CoCoNet: TOWARDS COAST TO COAST NETWORKS OF MARINE PROTECTED AREAS (FROM THE SHORE TO THE HIGH AND DEEP SEA), COUPLED WITH SEA-BASED WIND ENERGY POTENTIAL

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Abstract

This volume contains the main results of the EC FP7 "The Ocean of Tomorrow" Project CoCoNet, divided in two sections: 1) a set of guidelines to design networks of Marine Protected Areas in the Mediterranean and the Black Seas; 2) a smart wind chart that will allow evaluating the possibility of installing Offshore Wind Farms in both seas. The concept of Cells of Ecosystem Functioning, based on connectivity, is introduced to define natural units of management and conservation. The definition of Good Environmental Status, as defined in the Marine Strategy Framework Directive, is fully embraced to set the objectives of the project, by adopting a holistic approach that integrates a full set of disciplines, ranging from physics to bio-ecology, economics, engineering and many sub-disciplines. The CoCoNet Consortium involved scientist sfrom 22 states, based in Africa, Asia, and Europe, contributing to build a coherent scientific community.

Keywords

Networks of Marine Protected Areas, Mediterranean Sea, Black Sea, Biodiversity, Ecosystem functioning, Connectivity, Wind energy, Offshore Wind Farms, Marine Spatial Planning, Economic valuation.

1 Summary

The objectives of CoCoNet were the production of a Manual with the guidelines for the institution of **networks of Marine Protected Areas** (MPAs) and a **Smart Wind Chart** evaluating the feasibility of **Offshore Wind Farms** (OWFs), in the Mediterranean and the Black Seas. Both objectives call for the identification of **spatially explicit marine units** where the management of human activities takes into account the ecological patterns and processes featuring natural systems.

Previous and novel experience gathered in two pilot areas called for the recognition of cells of ecosystem functioning (CEFs): parts of the marine ecosystem (sea bed and water column) that are more connected with each other than with other parts. MPAs are meant to protect relevant habitats and the ecological processes that occur within their borders. MPA networks fulfil the strategic conservation objective of assuring, through the preservation of large-scale ecosystem functioning, the persistence of a good state for biodiversity.

Habitats should be considered holistically to allow matching wind availability with compatibility of OWFs installation within the ecological units comprising MPA networks.

The core steps of the guidelines for the institution of Networks of MPAs are:

Step 1: Collect all available information. The data gathered during the project are stored into a **multilayered Geodatabase** platform.

Step 2: Define spatially explicit management and conservation units. The CEFs were identified based on oceanographic features, composition of benthic communities, propagules in the water column and genetics of target species.

Step 3: Identify networks and priority areas using Marxan, a freely available software that provides decision support to conservation planning.

Step 4: Formation, management and monitoring of networks of MPAs, recognising seven core principles: Representativity, Replication, Viability, Adequacy, Connectivity, Protection, Best Available Evidence.

The networks of MPAs are conservation, monitoring and management units that put in practice part of the programmes of measures that EU member states are setting up to attain Good Environmental Status (GES) as defined by the Marine Strategy Framework Directive (MSFD); thus, these networks constitute a vehicle for the implementation of the MSFD. These visions should be expanded to non-EU countries, to enable a consistent use of the marine space: CEF management is effective only if it comprises the whole cell.

The Smart Wind Chart has been designed and implemented considering mean annual wind speed, bottom depth, distance from shore, proximity to ports, electrical grid infrastructure, type of bottom sediments, coupled with environmentally restricted and sensitive areas (National protected areas/marine protected areas (MPAs), Ramsar/Natura 2000 sites, coralligenous and maerl, deep sea corals, *Phyllophora* fields and *Posidonia*/sea grass meadows). The **design, permitting, installation, operating and decommissioning of OWF** involves:

Step 1: Consultation of the Smart Wind Chart results.

Step 2: Design and implementation of detailed local studies.

Step 3: Integration of the acquired information into a single framework

Step 4: Building of synergies with other marine space users.

OWFs should be developed according to wind availability and to suitability studies in the CEFs in which they will be nested, considering their role in the networks of MPAs.

The project applied the holistic approach to the understanding of marine volumes. The vision of CoCoNet has been fully embraced by the recent report of the European Academies Science Advisory Council and the EU Joint Research Centre on "Marine Sustainability in an age of changing oceans and seas". A solid theoretical basis is now available, guiding a more holistic way to provide solutions leading to Blue Growth, to increase the economic capital while preserving the natural capital. The attainment of GES through networks of MPAs, and the production of clean energy through OWFs will be instrumental to the attainment of sustainable growth with an increase of blue jobs to enhance the knowledge of marine systems.

1.1 A framework towards a holistic approach to sustainability – the contribution of CoCoNet

The protection of the natural capital in marine systems is the core of sustainable development,

as the Blue Growth initiative prescribes. The production of energy through fossil fuels is a major threat to environmental integrity and clean energy production is conducive to the preservation of the natural capital. To satisfy these two strategic aims, CoCoNet produced two pieces of work:

1.2 Guidelines to create MPA networks in the Mediterranean and Black Seas

The **first** core objective of CoCoNet was the **definition of guidelines** to establish networks of MPAs in both the Mediterranean and the Black Seas, with a **holistic approach to marine conservation**.

The persistence of valuable expressions of **biodiversity patterns** (as those protected in MPAs) is based on the avoidance/regulation of **direct threats** (as enforced in MPAs) but ultimately depends on the **functioning of the ecosystems at all significant scales**, so requiring wise and effective management throughout the ecosystem.

The biodiversity and ecosystem functioning of a restricted marine space (such as MPAs and Sites of Conservation Importance) depends both on local features and on larger scale processes that take place outside the range of focused protection initiatives. Hence, the **networks of MPAs must be designed to maintain ecosystem functioning** throughout their extension, increasing the effectiveness of individual MPAs.

CoCoNet identifies Good Environmental Status (GES) as the main objective of the management of Networks of MPAs, and recommends effective actions towards the fulfilment of GES prescriptions. EU member states are responsible for the enforcement of the Marine Strategy Framework Directive (MSFD) in their own waters. Management and monitoring should be harmonized, based on **sound ecological principles**. Since ecological boundaries do not match with political borders, it is important that management and monitoring are coordinated among **EU and non EU States** bordering the Mediterranean and the Black Seas.

Socio-economic expectations must be consistent with the features of the environment otherwise, in the medium-long term, the ecosystems will fail to provide essential goods and services, nullifying any short-term progress.

1.3 The Smart Wind Chart

The **second** core objective of CoCoNet was to **explore the possibility of installing OWFs** in the Mediterranean and the Black Seas, through the realization of a **Smart Wind Chart** (SWC).

The SWC identifies the areas in the Mediterranean and the Black Seas where two strategic requirements for the installation of OWFs are met:

1 – the availability of **sufficient wind power** to guarantee profitable energy production.

2 – the compatibility of OWF installation with the preservation of the natural capital and of its attractiveness/profitability for touristic and other socio-economic enterprises.

A Smart Wind Chart, then, **synthesizes both opportunities** (wind availability) **and constraints** (biodiversity and ecosystem conservation, socio-economic potentials), fully embracing the vision of **Blue Growth**: the growth of the economic capital, to be sustainable, must not erode the natural capital. **The achievement of GES, and its persistence, is the measure of sustainability** and the objective of MPA networks is just to secure good biodiversity conditions by enhancing the functioning of ecosystems. The reduction in the use of fossil fuels and consequent clean energy production, furthermore, are coherent with the objectives of Blue Growth.

2. GUIDELINES TO THE DESIGN OF EFFECTIVE NETWORKS OF MARINE PROTECTED AREAS IN THE MEDITERRANEAN SEA AND THE BLACK SEA

2.1 Rationale

The manual provides the guidelines for designing, managing and monitoring networks of MPAs, centered on science-based criteria, concepts and models (physics, biology, ecology and evolution) but also takes account of socio-economics and legislation. The Cells of Ecosystem Functioning, in particular, provide a conceptual tool to guide ecologically coherent planning of human activities in the marine space.

The manual thus describes which knowledge is necessary to design MPA networks, providing a holistic view of the marine space. General recommendations for the establishment and management of MPA networks are given, covering habitat mapping, connectivity, oceanography, dispersal studies, beta-diversity studies, genetics, threats, objectives, socio-economic and cultural aspects, and applicable legislation.

Based on all this, a map of the networks of MPAs is produced, with special focus on pilot areas.

2.2 Objectives

This manual explains the rationale, processes and methods for selecting sites and establishing MPA networks in the Mediterranean and Black Seas, outlining general principles that are applicable to any marine environment. This manual of guidelines and recommendations is primarily aimed at:

1. Managers of MPAs and MPA networks

2. Policy makers

3. NGOs that focus on environmental protection

4. Local, regional, national and international authorities that should implement policies that aim at removing the threats to environmental integrity

5. The tourist and the fisheries sectors that derive benefits from good environmental status to gain their income

6. The scientific community

However, it should be noted that the in-depth comprehension of these recommendations by non-professional users might be limited since many issues require technical know-how to be properly understood and applied.

2.3 Building Networks of MPAs

'Marine Protected Area' means a geographically defined area of the sea which is designated or regulated and managed to achieve specific conservation objectives (cf. CBD 1992, Article 2). A network of MPAs comprises a suite of MPAs that are highly linked to each other by propagule fluxes (connectivity) and also considers the space wherein connectivity takes place. A network of MPAs will normally cover large geographical areas in order to ensure ecosystems resilience, increasing the resistance against natural and human driven impacts. In this regard, the often limited size of MPAs is a major shortcoming for their efficacy. It is vain to protect a minimal portion of the marine environment, while leaving the rest unmanaged and unprotected.

To cope with this problem, and to include the high and the deep sea into management actions aimed at protecting biodiversity, it is necessary to build networks of MPAs that are ecologically coherent and that use the MPAs as nodes of a much wider space. Networks of MPAs can be simply aimed at the coordination of management of each MPA through exchanges of good practices, without considering the space across the MPAs. However, these management-based networks can only improve the management of individual MPAs. An ecologically coherent network of MPAs must cover a volume of water and an area of sea bottom where the exchanges of propagules across marine space maintain full expressions of biodiversity and sustain ecosystem functions. Connectivity (i.e. the intensity of propagule exchange) is the main feature of an ecological network.

