Islands protected area, located close to the Israeli–Lebanese border and centered around several tiny rocky islets - had none or minimal protection, and were mostly paper parks. In 2008, another small coastal

TABLE 2 | Main institutional and ecological features in two small MPAs (now both marine reserves) in northern Israel.

Features	Rosh Hanikra	Shikmona
Year established	1968	2008
Year effective management started	1995	2016
Management plan	Yes	Yes
Size	Few km^2	Few km^2
Main critical habitat	Rocky reef	Rocky reef
Fishing effort assessment	None	None
Ecological surveys	A few between 2010 and 2014	A few between 2011 and 2017
Regular, funded pilot monitoring	Twice per year since 2015	Twice per year since 2015
Public knowledge of the MPA	High	Low
Recreational diving activity	High	Low
Fish abundance	High	Low
Commercial fish abundance	High	Low
Commercial fish size	High	Low
Proportion of invasive alien species	Very high	Very high

reserve on the Haifa coast (Shikmona Reserve) was added to the list of MPAs/reserves, with no real protection or monitoring. In 2010, INPA launched a plan to expand the coverage of protected territorial waters up to 20% with a network of large and small MPAs that will cover most marine habitat types of the region (Yahel, 2010). As part of this effort, in 2016 the small Rosh Hanikra protected area was officially approved as marine reserve, and was enlarged to the edge of the territorial waters, even though not yet officially declared (**Table 2**). More effective protection started only in 1995, and the results of this protection are now visible. The intermittent ecological surveys conducted inside and outside the reserve between 2010 and 2014 showed that, on average, fish abundance inside the reserve was 40% higher than outside (Rilov, 2016; Rilov et al., 2017). Commercial native species (mostly sparids and groupers) were much more abundant (from fourfold up to two orders of magnitude) in shallow waters inside the reserve compared to reefs 1 km to the south, outside the reserve. There were also more invasive alien fish – mainly rabbitfish, *Siganus* spp. – inside the reserve. By contrast, the small Shikmona marine reserve declared in 2008 in Haifa and without enforcement until 2016 has poor ecological state with low overall abundance of fish (in particular low abundance of predators) and high proportion of invasive alien species (Rilov, 2016; Rilov et al., 2017). INPA has carried out since 2015 a biannual pilot monitoring program in four small coastal marine reserves, including Rosh Hanikra and Shikmona.

Black Sea: Bulgaria

Marine conservation under national law in the Bulgarian Black Sea is relatively underdeveloped compared to the more advanced terrestrial nature conservation. Only two tiny MPAs are designated under the Protected Areas Act: the marine part of Strict Nature Reserve "Kaliakra" and the fully marine Habitat/Species Management Area "Sand bank Cocetrice" with a total MPA of 4.76 km^2. Designated in 1941 and 2001, respectively, both areas lack a management plan, hence protection of species and habitats from anthropogenic activities is absent. With the obligations arising from EU accession, the proposed Natura 2000 network of protected sites, and further conservation measures implemented under MSFD, have the potential to ensure protection of marine biodiversity in the Bulgarian Black Sea.

Marine Strategy Framework Directive

As for Natura 2000 sites and national MPAs, the Member States reporting for the MSFD (initial assessment: reports are hosted in the EEA's Central Repository) and more specifically on the top priority pressures, acting on all biodiversity elements from species to ecosystem level, shows an analogous spatial sub-regional variance in priorities (**Figure 5**). Nutrient input is highly ranked in the Baltic Sea and less in the Black Sea and the Adriatic. Non-indigenous species are of major concern in several areas of the Mediterranean and North Sea. The differences in prioritizing pressures, and the complexity of disaggregating pressures from human activities, indicate that different measures are required to tackle single pressures across the MSFD subregions. The requirement of numerous management measures challenges their coherent and coordinated implementation. For instance, although nutrient input is of major concern in both the Baltic and the Adriatic Seas, different human activities were indicated as the main causes of pressure leading to the necessity of taking a series of different measures to deal with each pressure.

The determination of GES across MSFD descriptors and criteria (EC, 2017) becomes very challenging, because it must reflect an impacted, but not adversely altered state of the environment. In practice GES, for most MSFD descriptors, corresponds to a gradient of pressure from undisturbed to heavily impacted areas. MPAs provide reference points for GES determination for MSFD descriptors, such as biological diversity, population of commercial species, food webs, sea floor integrity, and noise. GES can be assessed by comparing MPAs with gradually impacted areas. MPAs are a unique tool for consistent and coherent determination of GES and should be further developed. For instance, MPA planning and designation, ensuring connectivity, could provide reference areas for GES determination of trophic guilds, and direct comparison of trophic guild responses to multiple pressures in heavily impacted areas.

The target-based perspective confirms the complexity and variety in implementation and decision-making processes of the MSFD across EU, indicating variant numbers of targets set from the Member States to assess GES. Target setting is correlated with the main pressures acting in each MSFD region or sub-region and, at different scale, with the "maturity" and knowledge of each MSFD descriptor. The toolbox to assess and tackle nutrients input is richer compared to non-indigenous species in the Baltic Sea due to differences in priority/intensity of each pressure in the area and the existing frameworks (e.g., WFD, HELCOM) already dealing with these pressures. Spatial or operational discrepancies in the measures, including protected areas, should be seen through the spatial diversity of drivers–pressures–impacts to the marine environment and the different priorities. Regional collaboration and coordination across the

EU policies may increase the capacity of each Member State to spatially extend and improve the efficiency of the measures.

Baltic Sea

As EU Members States, all Baltic Sea countries (except Russia) report on the status of the marine environment according to the MSFD. To enable regional coherence in assessment results, HELCOM initiated the process known as State of the Baltic Sea Report – Holistic Assessment. The first version of the report is based on HELCOM indicators divided in modules covering the main pressures and structural elements of the marine environment. The indicators assess the status of selected elements of biodiversity and human-induced pressures on the Baltic Sea against regionally agreed threshold values, based on current knowledge and available data. In addition, integrated assessments for biodiversity, eutrophication, and contamination status are made, based on the core indicators. The structure of the assessment follows the logics of GES. Some elements of biodiversity also targeted by MPA network are assessed (e.g., benthic and pelagic habitats, Red List species).

Denmark

In 2016, the Danish government designated nine additional protected areas in Kattegat (**Figure 2**) to fulfil GES descriptors "biodiversity" and "sea floor integrity," so as to complement the existing Natura 2000 network adding deeper soft bottoms with associated communities as a main conservation target. The selected areas were a compromise between fishery interests and the value of benthic soft bottom habitats. In those areas, extraction and dumping of marine sediments are prohibited and the final obligatory Hearing procedure for the ban on fishery with bottom contacting is in process. Monitoring is established and enforced as described in the section Natura 2000 Sites Denmark. New MSFD MPAs on soft bottom habitats are planned in the Danish North Sea, Skagerrak, and Baltic Sea in the coming years.

Israel

Being part of the Organisation for Economic Cooperation and Development, Israel is now increasing efforts to comply with the guidelines and targets of the MSFD. Initially, monitoring included chemical and organic pollution along the coast. Biological sampling of soft bottoms started in 2005, and monitoring of intertidal rocky reefs initiated in 2009. In 2014, soft bottom macrofauna monitoring was initiated, as well as pilot surveys of subtidal rocky reefs. Hydrographic monitoring started in 2012 to follow the impacts of climate change. This monitoring program will be expanded to all marine habitats, including the deep sea and subtidal reefs.

Beyond monitoring, point-source pollution has been reduced with some success over the past several decades (Herut, 2016), and protection increased through MPAs and better fishing regulations. Some of the MSFD goals might be partially achieved through the reduction of local stressors but, being a hotspot for bioinvasions and ocean warming (with the establishment of

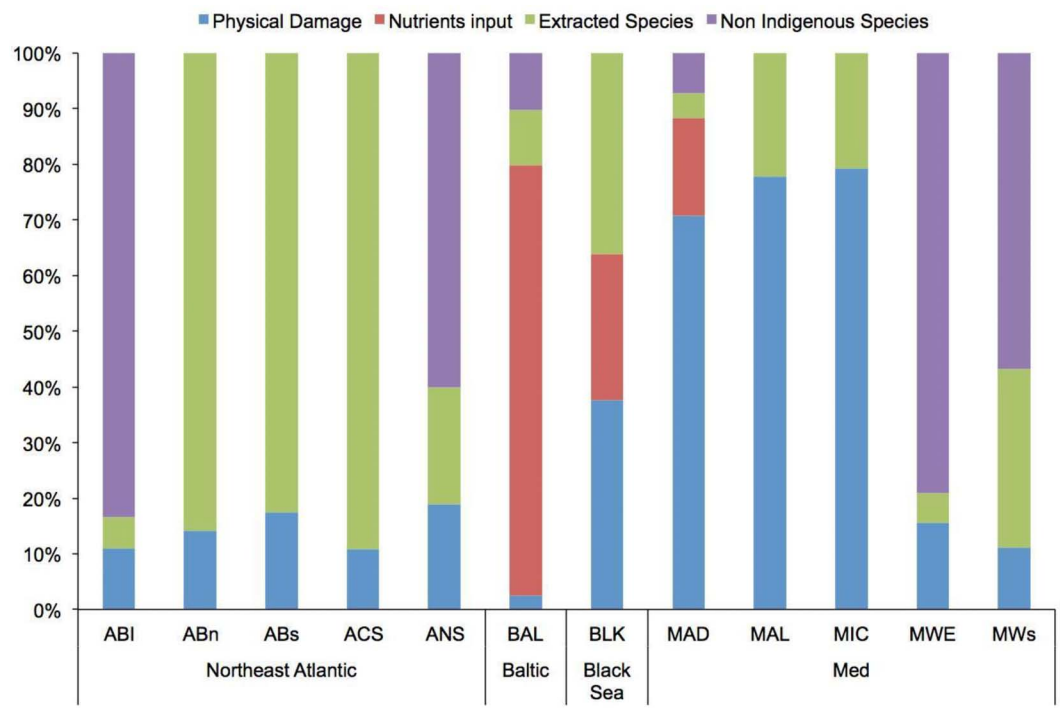


FIGURE 5 | Top priority pressures reported by the EU Member States in the initial assessment of their marine environment at the first cycle of the MSFD. Results were aggregated to regional or sub-regional level. Northeast Atlantic includes the subregions of Celtic Sea (ACS), North Sea (ANS), North and South Bay of Biscay and Iberian Coast (ABn, ABs, and ABI). The Mediterranean Sea includes the subregions of Adriatic (MAD), Aegean and Levantine Sea (MAL), Ionian and Central Mediterranean (MIC), and Western Mediterranean (MWE and MWs).

thermophilic Indo-Pacific invaders), adaptation measures must be considered, as these two global stressors will not disappear in the near future.

Maritime Spatial Planning Framework Directive

Baltic Sea

A Working Group on MSP was established in 2010 by the HELCOM convention and the Vision and Strategies Around the Baltic Sea Committee on Spatial Planning and Development of the Baltic Sea Region. The Working Group was established to ensure cooperation among Baltic countries for coherent regional MSP in the area. The Regional Baltic MSP Roadmap (2013–2020) was created to fulfil the goal of drawing up and applying maritime spatial plans throughout the Baltic Sea region by 2020, which are coherent across borders and apply the ecosystem approach.