The design of networks of MPAs, thus, requires knowledge about structure (in terms of biodiversity expressions at the level of species and habitats) and function (in terms of connectivity). The networks have to be designed giving priority to solid ecological principles. Although political, economic and social imperatives have been demonstrated to be of critical importance for building successful protection initiatives, humans cannot expect that nature will adapt to their needs: in order to preserve nature (the scope of MPA networks) we must adapt to nature. MPAs are often, if not invariably,

instituted to protect unique features of biodiversity as perceived by people, linked to the existence of important species (mainly vertebrates) or habitats (e.g. biogenic reefs, sea grass meadows), or special features of the sea bottom character as specified in the EU Habitats Directive. Zones closed to fisheries comprise habitats where the target species spawn, grow, and forage, but otherwise have restricted goals.

However, these traditional approaches neglect the importance of the dynamic three-dimensional nature of the marine environment. It as an environment dominated by volume, in which the water column is a specific major feature (itself comprising a range of habitats according to flow, depth, chemistry, temperature, light penetration and so on). Accordingly, specific marine protection schemes of any kind are not ecologically independent, but are part of larger and more complex systems. Consequently, an ecologically coherent network of MPAs is not simply the sum of a group of MPAs that coincide in managing their protected spaces while disregarding the space between them: the individual MPAs must also contribute to protecting the much wider space in which they function.

The chief innovation of CoCoNet has been to pay particular attention to the physical water column and its associated ecosystems, and how these interact and are ecologically connected in identifiable spaces termed "Cells of Ecosystem Functioning" (CEF) (Boero, 2015). The application of this concept means that individual MPAs must be established into a coherent conservation unit, whose definition is the key challenge for an ecologically sound design of MPA networks, and managed accordingly. The current two-dimensional approach, with individual site-based management determined by political opportunities that do not coincide with ecological features, is destined to failure.

Recognition of this fact is becoming clear in that a general and strategic goal for MPA networks can be found in the EU Marine Strategy Framework Directive, which prescribes that Good Environmental Status should be reached in all European waters by 2020. The eleven descriptors of GES are based on biodiversity and ecosystem functioning and consider the main threats to environmental integrity. No better goals for MPA networks are available.

3. Practical guidelines for building ecologically coherent MPA networks

The following guidelines, set out in four steps, provide a roadmap for applying the concept of Cells of Ecosystem Functioning (CEF) in order to construct ecologically coherent networks of MPAs as described in the previous sections. Important terms, aspects, resources and approaches are highlighted in **bold** throughout the text.

3.1 STEP 1: collect and organize all available information

The more information that is collected and analysed, the better will be the resulting scheme of MPAs forming a network, within the relevant CEF. The following procedure, for example, was undertaken by the CoCoNet project.

From real world to Geodatabase Architecture

The data collected in CoCoNet come from a great number of sources and span from physical oceanography to chemical oceanography, geology, biology, ecology, socio-economy and law. To overcome data fragmentation, and to integrate knowledge and compare data and products in a holistic view, the CoCoNet project designed a **digital architecture of 11 geodatabases** following a specific data flow. The design of **conceptual data models** (coming from INSPIRE (Infrastructure for Spatial Information in Europe) themes and properly adapted for CoCoNet objectives) was the starting point, then we created a logical Unified Modeling Language (UML) structure and finally physical repositories for data storing (Figure 1).

The geodatabase architecture is the core of the system and is a powerful tool to homogenize the incoming data and provide means of communication across different fields to reach the scopes of the project. **The 11 geodatabases are integrated in a WebGIS platform**, as visible layers (Figure 2) accessible by partners and public at the following address: http://coconetgis.ismar.cnr.it/ . The WebGIS provides easy tools for data visualization, retrieving through advanced search, downloading and printing. The integrated Geodatabase, thought the WebGIS system, represents the linking tool for

Real world data

INSPIRE Conceptual data model

Geodatabase

CoCoNET UML
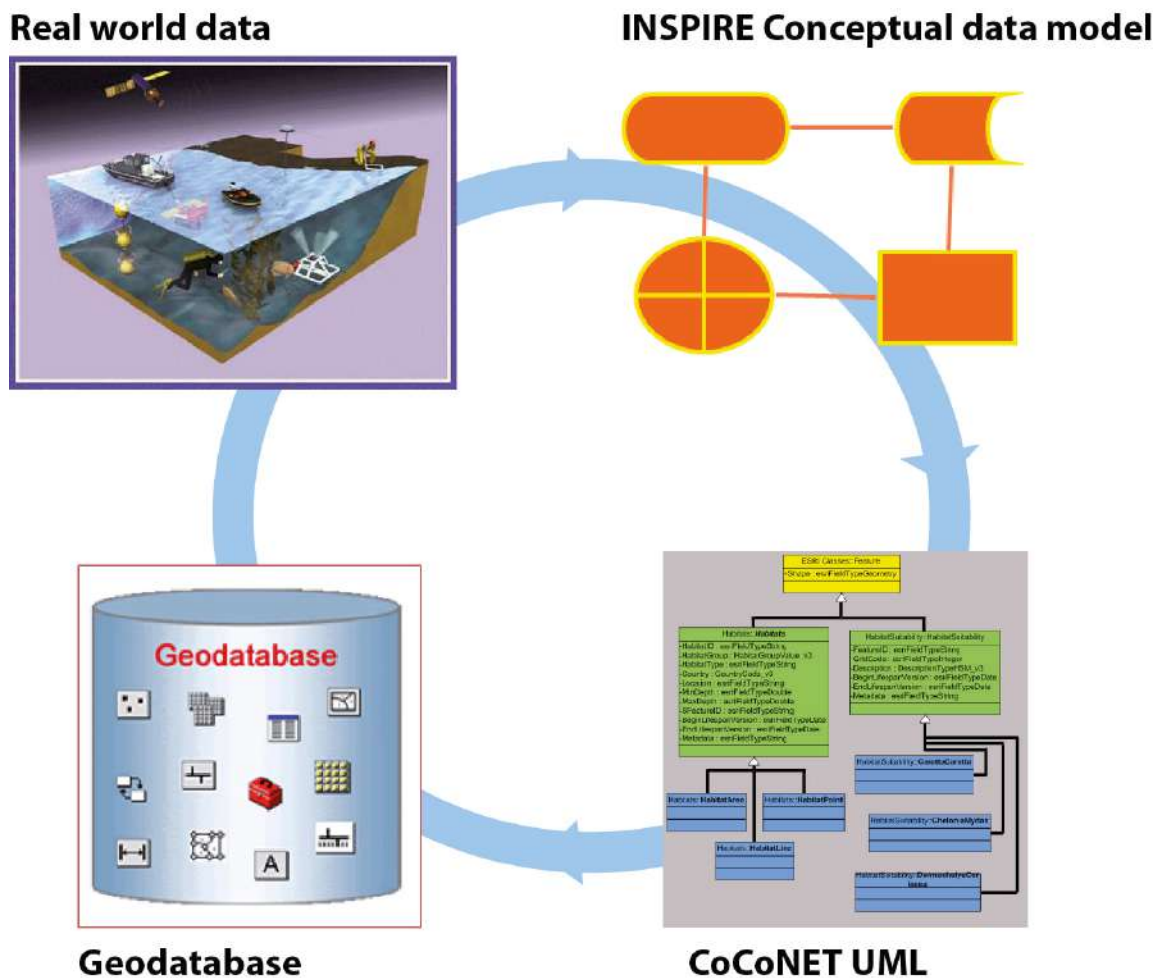
Figure 1. CoCoNet Data flow: from real world data to Geodatabase

all partners, regions and thematic research involving the entire consortium in topics such as data provision and integration, GIS products, GIS interpretation, data archiving and data exchange.

Habitats in MPA networks

Information on the **distribution of species and habitats**, and on whether and how different anthropogenic drivers interact is central in ecological research (Fraschetti et al., 2008). Habitats are often good surrogates for species diversity: the greater the number of habitats in an area, the greater the number of species found there (Thrush et al., 2006). The **conservation of marine habitats** may serve as a **practicable surrogate for conserving scales of diversity** that include species and ecosystems. The value of

habitats and environmental factors as potential surrogates is largely unknown (Ward et al., 1999). In marine systems, **maps** are either used directly as a **surrogate** for diversity or combined with environmental data to model patterns of species distributions. Habitat mapping is fundamental for the identification of hot spots of habitat diversity. **Maps** permit detection of **changes** in habitat cover, and allow **boundary demarcation** of multiple-use zoning schemes. Large-scale maps visualise the spatial distribution of habitats, thus aiding the planning of networks of MPAs and allowing to monitor the degree of habitat fragmentation (Martin et al., 2014).

The European Nature Information System (EUNIS) catalogues European habitats, marine ones included, so as to meet the needs of conservation programmes. EUNIS stems from a UK perspective and does not cover the features

GEODATABASE LAYERS

Sea Regions: physical conditions of seas and saline water bodies divided into regions and sub-regions with common characteristics.

Socioeconomics: units of administration at land, dividing areas where States have and/or exercise jurisdictional rights, for local, regional and national governance, separated by administrative boundaries.

OWF: existing and planning site for Offshore Wind farms turbines and potential locations based on physical parameters (depth, distance from shore, etc) or environmental data (habitat presence, marine protected sites, etc).

Threats: storing data about natural and anthropogenic activities and impact such as: invasive species, outfalls, marine litter, fishing, navigation routes

Geology: geological samples, geological units (lithostratigraphic units, seabed substrate, system tracks, base of Quaternary, etc), geological structures (folds, faults), geomorphologic features and geophysical elements.

Maritime Units: data about units of administration at sea, dividing areas where States have and/or exercise jurisdictional rights, for local, regional and national governance, separated by administrative boundaries.