The HELCOM-VASAB Baltic Sea Broad–scale MSP Principles were adopted at the end of 2010, fulfilling the commitment of the HELCOM Baltic Sea Action Plan. Currently the MSP is at different development stages in different countries. MPAs are important for achieving the environmental and sustainability goals of MSP and other legal instruments and directives in all Baltic Sea countries. Guidelines for the implementation of EBA in MSP were adopted in 2016 stating, among others, the importance to achieve the goals set by Natura 2000 (with SPAs and SACs designation) and HELCOM MPA networks through the MSP process.

Portugal

Portugal has the second largest EEZ in the EU (1,727,408 km^2), and, in line with EU policy and guidelines, it has just completed its legal framework for MSP. In 2006, the relevance of MSP as one of the three pillars of its National Ocean Strategy has been recognized by the Portuguese government and in late 2008 the development of a national marine spatial plan was established (Calado et al., 2010; Santos et al., 2016). For the continental part, a maritime spatial plan was initiated in 2009 and set to approval in 2010, with the claim to extend the national continental shelf as one of its driving forces. The idea was to characterize, map, and categorize the existing and potential future human uses, while considerable attention was paid toward ensuring the coherence between land and marine planning strategies. To overcome conflicts resulting from the many overlapping uses and to assure sustainable development to all sectors, a conflict analysis was included. The applied zoning scheme represented an exercise of conflict solving and proved to be a powerful tool to promote discussion and participation among stakeholders.

The successful implementation of Portuguese MSP largely relies on its ability to provide efficient management along with financial and legal mechanisms to achieve the integration of all strategies and spaces under the Portuguese maritime jurisdiction (Calado and Bentz, 2013). Since the same government entity has responsibility over the implementation of both MSP and the MSFD (Thiel, 2013), it is expected that coordination and communication between processes and sustainable maritime uses will be promoted. However, a recent analysis on the main environmental topics addressed by the Portuguese MSP shows that environmental references represent only a small account of it and even though there is mention of environmental "monitoring" and "evaluation," "environmental protection," "sustainability," and "good (environmental) status" the EBA is never referred to (Santos et al., 2015). The Portuguese framework for MSP may lead to favoring new uses over existing ones and defines ambiguous criteria for the selection of alternatives that are mostly financial in nature (Ferreira et al., 2015).

Mediterranean Sea

Acknowledging the challenge of coordination between Member States and neighboring countries, the EC has launched two communication strategies related to the Eastern (the EUSAIR, EC, 2014c) and the Western Mediterranean [SWD COM (2017) 183 final], addressing environmental conservation as a key target that can be achieved through cooperation, respectively, through Pillar 3 on Environmental Quality [EUSAIR, Action Plan, SWD(2014)190, EC, 2014d], and priority for biodiversity and conservation under goal 3 in the SWD COM (2017) (183 final). MSP is appointed to support sustainable blue economy while responding to transboundary governance settings. Moreover, under the Barcelona Convention on the protection of the sea and coastal zone, very recently UNEP launched a communication on the need for MSP in the Mediterranean high seas (United Nations Environment Programme [UNEP], 2017).

To push MSP implementation through collaboration between countries on transboundary concerns, the EU has supported pilot initiatives through targeted projects to build a dialog between countries. The "ADRIPLAN" project (2013–2015) tested an MSP process in the Adriatic and Ionian Region (Barbanti et al., 2015). The "ΘΑΛ-ΧΩΡ – Cross-border Cooperation for MSP Development" (THAL-CHOR) strategic project aimed at the development of a MSP methodology and its pilot implementation in selected areas of Cyprus and Greece (source: www.mspcygr.info). The "MARISCA" project (2015–2017) aimed to apply systematic conservation planning principles in the context of MSP in the Aegean Sea[1]. The "SUPREME" ("Supporting MSP in the Eastern Mediterranean") and "SIMWESTMED" ("Supporting Implementation of MSP in the Western Mediterranean") projects were launched in 2017 to elaborate concrete solutions for transboundary concerns while supporting the national implementation of MSP, with both projects involving Member States' responsible authorities. However, several uncertainties were depicted when implementing the cumulative impacts assessment in the Adriatic and Ionian regions, due specifically to the geographical scope of MSP and the way the countries will implement it (Gissi et al., 2017).

As already stressed, few Mediterranean Member States have gone through national MSP processes, beside the fact that the MSPFD has been transposed in all national legislations. For example, having a long history on legislative and planning initiatives related to the marine domain (Deidun et al., 2011), Malta approved the "Strategic Plan for the Environment and Development" in 2015, which includes high level goals

[1]http://www.marisca.eu/index.php/en/

and provides a framework policy for the use of land and sea, but without a zoning scheme at sea (source: EU MSP platform, https://www.msp-platform.eu/ accessed 29/8/2018). Croatia and Slovenia do not have overall binding MSP plans for their marine areas, but other planning tools have marine implications. In Croatia, the Zadar county "integrated sea use and management" focuses on marine aquaculture, with links to MSP. In Slovenia, the "National Spatial Plan for the integrated spatial development" of the port of Koper includes consideration on coastal tourism, nature protection, and military areas (source: EU MSP platform). The Israeli marine spatial plan (Technion Israel Marine Plan) was led by an initiative of academia (Technion – Israel Institute of Technology) (Portman, 2015) for the entire EEZ. The plan appoints the goal to "protect, conserve, and rehabilitate the marine environment." The spatial structure identifies five functional marine areas across a gradient between protection-oriented and development-oriented scopes, according to a compatibility analysis of uses and conservation features. However, the effort did not combine with the ongoing official MSP process, called "Israel's Marine Spatial Policy," implemented by the Israel government (Portman, 2015). In January 2017, a draft of a "marine areas" law was submitted to the Israeli parliament, to define the marine areas of Israel, including the EEZ, and the rights, obligations and State authority in these areas, as well as to protect the marine environment. The proposal calls for increased protection of marine and coastal environments to ensure ecosystem functioning and biodiversity protection.