Habitat and Biotopes: habitats extension and characterization. The geographical information is completed by no-spatial information about species, sources and cover types

Oceanography: data about physical (temperature, **s**alinity, currents), biogeochemical variables (chlorophyll, phytoplankton, dissolved oxygen, etc) and ecoregions.

Biodiversity: species occurrences, species distribution, mammals, birds and turtles at sea and nesting sites at land. Information about taxonomy and sources are stored in related tables.

Protected Site: protected sites at sea and in 15 km inland from the coast.Each site has its zones of protection and its characteristics are described in related table.

Elevation: Digital Elevation models for land and sea surface. Includes bathymetry, marine contours, bathymetric surfaces.

Figure 2. The CoCoNet GEODATABASE layers integrated in the WebGIS
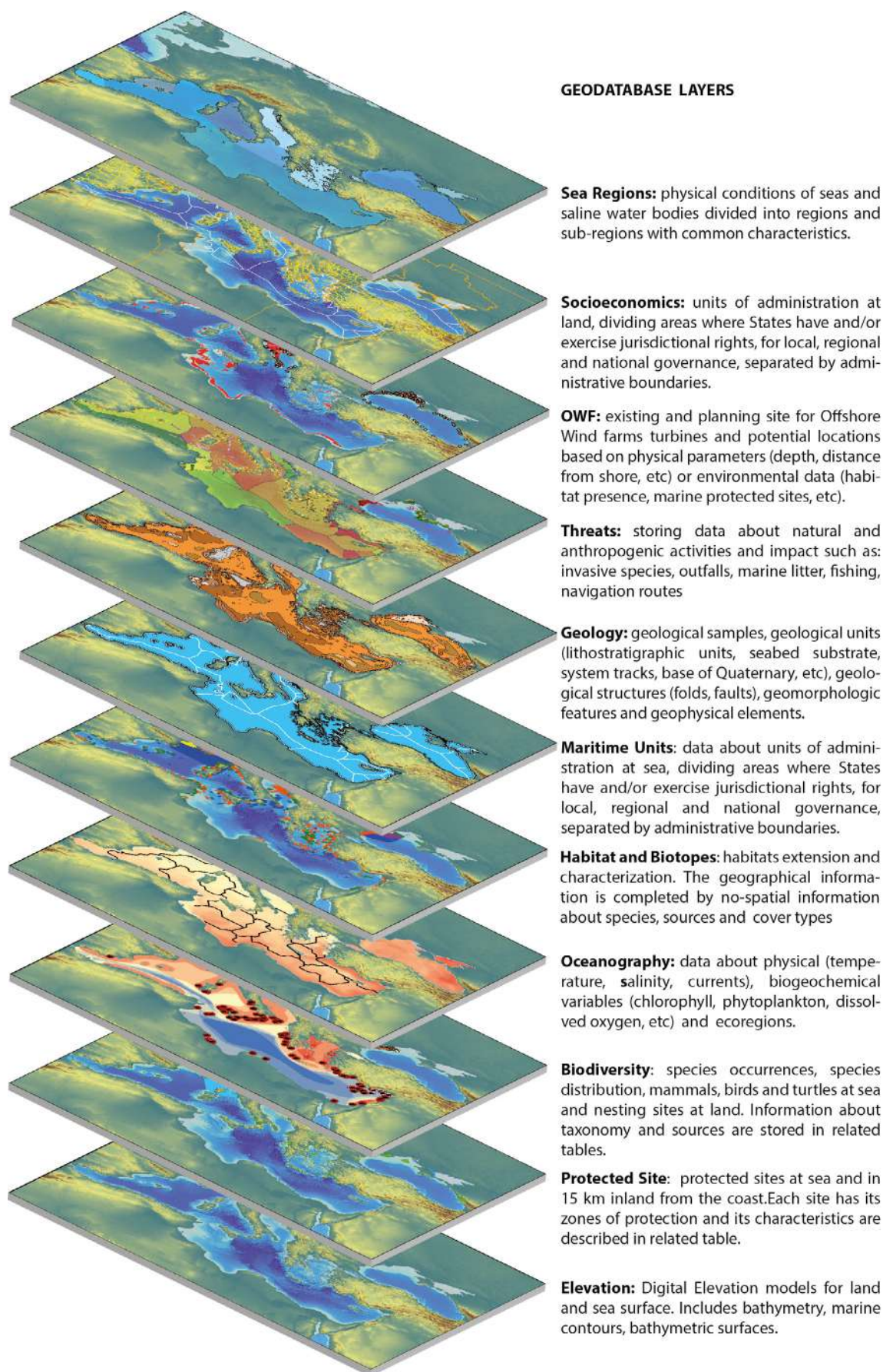
of Southern European Seas properly. For the Mediterranean Sea, the **Habitats Directive**, the Protocol for **Specially Protected Areas** and **Biodiversity in the Mediterranean** (SPABM) of the **Barcelona Convention**, and the **Bern Convention** require cataloguing of marine habitats. Mediterranean habitats as defined by **UNEP/MAP** were inserted into the EUNIS system based on their biological characteristics with respect to a specific EUNIS template (depth zone, substrate type, energy, characteristic and accompanying species etc.). However, **several structural caveats and discrepancies are observed in the way Mediterranean and Black Sea marine communities are classified in the EUNIS system**. In addition to the above named schemes, and others derived from them, independently developed local schemes are used in particular regions or countries. This calls for **data integration** throughout the Mediterranean and the Black Sea regions, since, at present, the application of EU standards is difficult in both basins. **Habitat features** are **poorly defined and biased towards benthos**, determining grouping of habitats that do not represent real distribution patterns. In addition, the **plant component** tends to be **over-represented**, reflecting a tendency to **treat marine habitats as terrestrial ones**, with the conceptual tools of phytosociology, while **neglecting groups** (e.g. invertebrates) and habitats (deep sea and, above all, the **water column**) that are of **fundamental structural and/or functional importance**. It is urgent to **standardise** the classification of Mediterranean and Black Sea habitats and to **develop a scheme that is applicable throughout the regions**, before more countries undertake further extensive habitat mapping that will exacerbate problems of integration. CoCoNet evidenced the bias, limits, gaps and pressures hindering the possibility of having a habitat classification scheme that represents the Mediterranean and Black Seas. Current classification schemes can be improved so as to better represent the complexity of ecological systems.

The CoCoNet Habitat Mapping Scheme

CoCoNet attempts to establish an integrated approach on the definition of habitats. This scheme combines multi-scale geological and biological data (Figure 3), organized into three levels (**Geomorphological, Substrate and Biological**), divided into several hierarchical sublevels. The Habitat layer is the sum of these levels leading to maps with several possibilities of level combination.

An organized system, such as the "CoCoNet Habitat Mapping scheme", is crucial for correct data management, since it allows to store, visualize, query and elaborate data to produce customized maps in an easy and efficient way. Moreover the use of the CoCoNet classification scheme gives to the system a multidisciplinary and multi-scale trait, essential for habitat mapping.

Habitat distributions: the baselines for conservation planning

CoCoNet combined already existent GIS information and collected additional data about habitat occurrence across the Mediterranean and the Black Seas, homogenizing information following a properly designed standard architecture. This effort set the scene to improve spatial prioritization in the Mediterranean and the Black Seas starting from biogenic habitats (e.g. coralligenous formations and maërl), seagrasses (e.g. *Posidonia oceanica*), macroalgal canopies (e.g. *Cystoseira* spp., *Phyllophora crispa*) and barrens that are considered of critical importance for the two basins. This activity allowed substantial improvement of basic habitat information, reaching up to about the 40% of the two basins. The information is still very uneven but, after the CoCoNet project, it is clearly evident that there are stretches of coast such as Morocco and Tunisia with a surprising data availability and willingness to share data (Figure 4). Despite the efforts, the deep sea still largely lacks GIS information.

Taken as a whole, this information is critical to MPA selection with algorithms elaborated for systematic MPA design and especially suited for the design of MPA systems rather than constructing single MPAs: ecological concepts such as **complementarity**, **comprehensiveness** and **representativeness**, **adequacy** and **self-sustainability** relay on adequate knowledge about habitat distribution and extent, together with their structure (physical organisation, habitat patches) and function (ecological and evolutionary processes). The effort carried out in the project on increasing the knowledge on habitat distribution is also critical
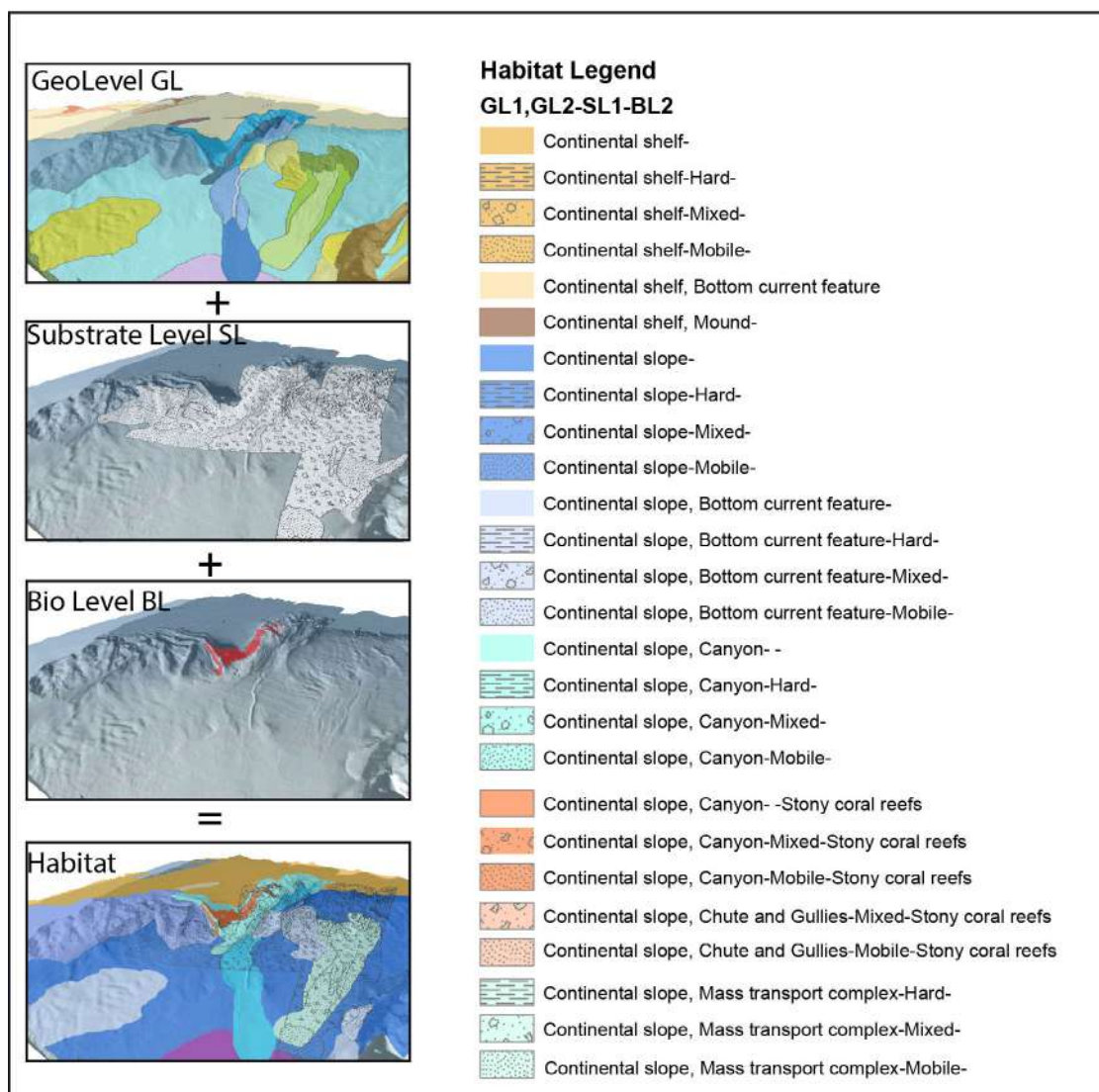
Figure 3. The CoCoNet Habitat Mapping Scheme. The Biological level is organized according to a detailed list of habitat types (CoCoNet product)

for informing real applications of Maritime Spatial Planning (MSP), to avoid cumulative impacts on marine ecosystems, user conflicts, and to create synergies between maritime activities promoting the blue economy. MSP visualizes conflicts and compatibilities among human uses. The mapping of habitats and ecosystems, and of the human activities affecting them, identifies where conflicts are or will be located, finding alternative solutions for the distribution of human uses.

Recommendations concerning habitats

Habitats are good **surrogates** of biodiversity, pending a sufficient knowledge about how to protect and manage species, biological communities and ecosystems. The Habitats Directive covers a

restricted list of benthic habitats and a short list of charismatic species. The descriptors of GES call for a more comprehensive knowledge of marine systems. These recommendations are directed mainly to EU and national policy makers. The scientific community is involved in the process of knowledge building.

· **Fully represent Mediterranean and the Black Sea habitats in EU Directives.** The nine marine habitats in the Habitats Directive do not represent the full diversity of marine habitats and make it difficult to enforce protection through the Natura 2000 system that, in the Mediterranean Sea, at present covers mostly *Posidonia* meadows.

· **Extend the habitat concept also to the water**

column. The exclusively benthic perspective of the Habitats Directive is not coherent with the principles of ecosystem functioning. The concept of CEFs represents a holistic approach to environmental management, integrating the sea bottom with the water column. Open waters, in fact, are not homogeneous and pelagic habitats are to be identified and framed not only in space but also in time. Crucial phenomena (e.g. plankton blooms) take place in pulses and are the main drivers of ecosystem functioning.

· **Upgrade the list of marine habitats and adapt it to the concept of CEFs**. CoCoNet developed a hierarchical approach to habitat definition and

types, allowing the assessment of biodiversity expression by comparison of the actual list of species recorded during a sampling campaign with the master list (the cumulative inventory of species found in that habitat). Master lists can be obtained by matching the European Register of Marine Species (ERMS: http://marbef.org/data/erms.php) with the habitats list. Each habitat, in this way, will be defined by a list of species (those recorded from that particular habitat). The suite of species that have been found in each habitat makes up the master list defining the potential biodiversity of that habitat. Some species are typical of a particular habitat (e.g. the species living only on the leaves of Posidonia) others occur in a suite of habitats.
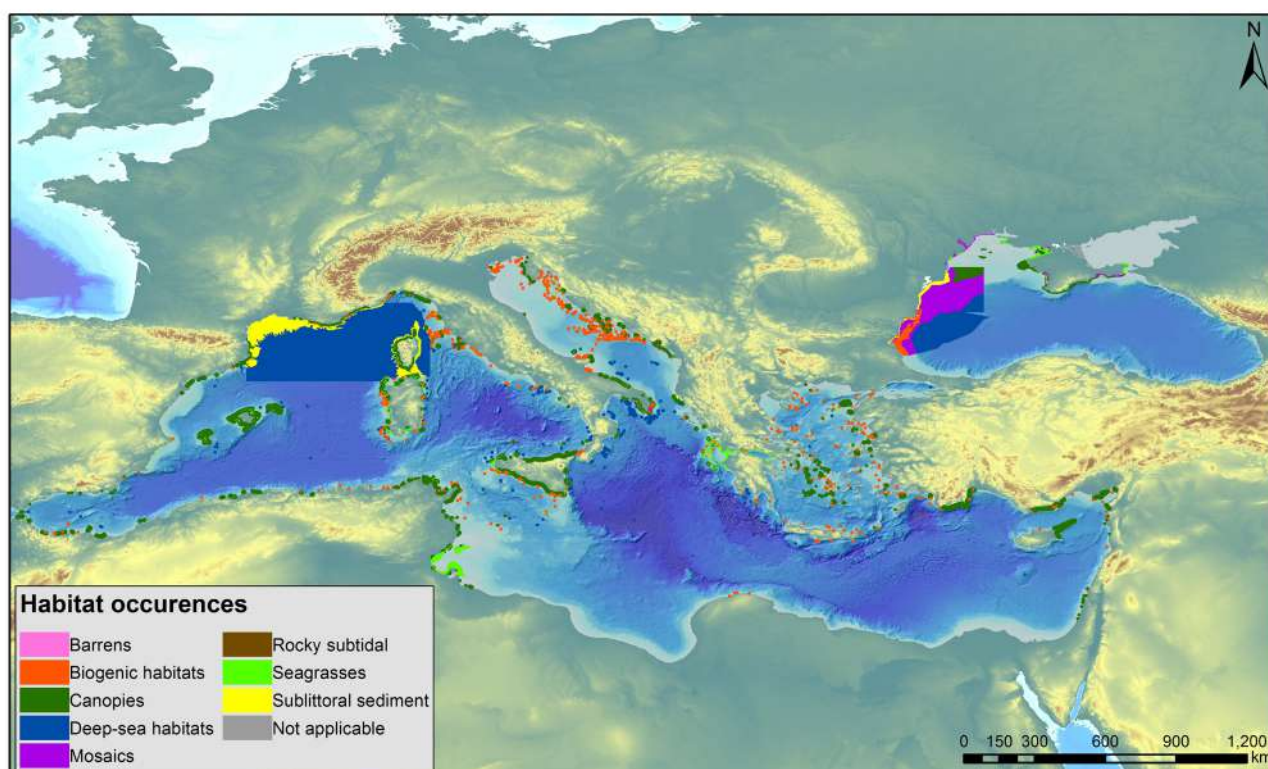
Figure 4. Distribution of biogenic habitats (e.g. coralligenous formations and maërl), seagrasses (e.g. *Posidonia oceanica*), macroalgal canopies (e.g. *Cystoseira* spp., *Phyllophora crispa*), barrens, deep sea habitats, rocky subtidal, sublittoral sediments and mosaic

compiled a full list of Mediterranean and Black Sea Habitats to provide a conceptual tool for the planning of habitat mapping, leading to protection and conservation.

· **Improve the knowledge of the distribution of marine habitats** to reach the quality attained for terrestrial systems (i.e. Corine land cover) and assemble an all-species inventory for each habitat (master list). This will link species lists to habitat

The assessment of the biodiversity at each habitat is realized by matching what is found during a sampling session against the master list. The value of the assessment varies between 1 (all species of the master list have been found) and 0 (no species are found: dead zone) (Boero and Bonsdorff, 2007). MPAs are the first places where this exercise might be carried out.

· **Base the institution of MPAs on fine-scale**

knowledge of habitat distribution. This requires the mapping of CEFs, so as to cover both the sea bottom and the water column, and the relationships between them. The mapping must be not only structural (what is where) but also functional (what is happening at specific places: e.g. phyto- and zooplankton blooms, spawning, nursery and feeding volumes for fish).

· **Identify priority areas using adequate tools** (e.g. MARXAN) for a refined selection of biodiversity hot spots. Use the conclusions reached by CoCoNet to inform a process of Maritime Spatial Planning (MSP) across the Mediterranean and the Black Seas, considering activities that are expected to increase in the future (e.g. aquaculture, maritime traffic, seabed mining). This will provide a solid scientific basis for planning the distribution of human activities in the seas.

· **Evaluate ecosystem goods and services linked to habitats and ecosystems**. In marine systems, we still exploit natural populations (with fisheries) whereas this is not possible on land anymore, where we obtain resources almost exclusively from agriculture. These natural capitals must be properly evaluated and managed. Furthermore, natural systems provide services that range from CO_2 sequestration to O_2 production, climate mitigation, cultural inspiration, tourist attraction, etc. The value of the natural capital is extremely large and allows for our survival.

· **Incorporate dynamic aspects** (connectivity, trophic interactions, spread of non indigenous species (NIS), and climate change) into spatial prioritization tools. Natural systems evolve, i.e. change. Ecology is a historical discipline (Natural History) and conservation cannot expect to just conserve the status quo. It is of paramount importance, however, to distinguish between natural change and human-induced change.