Black Sea: Bulgaria

So far, in Bulgaria MSP has been sector-based. Some measures covering MSP and ICZM are in the Development Strategies of the coastal administrative districts (Burgas, Varna, and Dobrich), in the National Strategic Plan for Aquaculture (2014–2020), and in the National Regional Development Strategy (2012–2022). The legal regimes of the maritime space of Bulgaria are set up in the Maritime Space Inland Waterways and Ports Act (2000). Legal transposition of the MSPFD into this Act has not been officially adopted yet. The amendments to the Act specify that MPAs shall be integrated in the national marine spatial plan. In the framework of the Cross-Border Maritime Spatial Plan for the Black Sea – a strategic framework for MSP in Romania, Bulgaria was developed[2]. This strategic framework represents an important starting point for MSP in both countries, to be realized within the implementation of the MSPFD.

Fisheries Management Tools

Baltic Sea

A 360 km^2 NTZ was established in 2006 around Gotska Sandön (Sweden, central Baltic Sea) as an experimental management measure to rebuild depleted flatfish stocks (Florin et al., 2013). A comprehensive monitoring program that included an estimation of larval export and consumption by large marine predators showed positive effects of the NTZ on two flatfish populations. Both turbot *Scophthalmus maximus* and flounder *Platichthys flesus* benefited from the total fishery closure, showing higher density, lower mortality rate, and higher mean age in the NTZ compared to adjacent fished grounds and to the pre-ban period. Furthermore, the model suggested net larval export from both species. The only downside was a lower growth rate of both species inside the NTZ, possibly due to density-dependent factors (Florin et al., 2013).

More recently, in conformity with the provisions of the CFP to implement EBFM in European waters (EC, 2013), a multiannual multispecies plan for the management of cod, herring, and sprat stocks in the Baltic Sea has been adopted, aiming at maintaining the harvested populations at levels that can produce MSY and at reducing discards (EC, 2016). Ramirez-Monsalve et al. (2016) highlighted the challenges and gaps identified in the initial phase of the plan as well as its outriding role for successive plans.

North Sea

The "plaice box" is a well-known example of partially protected area in the North Sea, established in 1989 over 38,000 km^2 encompassing Dutch, German, and Danish waters (EC, 1988) with the purpose of reducing the by-catch of young plaice, *Pleuronectes platessa* and increasing its SSB and overall yields, as a result of expected increased recruitment to the adult stock (Pastoors et al., 2000; Beare et al., 2010). Fishing vessels with >300 HP were banned initially for 6 months/year, then year-round, expecting a 25–35% increase in plaice SSB (Grift et al., 2004). The situation after the ban was different from expectations: the undersized plaice discards decreased, the SSB did not increase and the North Sea landings of plaice decreased from 169,818 t in 1989 to 48,875 t in 2008 (Beare et al., 2010). Scientists, fishers, and environmental NGOs had different explanations of what was going on (**Figure 6**): the final result was probably due to interactions between fishing mortality, density-dependent growth reduction, climate change, and other environmental drivers (Pastoors et al., 2000; Beare et al., 2010). A reliable assessment of plaice box effectiveness is impossible due to box design and to absence of control areas. Several human (poor design and the use of poorly selective gear) and environmental factors concurred in the failure of the plaice box as a fishery management tool.

Similarly to the Baltic Sea, a multiannual multispecies plan has recently been adopted, aimed at the management of the main demersal fish (including plaice) and crustacean stocks in the North Sea (EC, 2018) in place of a previous multiannual plan for plaice and sole (EC, 2007).

Mediterranean Sea

Several types of fully or partially protected areas specifically aimed at the spatial management of artisanal and industrial fisheries exist in the Mediterranean, but only a small number of such managed areas has been monitored (Pipitone et al., 2014).

Southern Tyrrhenian Sea

No-trawl areas exist as fisheries recovery and conservation tools in the Mediterranean (e.g., EC Regulation No. 1967/2006 for sensitive habitats, coastal areas, and deep bottoms). They represent a form of partial protection, since artisanal and recreational fishing are generally permitted. The trawl ban imposed in 1990 in the Gulf of Castellammare (NW Sicily)