Identifying and Mapping Environmental Threats

Knowing the location and impacts of human activities on marine ecosystems, and understanding the consequences of multiple human pressures on marine systems is crucial to develop spatial plans based on the analysis of management alternatives. In the Mediterranean and the Black Seas, threats on species, habitats and ecosystems have been identified at basin and regional-scales (Coll et al., 2011; Micheli et al., 2013a). These analyses are of critical importance to move beyond the traditional single-threat approach, identifying key threats to different components of biodiversity and allowing site prioritization for different uses. However, these maps are not accurate enough to be applicable in strategies for local scale conservation and management, and to assess actual local impacts: more detailed, regional analyses are needed, as CoCoNet undertook in the two Pilot Areas (Figures 5, 6).

In addition, these studies on the effects of cumulative impacts on marine systems are largely based on expert knowledge, since costs and logistics often impair experiments at large spatial and temporal scales. Expert- or literature-based techniques have a limited potential to detect and understand the complex interactions that may exist among pressures (e.g., synergisms or antagonisms): **real data are needed**. The effects are spatially variable and site-specific, making it difficult to extrapolate general rules covering vast spatial scales. Quantitative assessments of the effects of different human-driven stressors among and within habitats are critical for understanding and predicting the cumulative impacts at a regional scale. Cross-habitats assessment is essential to adapt and respond to threats to marine environments.

Bioinvasions and MPA Networks

Intensification of anthropogenic activities, coupled with growth of littoral resident and transient recreational populations, are driving unprecedented changes in the Mediterranean Sea (EEA, 2015). Symptoms of complex and fundamental alterations to the sea's ecosystems proliferate. Invasive alien species (IAS) of warm water affinity are on the increase, affecting the functioning of marine ecosystems, causing deep concern to scientists, legislators and managers (Williams & Grosholz, 2008; Ojaveer et al., 2014). The number of introductions into the Mediterranean Sea is far higher than in any other sea (Galil et al., 2014). The greatest increase was recorded in the 1990s and the 2000s, a period in which the most severe thermal anomalies occurred (Rivetti et al., 2014), as well as the expansion of shipping, mariculture and size of the Suez Canal.

The number of multicellular non-indigenous species (NIS) is 726, of these, 450 are 'Erythraean' NIS introduced into the sea through the Suez Canal: the number of NIS is substantially greater in the eastern than in the western Mediterranean (Figure 7). This is only a partial inventory, as our ignorance of the marine biota leads to massive underreporting and understatement of bioinvasions.

MPAs were established to conserve the diversity of native species in their habitats, with an ecosystem-based approach to conservation, providing protection to habitats, biodiversity and ecosystem services, and insurance against environmental or management uncertainty.

Contrary to these expectations, Erythraean NIS are frequently the most common species encountered in the MPAs in the Eastern Mediterranean, where the invasion has already altered the structure and function of ecosystems in a pervasive fashion. Currently, rocky reef fish assemblages in Eastern Mediterranean MPAs were observed to be prone to the Erythraean invasion through the Suez Canal (Guidetti et al., 2014), and the same was observed for opisthobranch NIS (Yokes et al., 2012). Along the Lebanese coast, surveys aimed at identifying locations for MPAs highlighted the prevalence of

Figure 5. Spatial distribution of human activities in the Mediterranean Sea. Top: main pressures at regional scale (Pilot Area); bottom: scale up with a focus on touristic pressure, artisanal fishery, port, discharges, *Posidonia* loss on a specific area of Apulia (Italy)
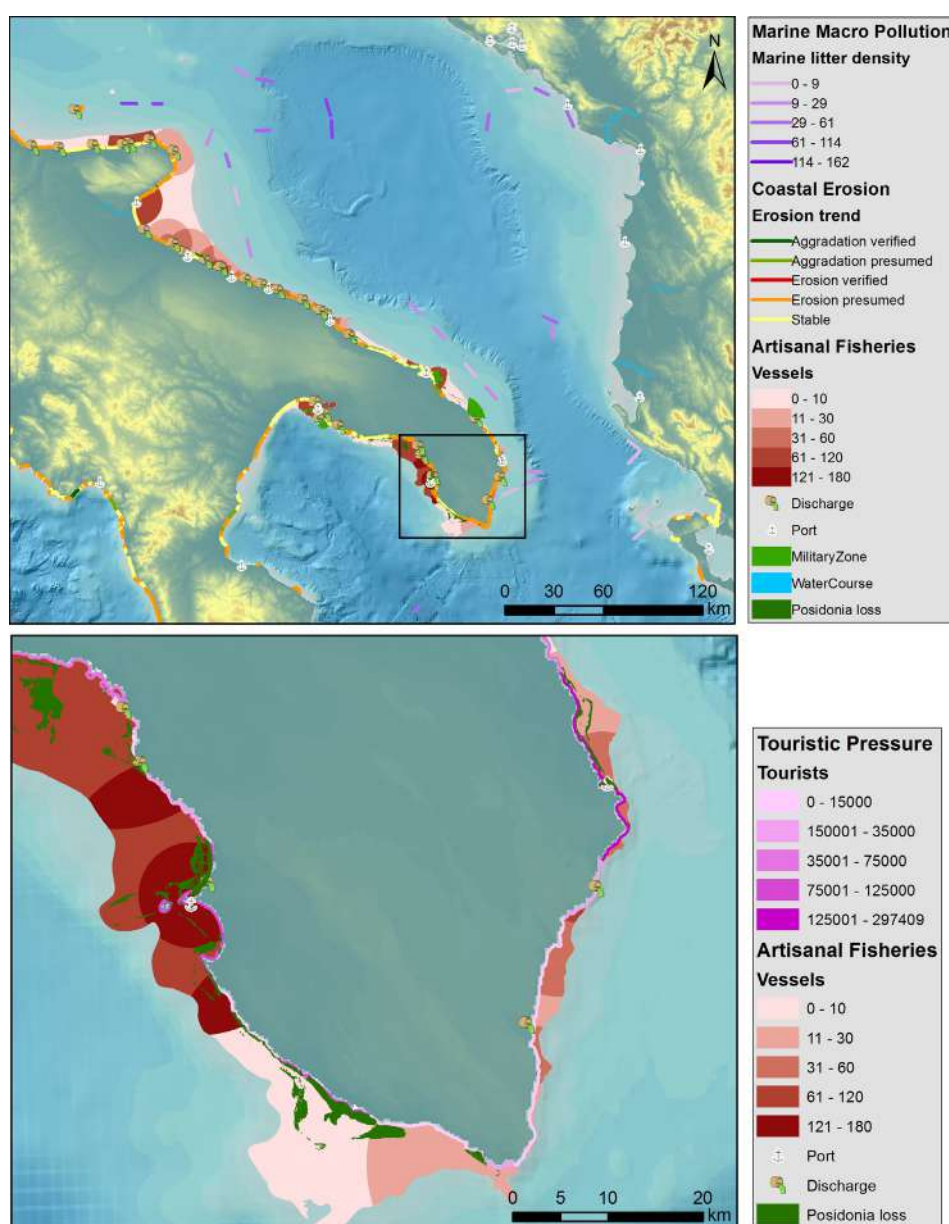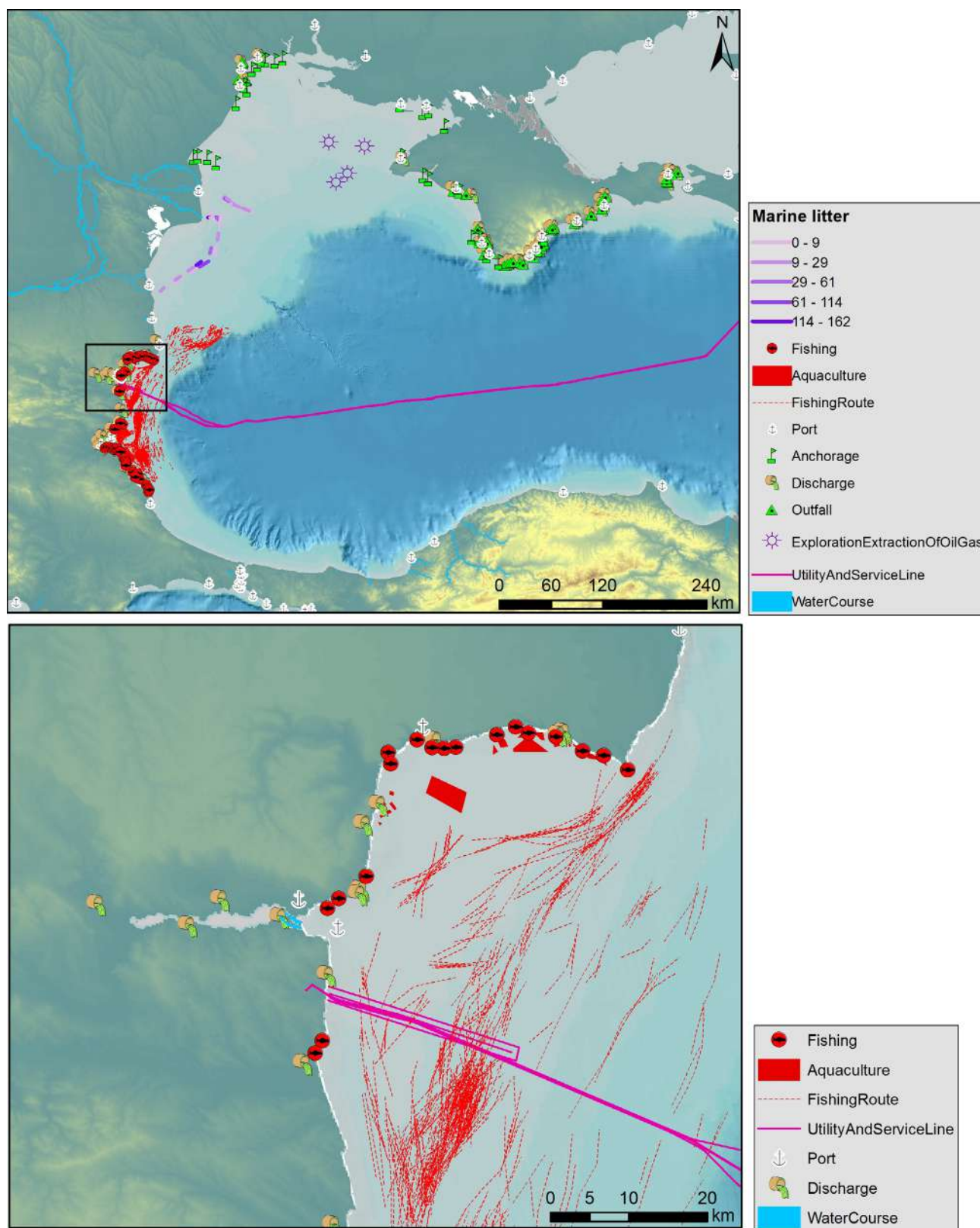
Figure 6. Spatial distribution of human activities in the Black Sea. Top: main pressures at regional scale (Pilot Area); bottom: scale up with a focus on aquaculture, fishery, ports, discharges, water courses, utilities and service lines, on a specific area of Bulgaria
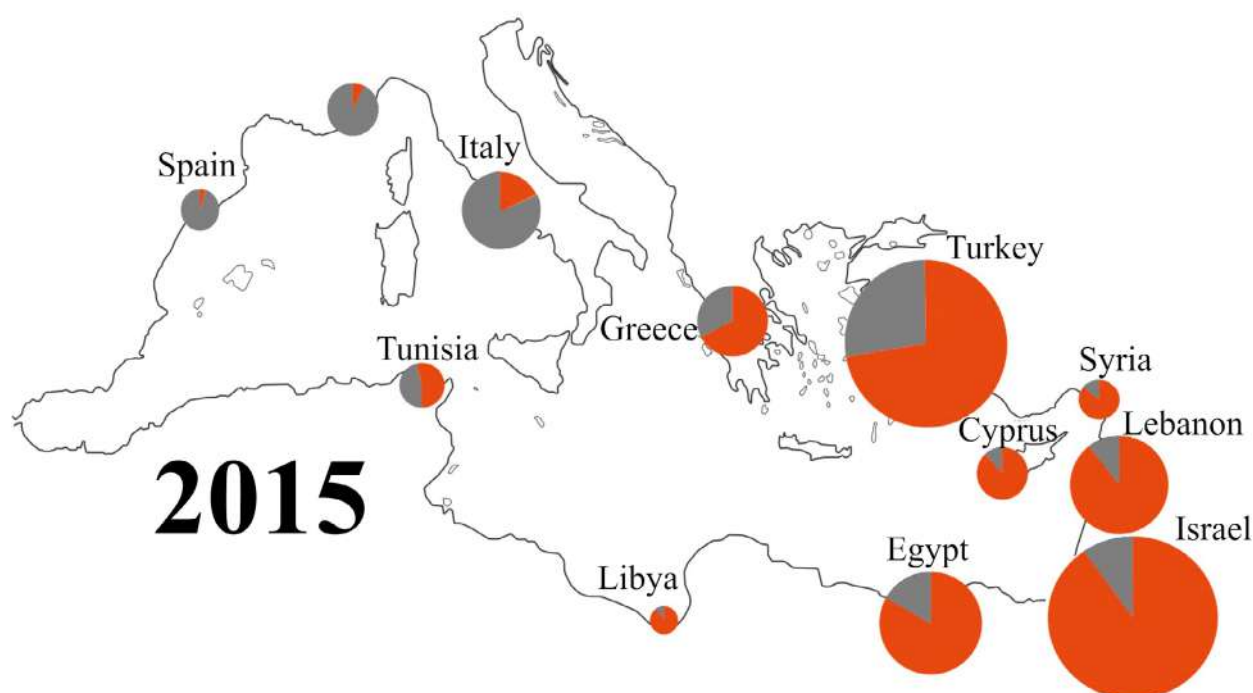
Figure 7. NIS pressure. The number of marine NIS recorded in some Mediterranean countries. In red, NIS considered to have been introduced through the Suez Canal; in grey, NIS considered to have been introduced by other vectors - mainly shipping and culture (after Galil et al., 2015)