[2]http://marsplan.ro/en/

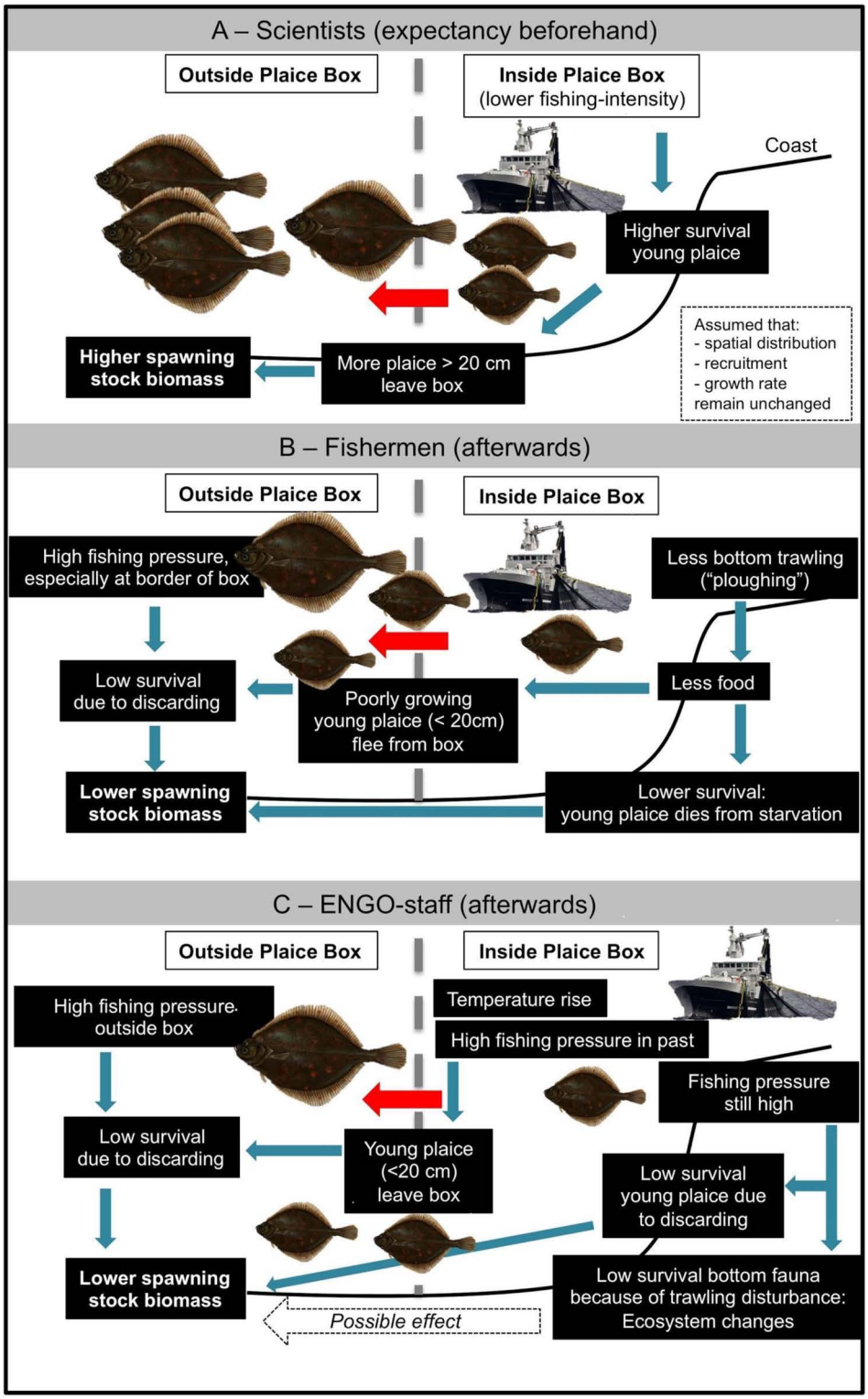


FIGURE 6 | Different perceptions about the plaice box. **(A)** The reasoning and communication by scientists at the time the box was implemented. **(B,C)** The functioning of the plaice box according to fishermen and environmental NGOs, respectively (modified from Beare et al., 2010).

with the purpose of recovering resources from overfishing and of reducing conflicts between artisanal and trawl fisheries is a case of successful trawl ban. The ban covers 200 km^2 over the shelf and part of the upper slope. The demersal fish assemblage in the 10–200 m depth range increased eight times after the first 4 years of trawl exclusion, with a dramatic recovery of commercially important species like the mesopredator *Mullus barbatus* and larger predators like *Lophius budegassa* and *Merluccius merluccius* (Pipitone et al., 2000). Trawl survey data suggested that spillover occurred from the untrawled gulf to adjacent trawled grounds (Pipitone et al., 2014). The effects of protection extended beyond fish biomass recovery and affected the composition and structure of the fish assemblage, with higher specific richness and lower evenness, due to high abundance of a few dominant species, in the Gulf of Castellammare compared to trawled areas. Socio-economic analysis, however, revealed that spatial patterns and costs issues affected fishers' response to the trawl ban. While artisanal fishers based inside the protected gulf experienced an increase in catches and incomes, those based in a nearby harbor just outside the gulf suffered from the displacement of trawling effort close to their traditional fishing grounds due to the ban. They did not enjoy the benefits of the trawl ban due to costs to reach the no-trawl area from their harbor (Whitmarsh et al., 2003). Also, some years after the ban onset, trawlers started to poach inside the no-trawl area since the heavy fines that they risked were an acceptable trade-off against the valuable catches they would get inside the protected gulf (Stefanoni et al., 2008).

Aegean Sea

In the Aegean Sea, the legal framework on spatio-temporal restrictions of fishing activities is complex, mainly as conventional fishery management measures, but also as a tool to resolve conflicts between users. Petza et al. (2017) mapped all FRAs in Greek territorial and international waters of the Aegean Sea. They cover the national fisheries, environmental, archeological, and maritime legislation, along with EU and international fisheries legislation, concerning spatio-temporal restrictions of fishing activities of all types. The legal framework of 116 legal acts established 521 FRAs; 38% of the Aegean Sea is covered by permanent and 27.6% by seasonal FRAs. Towed, mobile, and static gears are permanently prohibited in 38%, 3.2%, and 2.4% of the study area.

Among the 521 FRAs in the study area (**Figure 7**), some have a potentially large contribution to biodiversity conservation, especially where fisheries are permanently restricted to protect entire ecosystems for stock recruitment, specific habitats (e.g., *P. oceanica* beds), or species at risk. Some are in force all year round for many years, based on difficult-to-reverse mechanisms (i.e., EU regulations or national laws).

Israel

Simultaneously to the efforts made to expand MPAs in Israel, formerly inefficient fishing regulations were modified in 2016 after heated debates that included forums with fishers. The new regulations include: (1) increase of the minimal depth for trawling from 15 to 30–40 m; (2) trawling ban during the main fish recruitment and sea turtle nesting season (June–August); (3) total fishing ban during the reproductive season of many target fish species (April–June); and (4) doubling of mesh size. Enforcement responsibility will pass from the Ministry of Agriculture fishery authority to INPA. Funding for boats and personnel to implement this are nearly secured at the time of writing. Regardless of promising efforts, the lingering geopolitical conflicts with neighboring countries are hindering marine conservation efforts in the area.

DISCUSSION

We have provided an up-to-date review of the conservation/management instruments used across ECS. Despite the differences in their development and application across countries, these tools can represent a valuable framework to regulate human activities and to protect marine biodiversity, with the potential to expand their application also in non-EU countries.

Synergies among these tools across countries and regions represent an opportunity to better manage human pressures in protected areas. In this respect, the success is still limited, but the European MPA system is a step toward GES achievement: in several case studies (e.g., Baltic Sea, Denmark, Belgium), the MSFD individuates nationally designated MPAs and Natura 2000 sites as reference areas and critical instruments to achieve the GES at the sub-regional scale. Local footprints into the marine environment, such as fishing and physical damage, can be efficiently mitigated with Natura 2000/MPA networks when properly designed and managed (Zupan et al., 2018). The benefit that MPAs bring into MSFD measures is their capacity to deal with cumulative pressures, reducing the intrinsic complexity in policy implementation. Fully protected MPAs avoid the impact of bottom-trawling on sea bed integrity, species extraction, and habitat degradation (MSFD descriptors 6, 3, and 1, respectively). However, transboundary pressures, such as nutrients input, noise, and marine litter (MSFD descriptors 5, 11, and 10), require measures on a spatial scale that goes beyond the capacity of MPAs. MSFD envisages the expansion of European MPA networks as an important tool for GES achievement (EC, 2015) (see the Israel case study). Also, MPAs are important for achieving the environmental and sustainability goals of MSP and other legal instruments and Directives. The coordination across legislative instruments (e.g., nationally designated MPAs including Natura 2000 sites) and between competent authorities rather than creating new measures will be central to implement the European environmental Directives. Finally, the EBFM, although complex, difficult to operationalize and with limited achievements, is trying to minimize the impacts of fishing activities on marine ecosystems and to mitigate unwanted interactions between fisheries and marine ecosystems by using fishery reserves, Fishery Restricted Areas (FRAs), NTZs, MPAs, and other spatial and temporal closures.

Although all EU countries are committed to fulfil EU Directives and other binding international legislation, the compliance with the common legislation on conservation

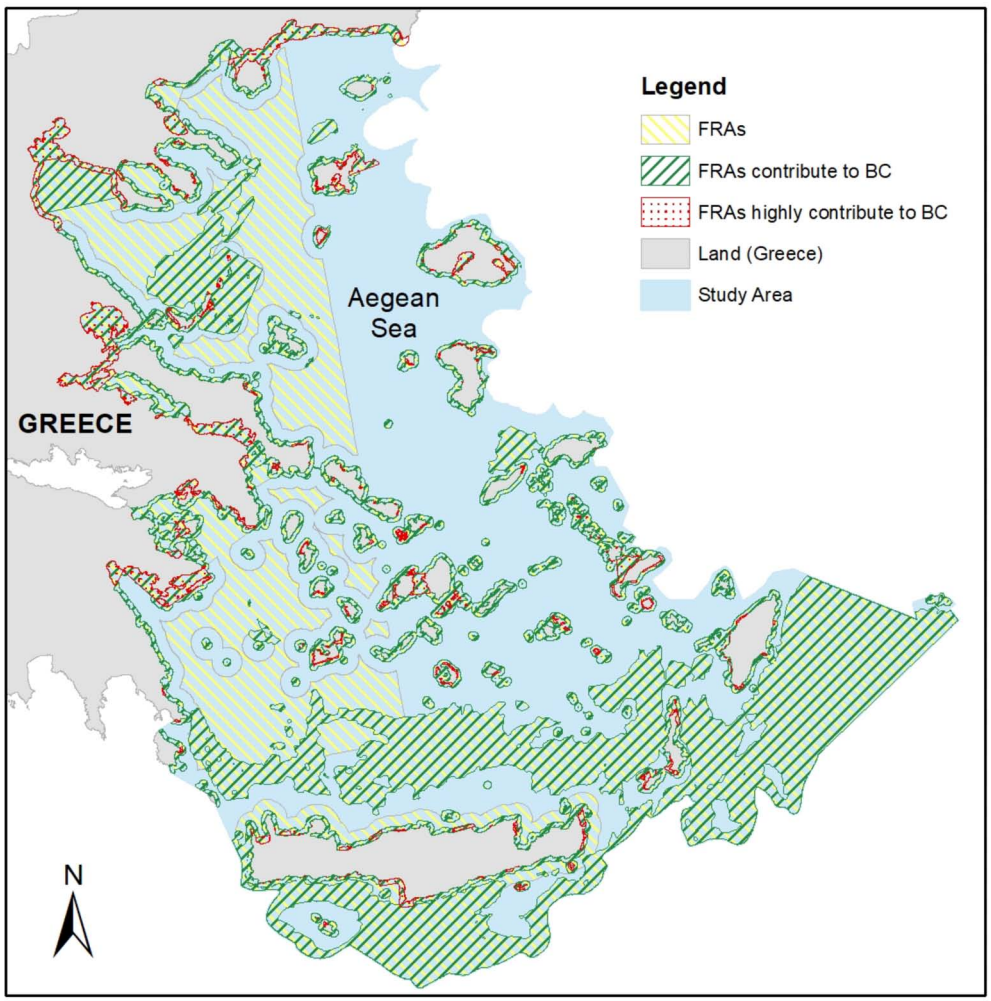


FIGURE 7 | Fisheries restricted areas (FRAs) in the Aegean Sea (Greek territorial and international waters). BC, biodiversity conservation.

and in its degree of implementation success is remarkably heterogeneous across countries. The Natura 2000 network is generally perceived as a dynamic conservation experiment, of great ecological, economic, social, and political significance. It can be considered a unified large-scale network based on common principles with an attempt of integrating resources, scientific knowledge gain, and improvement of public perception toward conservation (Kati et al., 2015). However, most case studies show clear gaps in the application and a gradient of success from northern to southern ECS. Denmark shows a concrete attempt toward building a coherent network of protected sites. Also the United Kingdom documents very promising results even though conflicts with fisheries have to be solved. Portugal made an important effort to establish a network of offshore MPAs in ABNJ. Conversely, in the Mediterranean and in the Black Seas, critical issues in terms of representativeness, management plans, monitoring of the conservation status, and enforcement in Natura 2000 sites have been documented and unresolved conflicts have been mentioned especially with the fishery sector.