NIS at all sites, with 31% and 21% respectively of the recorded mollusc and fish species identified as Erythraean NIS (RAC/SPA - UNEP/MAP, 2014). The Akhziv-Rosh HaNiqra nature reserve, the largest and best managed of the marine reserves along the Mediterranean coast of Israel, harbours an exceptionally high number of Erythraean NIS. Temperature increases are probably conducive to the extension of the invasion also in the Western Basin, where many of these species already thrive, even though some can undergo a strong reduction of their populations. Montefalcone et al. (2015), for instance, showed that the abundances of the so-called killer alga *Caulerpa taxifolia* declined in recent years, though the equally invasive *C. cylindracea* became dominant at many places, with unexpected impacts on the quality of commercial fish (De Pascali et al., 2015). The grazing of the schooling Western Indian Ocean rabbitfish *Siganus rivulatus* and *S. luridus* replaced algal forests with wide areas of bare substratum, results in a dramatic decline in biogenic habitat complexity, biodiversity and biomass (Vergés et al., 2014). These grazers are rapidly expanding to the Western Mediterranean. The Mediterranean network of MPA managers

(MedPAN) recognized that "Marine Protected Areas in the Mediterranean don't escape of this general trend [of bioinvasion] and most of them have been affected by the introduction of alien invasive species for a long time, threatening marine biodiversity.... MPAs across the MedPAN Network face common challenges, among them, the lack of awareness and understanding of the impacts of invasive species, the scarcity of information on best practices for management as well as the insufficient baseline information, guidelines and trained local staff to identify and gather knowledge on species introductions and impacts... At a regional level... there is still a weak networking, coordination and collaboration on this issue" (IUCN, 2012). MedPAN focuses its attention on the internal governance, strategies, and management effectiveness of MPAs. Otero et al. (2013) highlight the risk posed by NIS to MPAs, introduce management strategy and actions, provide a priority list of invasive species with the greatest potential impact, present NIS monitoring and data recording protocols and offer well illustrated fact sheets for priority Mediterranean IAS. Due to a lack of monitoring, detection of NIS in MPAs may lag introduction by years, if not decades,

and their numbers, as reported by MPA managers, are likely to be grossly underestimated (Abdulla et al., 2008).

Considering the highly connected nature of the sea, a MPA will not be free of NIS unless embedded in an integrated ecosystem management regime, as well as a network of MPAs. The European Union's ecosystem-based 'Marine Strategy Framework Directive' (MSFD) that aims to protect biodiversity in European marine regions acknowledges that NIS represent one of the main threats to marine biodiversity and related ecosystem services, and places the absence of NIS impacts as the second descriptor of 'Good Environmental Status: **"Non Indigenous Species do not adversely alter the ecosystem".** The success of the MSFD is key to achieving the long-term objectives of MPAs. However, management in the Mediterranean Sea is hampered by political, economic and societal fragmentation: only 8 of the riparian countries are EU Member States. The option of implementing European environmental policies in those states alone may seem expedient but piecemeal protection is futile. The crucial element of an effective strategy for slowing the influx of marine NIS into MPAs in the Mediterranean Sea is policy coordination with the Regional Sea Convention ('Barcelona Convention') to ensure consistency in legal rules, standards and institutional structures. Research may ascertain that healthy ecosystems, as those attaining GES, improve both the resistance and the resilience of networks of MPAs also to bioinvasions, but unquestionably prevention remains the best management option. No MPA, for instance, can stop the blooms of the non indigenous ctenophore *Mnemiopsis leyidi*, once they are formed. *Mnemiopsis* devastated Black Sea ecosystems, and was possibly introduced in ballast waters. The containment of *Mnemiopsis* depends primarily on ballast water management. The same is true for all NIS: prevention is the only practical option. Networks of MPAs, however, might play a role in both the management and the study of NIS. NIS should be considered in designing the placement and management of networks of MPAs.

Recommendations concerning threats and bioinvasions

The concept of protection implies that there are threats to the to-be-protected object. Marine environments are subjected to a varied array of threats, categorized in the Descriptors of GES in the MSFD. The objective of MPA networks is to identify threats and remove them, whenever possible.

The stakeholders of this section are mainly the managers of MPAs and MPA networks, the NGOs that focus on environmental protection, local, regional and international policy makers that should implement policies that aim at removing the threats of environmental integrity, the tourist and the fisheries sectors that take advantage from good environmental status to gain their income. The following actions are recommended:

· **Improve knowledge of the distribution and intensity of threats** (e.g. fishery, bioinvasions, marine litter) to reduce uncertainties on their effects. The definition of GES comprises 10 descriptors (in addition to the first one: biodiversity) that cover the array of stressors on both biodiversity and ecosystem functioning.

· **Base large-scale approaches on fine-scale spatial data** and develop shared methodologies and strategies for the management of potential impacts and consequent changes. The extrapolation of few small-scale studies or of low-resolution large-scale assessments often bias large-scale pictures, representing threats inadequately. Fine-scale data, from intensive observation and monitoring strategies, reliably account for the state of the environment.

· **Link threat mapping with specific actions** identified on the base of successful cases of recovery to make better conservation/ management decisions. Once threats are identified, it is important to implement measures aimed at their reduction, leading to environmental restoration. These actions must be taken into account in association with the information about stressor distribution, since remedies that were effective at one location might also be effective at other places. The share of this information is crucial.

· **Prioritise and monitor areas** highly exposed to present/future human pressures, including the consideration of critically dynamic changes (e.g. hot spots of thermal anomalies, invasions by NIS). The high exposure to threats should be followed by mitigation and restoration actions, through

proper management of ecologically coherent marine spaces (e.g. MPA networks).

· **Develop novel tools and strategies** to move beyond the traditional single-threat approach to assess the response of ecosystems to multiple stressors (present and future), identifying key threats to different components of biodiversity and allowing site prioritization for different uses. The MSFD requires, with GES, that neither biodiversity nor ecosystem functioning are altered by human action. Before, human action was requested to remain under presumed thresholds, while considering threats in separation from each other. When acting in synergy, however, stressors can have effects that are not the simple sum of the effects of each stressor.