Despite important limitations also for national designated MPAs, particularly encouraging case studies have been presented especially in the Mediterranean Sea, highlighting their relevant ecological effects, especially when enforcement is adequate (MedPAN UNEP/MAP-SPA/RAC, 2017). Marine conservation is still underdeveloped in the Black Sea where the lack of management plans substantially prevents the protection of species and habitats from human activities.

The MSFD, based on the pillars *biodiversity* and *ecosystem functioning*, is widening the scopes of the HD by linking structures (such as seabed integrity and biodiversity) to function (ecosystem functioning). This is a revolution that focuses on biodiversity and requires the assessment of processes affecting ecological systems (Boero and Bonsdorff, 2007). However, the target-based perspective highlights the complexity and variety in implementation and decision-making processes of the MSFD across EU, with northern countries very advanced in the

application of this tool. As regards the MSP process, in northern Europe, the Regional Baltic MSP Roadmap was created to fulfil the goal of drawing up and applying maritime spatial plans throughout the region by 2020, coherent across borders and inspired to an ecosystem approach. Portugal has just completed its legal framework for MSP. On the contrary, in the Mediterranean Sea, few Member States (e.g., Malta) have gone through national MSP processes. In the Black Sea, a region which is far behind other areas in terms of application of purely conservation tools, the Cross-Border Maritime Spatial Plan represents an important starting point for MSP in Romania and Bulgaria, to be realized within the implementation of the MSPFD. In the Mediterranean Sea, it is interesting to see the Israel efforts to comply with the guidelines and targets of the MSFD and to implement a MSP process to increase the protection of marine and coastal environments.

As regards fisheries management tools, the multiannual multispecies plans for the management of fish and crustacean stocks in the Baltic and North Seas represent an excellent opportunity to favor the recovery of exploited populations. Also in the Mediterranean Sea, several initiatives have been implemented showing the potential of fishery restrictions. However, lack of monitoring and enforcement still remain major issues across countries.

Despite recent progresses, most case studies stress the lack of representativeness, management plans, monitoring of the conservation status, and proper enforcement. Given that, four main challenges remain to be addressed to fully achieve environmental policy goals:

Lack of Shared Vision Limits Transboundary Collaboration

European countries markedly differ in the degree of development of the MSFD, the operability and ecological relevance of the biodiversity indicators, and lack of consistent and harmonized approaches for the description and assessment of marine biological diversity. The ambiguity in the use of key terms and concepts such as GES monitoring, the inconsistent adoption of criteria and indicators, and the low level of coherence with the relevant policies and the Regional Sea Conventions' assessments reduce the efficiency in determining and comparing GES assessments. The differences across Member States in pressures prioritization, the ambition in setting targets and threshold values, and their capacity to cover not yet well-developed descriptors (e.g., non-indigenous species, noise, litter) jeopardize implementation.

Some recently developed operational criteria and standards on MPAs success are already available (Edgar et al., 2014; Gallacher et al., 2016) but an EU-level system to evaluate the effectiveness of European MPAs and MPA networks for the attainment of GES is not yet developed. Considering the centralized role of the Regional Sea Conventions in the MSFD implementation, differences in the designation of MPAs are expected to be magnified, due to regional differences in funding, organization, and proportion of EU Member States among the contracting parties.

Maritime Spatial Planning Framework Directive implementation differs across Member States (Gissi and de Vivero, 2016), with Netherlands and Sweden sharing advanced MSP processes and Mediterranean and Black Sea Member States without any MSP in place. This consideration is particularly serious considering the increasing uses of the marine coastal environment as requested by Blue Growth.

A lack of shared management and monitoring schemes is frequently reported for most of Natura 2000 sites and for most MPAs. The percentage of sites lacking management plans and conservation measures varies among Member States with many paper parks without any benefit for marine conservation, reflecting different degrees of implementation of the European legislation.

The differences in managing MSP among EU Member States and adjacent countries increase challenges in setting transboundary collaborations and potentially undermine the feasibility of regional ecologically coherent MPA networks. Other critical differences further complicate the matter. For instance, while partially protected areas (e.g., fishing boxes) are a common fisheries management tool in north-eastern Atlantic waters, NTZs are more frequent as part of the MPA zonation system in the warmer Mediterranean Sea (Abdulla et al., 2008; Perez-Ruzafa et al., 2017). Large-scale fishing effort limitations are applied in northern Europe to manage few- or single-species stocks in offshore, soft-bottom temperate areas, as opposed to small-scale protection of highly diverse and complex coastal rocky-bottom Mediterranean areas (Perez-Ruzafa et al., 2017). Denmark, on the other hand, follows both tracks adopting restriction for fishery in Natura 2000 sites hosting reefs and bubbling reefs habitats.

Lack of Systematic Planning

A lack of systematic procedures for the selection of protected marine sites is common. Conservation planning (Pressey et al., 2007) relies on spatially explicit data that are lacking in many areas of conservation concern and, when present, exhibit high heterogeneity in collection methods (Levin et al., 2014). This includes also socio-economic data, essential to evaluate the social component of the area to protect, and to prioritize possible areas for protection, but the availability of such data is generally very limited (Pascual et al., 2016). Systematic conservation planning can improve cost-effectiveness of conservation, and also equality between countries (Gissi et al., 2018), as it considers not only the distribution of biodiversity but also of threats (Tallis et al., 2008) and the implementation costs (Carwardine et al., 2008). Regional and national approaches in designating Natura 2000 sites and nationally designated MPAs vary greatly, reflecting varying conservation targets and importance of conservation issues in the political agendas. Hence, selection of most marine sites was not based on systematic conservation planning (see the Aegean case studies), and certainly not because of their importance for marine biodiversity. Conservation targets are difficult to assess and reach when clear criteria and ecological and socio-economic data are lacking.

Lack of Coherent Ecological Networks

Natura 2000 sites and other MPAs are still far from reaching the status of effective networks. Properly designed MPA networks outperform single MPAs for ecological, economic, and social management goals (Boero et al., 2016). The five key principles are representativeness, replication, connectivity, adequacy, and management. The first four criteria cover the natural features of the networks, while the fifth must respect the features of the environment. The main challenge in achieving coherence then is the identification of spatially explicit and ecologically coherent conservation and management units. Lack of knowledge-based management able to adapt to the features of the natural environment is an important constraint. The EC-funded project CoCoNet produced the guidelines for the institution of MPA networks in the Mediterranean and Black Seas, calling for the identification of spatially explicit marine units where the management of human activities adapts to ecological patterns and processes (Boero et al., 2016). The approach focuses on the ecosystem level, covering the ecological processes that allow for the distribution patterns, habitats, and species. Besides the Danish case, where network coherence is high on the agenda in terms of replicability, representativeness, and connectivity, these concepts have rarely been tested with the consequence that the EU needs tools and approaches to build MPA networks.

Hotspots of Conflicts

Private economic interests often prevail over conservation aims. In Belgium, restrictions to recreational and professional fisheries in Natura 2000 sites have been challenged in court and are currently not enforced. Similarly, in Bulgaria, due to conflicts on marine uses, most fisheries conservation actions are delayed. Jones et al. (2016) reported conflicts among biodiversity conservation, offshore energy, and fishing. However, fishery restrictions are in force in most reef and "bubbling reef habitats" in Danish Natura 2000 areas, the few remaining reefs will be protected in 2018. Conservation goals must be prioritized and declared in advance since stakeholder involvement is fundamental from the start of conservation plans. Observation is important considering the emerging human uses within the framework of the Blue Growth (Inger et al., 2009).

FINAL RECOMMENDATIONS

The Need for Good Data

Knowledge of habitat distribution is fundamental for protection (Fraschetti et al., 2011). Habitat mapping on a fine scale is a prerequisite for conservation measures (Levin et al., 2014) and can be greatly assisted by new technologies (e.g., Topouzelis et al., 2018). Biodiversity as species composition of the main assemblages should be known and monitored. The biology of at least the ecologically important species (i.e., location of spawning and nursery areas, reproductive period, movement patterns, beta-diversity) should be known to assess the potential for network connectivity, to provide a solid background for reserve siting, designing, and zoning. A stable funding for the onset of observation systems should be part of the management plans to assure the knowledge of the ecology of protected ecosystems and an adaptive management to face ecological changes.

The Need for Effective and Adaptive Management

Management plans are vital for successful conservation, yet they are still missing in several protected and spatially managed European waters (Buhl-Mortensen et al., 2017). Poor governance and overlapping competences among the managing body, institutions, and stakeholders hinder the application of existing management plans, leading to unresolved conflicts (D'Anna et al., 2016). If management is not adaptive and based on participatory approaches leading to public acceptance and compliance, management success is put at risk (Stelzenmüller et al., 2013). Conservation goals (Halpern, 2003) should be achieved through public consensus, and strategies should involve stakeholders as a first step toward the comprehension of ecological, cultural, and social benefits (Badalamenti et al., 2000; Rife et al., 2012).

The Need of MPA Networks in the Framework of MSP

Networks are central in the policies of European and contiguous countries. Analyzing MPA coherence under the MSFD requires a shift from "within" to "across" MPAs, with holistic, integrated thinking, passing from single to network-connected MPAs to assess their adequacy and management against the objectives of MSFD (Boero et al., 2016). The network concept requires putting protected areas into a wider space, using them as nodes of a larger system. Networks should be based on effective ecological connections between MPAs, and in principle the conservation policies enforced in MPAs should be spread to the whole marine space. In such a scenario, a portion of marine space would be actually protected while the remaining space would be managed according to the MSFD specifications, since these apply to all EU waters and not only to protected areas. Designing networks of MPAs in the framework of MSP, based on systematic conservation planning principles, will reduce conflicts with other human uses and increase probabilities of success. Furthermore, as networks of MPAs interact with and depend on the surrounding environment, MSP provides the broader context leading to ecosystem-based management and GES in the entire marine area (Katsanevakis et al., 2011).

The present status still reflects a fragmented approach in the conservation and management of coastal marine environment: a holistic, integrated, ecosystem-based, cross-cutting approach able to avoid conflicts among institutions will provide effective and timely solutions to current and future challenges concerning the conservation and management of marine ecosystems and associated goods and services.

AUTHOR CONTRIBUTIONS

SF developed the initial idea, coordinated all steps of the study, and wrote the final version of this manuscript. CP prepared the **Supplementary Table S1**. HC and BL prepared the

Supplementary Table S2. CP, SK, AM, and GR contributed to the general writing of the manuscript. GG and SB also assisted in formatting and editing the manuscript and prepared the figures. All co-authors equally participated providing case studies and contributing to the final draft.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2018.00420/full#supplementary-material

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