· **Evaluate early warning indicators** to identify approaching changes in marine biodiversity and ecosystem functioning, supported by biodiversity monitoring methods and the quantification of ecological thresholds. The compound effects of regional and global stressors erode the resilience (the ability of a system to withstand to and to recover from perturbations) of marine systems may cause transitions towards undesired states. The knowledge of "natural history" provides insight in the way ecosystems function. Expert opinions can interpret environmental data and early worning indicators can reveal signs that inform us about the possible onset of events leading to regime shifts.

· **New MPAs should be located away from the regional hubs of vectors and pathways** (i.e. ports, marinas, fish and shellfish farming, and from the major pathway of invasion in the Mediterranean - the Suez Canal)

· **Use MPAs as "sensors" of NIS, with continuous monitoring**, especially in MPAs with high NIS load, near invasion hubs; conduct risk assessment of secondary spread; analyse cost-effective options for long term control of NIS populations. **All-species inventories** have not been carried out at any marine location: it is advisable that the biodiversity of MPAs and of their networks is continuously assessed through focused programmes involving biodiversity specialists. This will allow the early detection of NIS and, even more importantly, will identify inconspicuous NIS that are not immediately perceived by casual observation. Inconspicuous species, in fact, can have great impacts on biodiversity and ecosystem functioning.

· **Consider changes to protection status** (e.g. allowing for eradication measures) if NIS populations adversely affect native natural diversity and risk secondary spread. The eradication of NIS requires destruction of living beings. There might be an apparent conflict between generalized protection and the eradication of NIS populations.

· **Enforce the precautionary principle** until science-validated results are available. Focus basin-wide management on prevention of new incursions of invasion vectors and pathways and, where practicable, on beachhead and hub sites to minimize secondary spread.

· **Inform stakeholders of the scope and status of threats (e.g. bioinvasions) in MPAs**. Discuss management options and commitment of resources for threat control, and possible changes to protection status.

3.2 STEP 2: define spatially explicit management and conservation units

Connectivity underlies marine conservation

These guidelines emphasise the crucial importance of **Connectivity** as the fundamental principle for building coherent networks of MPAs. The demographic linking of local different populations through the dispersal of individuals (also called **propagules**) as larvae, juveniles, adults or asexual dispersive stages (Sale et al., 2005) is key to metapopulation persistence (Botsford et al., 2009). Thus, the existence and the maintenance of connectivity between MPAs are critical to the long-term success of MPA networks, which essentially operate as **complexes of metapopulations** (Roberts et al., 2003). Ensuring connection between MPAs will increase in importance as climate change increasingly impacts the future of marine ecosystems (Munday et al., 2009).

Since MPAs are mainly **coastal** (with the exception, in the Mediterranean Sea, of the Pelagos Sanctuary), connectivity has been mainly been regarded as larval dispersal, disregarding the connectivity

roles of asexual propagules, juveniles, adults and some ontogenetic migrations, or rafting (Figure 8). To understand the effects of dispersal on population replenishment and resilience, it is important to differentiate between (1) "**sustaining**" dispersal: ecologically/ demographically important in maintaining or increasing a local population (Halpern and Warner, 2002) and (2) "**seeding**" dispersal: evolutionarily important in maintaining gene flow and decreasing the long-term probability of local extinction. Sustaining dispersal occurs over **small** spatial scales whereas seeding dispersal occurs over **large** spatial scales. Small populations produce fewer propagules than large populations. As a result, as population size (or MPA area) decreases, the distance over which it can provide both sustaining and seeding dispersal decreases (Figure 9).

Ensuring that MPAs in a network are connected to one another via propagule dispersal is, all else being equal, largely a function of **spacing** between MPAs and of the **biology** of the species forming the species assemblages inhabiting them. Since small populations/MPAs produce fewer propagules than large populations/MPAs, the spacing between small MPAs needs to be **smaller** to ensure connectivity between them. This can be achieved by **decreasing the distance** between MPAs, either by **increasing the size** of individual MPAs (leading to overlaps) or by **adding more MPAs** to the network (Figure 10). Many MPAs in the Mediterranean Sea, however, protect unique places that are **not homogeneously distributed**, so these principles of how to arrange MPAs in space are not always applicable, unless connectivity is **enhanced** through proper management.
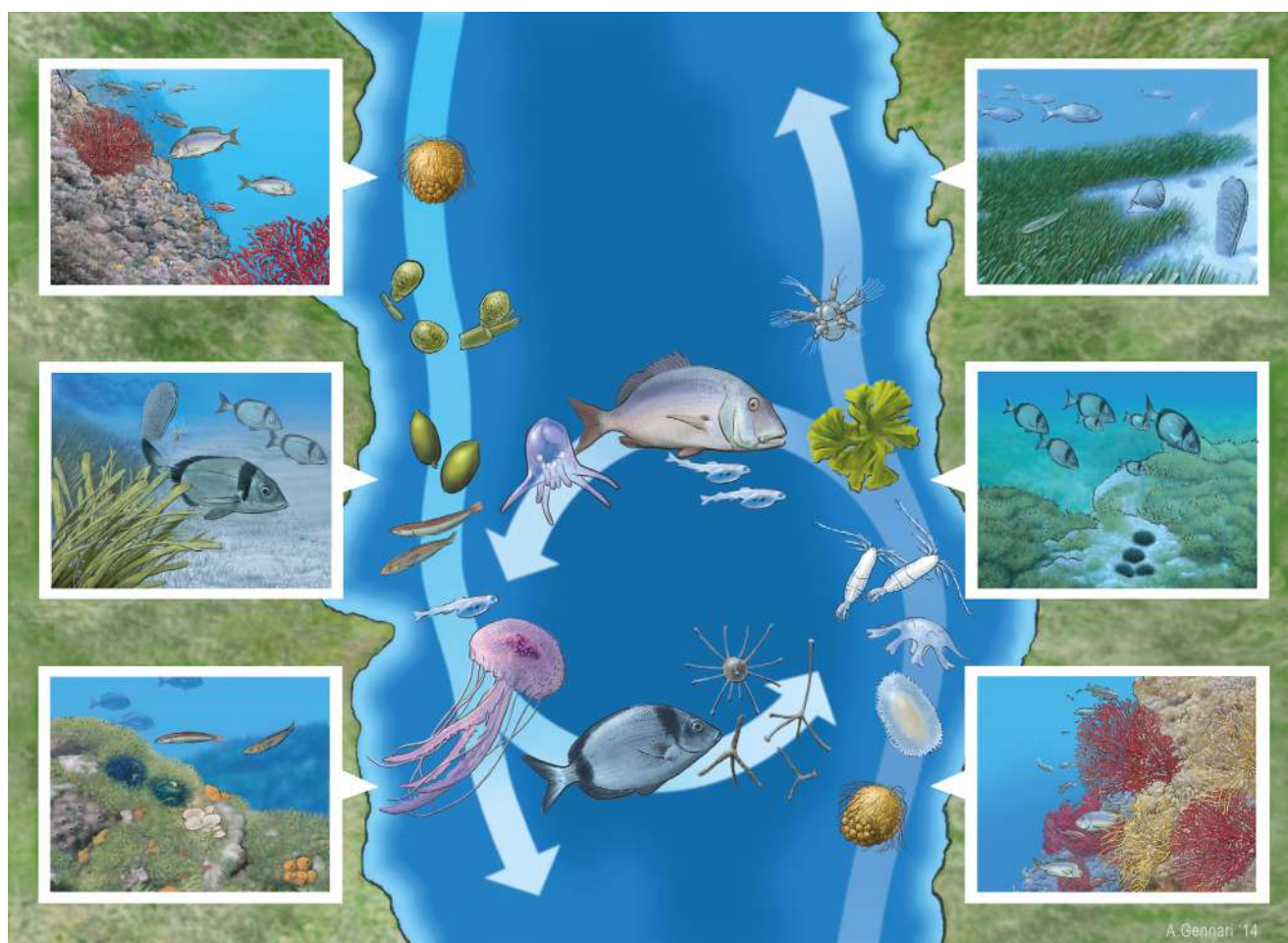

Figure 8. Connectivity with several propagule types (concept: F. Boero; art: A. Gennari)
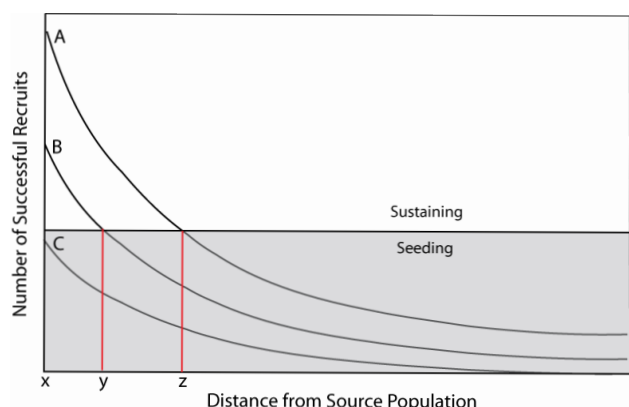
Figure 9. Hypothetical dispersal kernels for three populations (A, B and C) that differ in size. The horizontal line differentiates between ecologically-important sustaining dispersal and evolutionarily-important seeding dispersal. As population size decreases (A→C), the distance over which it provides sustaining dispersal decreases (z→x), and the distance over which seeding dispersal occurs may decrease as well. Population C is too small to provide any sustaining dispersal. After Steneck et al. (2009)

Determination of connectivity

Connectivity is widely recognized as an important process in sustaining biodiversity, but until now we have had to use simple rules of thumb about spacing, developed largely without empirical evidence, to account for connectivity in MPA network designs (McCook et al., 2009). Historically, it was assumed that **oceanographic conditions** (currents and tides) played a dominant role in determining how far and to where propagules disperse.

While oceanography clearly does play a role, the last several decades of research on **pre and post-settlement processes** (Fraschetti et al., 2003) have demonstrated that propagules are not all passive particles, but instead display a range of sophisticated behavioural, sensory, swimming and floating abilities that allow them to influence species dispersal (Dixson et al., 2008; Dixson et al., 2011). Indeed, the occurrence of **self-recruitment** in species with planktonic larval durations of ~30 days demonstrates this fact; models that assume passive transport of propagules by currents and tides predict little or no self-recruitment, and certainly not at the levels observed in recent studies. As a result, **oceanographic conditions are unlikely to fully explain dispersal patterns**, but instead **interact** with a host of ecological, environmental and behavioural factors to
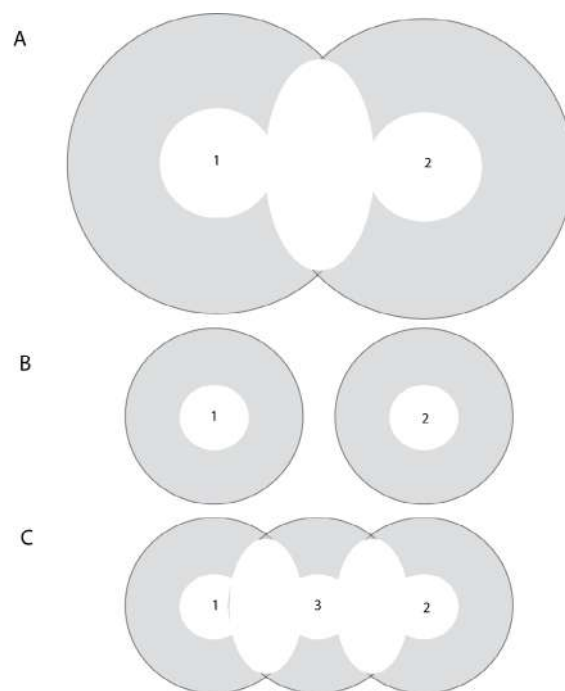
Figure 10. Simplified conceptual model illustrating the effect of MPA size and spacing on connectivity in a MPA network. In each diagram, numbers (1-3) designate the centre of the MPA, white space the distance over which ecologically-important "sustaining" dispersal occurs, grey space the distance over which evolutionarily-important "seeding" dispersal occurs. A. Spacing between two relatively large MPAs appropriate to insure sustaining dispersal between them. Note that the area of overlap of the seeding dispersal kernels for the two MPAs may or may not be sustaining. B. 50% smaller MPAs than in A but the same distance apart. MPA populations are smaller, producing fewer propagules, thereby decreasing the spatial scale of dispersal resulting in no connectivity between them. Re-establishing connectivity between small MPAs can be accomplished by decreasing the distance between them or C the addition of a third small MPA to the network. After Steneck et al. (2009)

determine the processes that realize connectivity. Connectivity measures the possibility of **propagule exchange** (i.e. **the bodies with which species propagate themselves, ranging from larvae, to adults, to fragments**) among different populations across a defined space. It can be measured from single species to entire communities. The physical features of the medium (defined by oceanography) influence each species in different fashions. The networks should comprise spaces that are highly connected (i.e. in which connectivity is high for a significant number of species).

In CoCoNet, considering the works developed in the last several decades, we investigated a wide variety of methods to understand connectivity, underscoring the importance of such information for achieving sustainable fisheries and conserving biodiversity. Four determinants were selected for detailed investigations to evaluate the degree of connectivity relevant for networks as described below.

1. **Currents**. The pattern of currents is the first and most important motor of connectivity but also the most variable and complex to predict. Currents can vary, according to seasons and other pluriannual fluctuations; they involve upwellings, fronts, downwellings, gyres and eddies, all contributing to connect or isolate regions, but characterized by some **temporal instability**. If currents would explain everything, biodiversity should be **equally distributed**, in all its facets, according to current patterns. The study of nature tells us that it is not so and that there is a high degree of **heterogeneity** in the way connectivity takes place.

2. **Propagules**. The presence of propagules in the water column is a necessary condition for transport and further potential successful connectivity. **Propagules are not inert particles**, passively transported by currents.

3. **Beta Diversity**. The **share** of species among various habitats of the same kind is informative about the degree of connection across habitats. If the same habitat (low beta diversity indicates high connectivity) type has **many species in common** (say 80%) at two separate locations, there is reasonable indication that the two locations, and their habitats, are **highly connected**.

4. **Genetic diversity**. The higher the **similarities** at genetic level, the higher the **connections** among the populations of investigated species at various investigated locations; and in that sense genetic differentiation is an indirect outcome of barriers to connectivity.

Oceanography/propagules are components in a **process-oriented** life-history approach assessing potential connectivity, connectivity variability and the sensitivity of connectivity to e.g. climate changes and direct anthropogenic impacts. **Beta diversity/genetics** are **pattern-oriented**, being

indirect and direct measures of past and realized connectivity, respectively. Together, they form an **integrated scientific suite** for connectivity assessment. The following procedures describe the CoCoNet approach to the evaluation of the four descriptors of connectivity.

Oceanography

Currents are the main driver of connectivity: the dynamics of the transport of passive particles through the movement of water (currents) is the starting point of connectivity evaluation (the null hypothesis that should lead to a homogeneous distribution of species according to current patterns). **A detailed and dynamic assessment of mesoscale currents is a prerequisite for any network design** (Carlson et al. 2016). Species reproduce in specific seasons, and currents are often subjected to seasonal changes. Matches and mismatches of physical and biological phenomena within a seasonal framework can explain the observed patterns of biodiversity distribution and the processes determining them.

However, **it is important to consider life trait-based variables in simulations with passive particles**. Averages of trait-based simulations from/to specific habitats do not correspond to the simulation of average water particles. If currents were solely responsible for connectivity, all the species in a given circulation pattern would disperse in an identical way, resulting in identical distributions for all species. This is not what we observe, even when habitat distribution is conducive to the presence of some species (i.e. the same habitat type, at different locations, instead of having the same set of species, can host different species assemblages) so species respond in different ways to the distribution potential of current regimes. The realized distribution of species across vast marine spaces, through current patterns, depends on the timing of reproductive processes, coupled with propagule features and pre- and post-settlement biotic interactions.

It is also necessary to **specifically address coast/offshore/deep sea exchange processes**. These are often disregarded due to the complexity of coastal dynamics, where turbulence plays a major role. General current patterns (e.g. the Gibraltar Current, the Intermediate Levantine Current, the cascading phenomena due to the influence of the
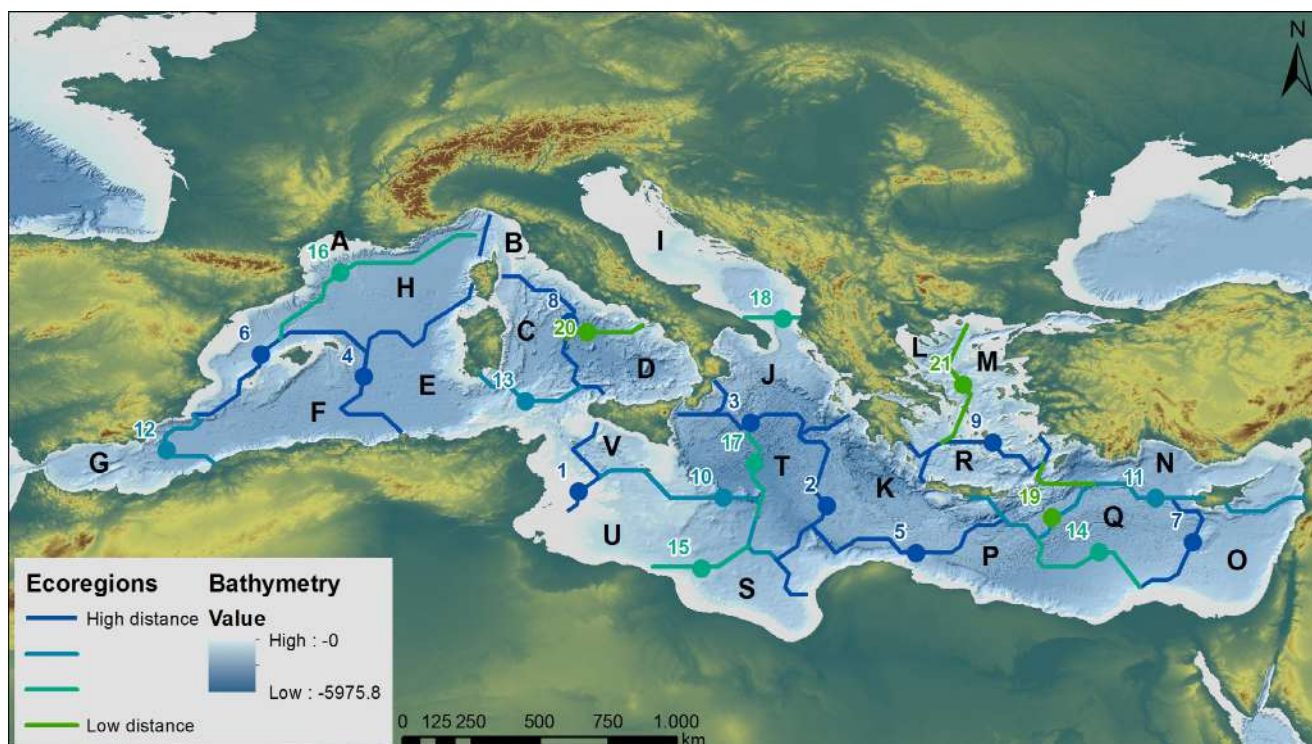
Figure 11. A connectivity-based regionalisation of the Mediterranean Sea (Berline et al., 2014 – CoCoNet work). Each boundary is colored and numbered according to the cut-off distance obtained on the dendrogram (from blue – high distance- to green low distance). Each region is identified by a letter from A to V. Most boundaries parallel to permanent currents. Some boundaries parallel to salinity/tracer fronts. Consistent with current expert knowledge of species biogeography

| Batumi, BaE | Crimea, CE | Kerch, KeE | Sevastopol, SeE | Caucasus, CaE | Eastern Gyre, EG | Rim current, RM | Sukhumi, SE |
| Bosphorus, BE | Danube, DE | Kizilirmak, KE | Sinop, SiE | Costantsa, CoE | Kali-akra, KaE | Sakarya, SE | Western gyre, WG |

Figure 12. General circulation features adapted for Korotaev et al. (2003)
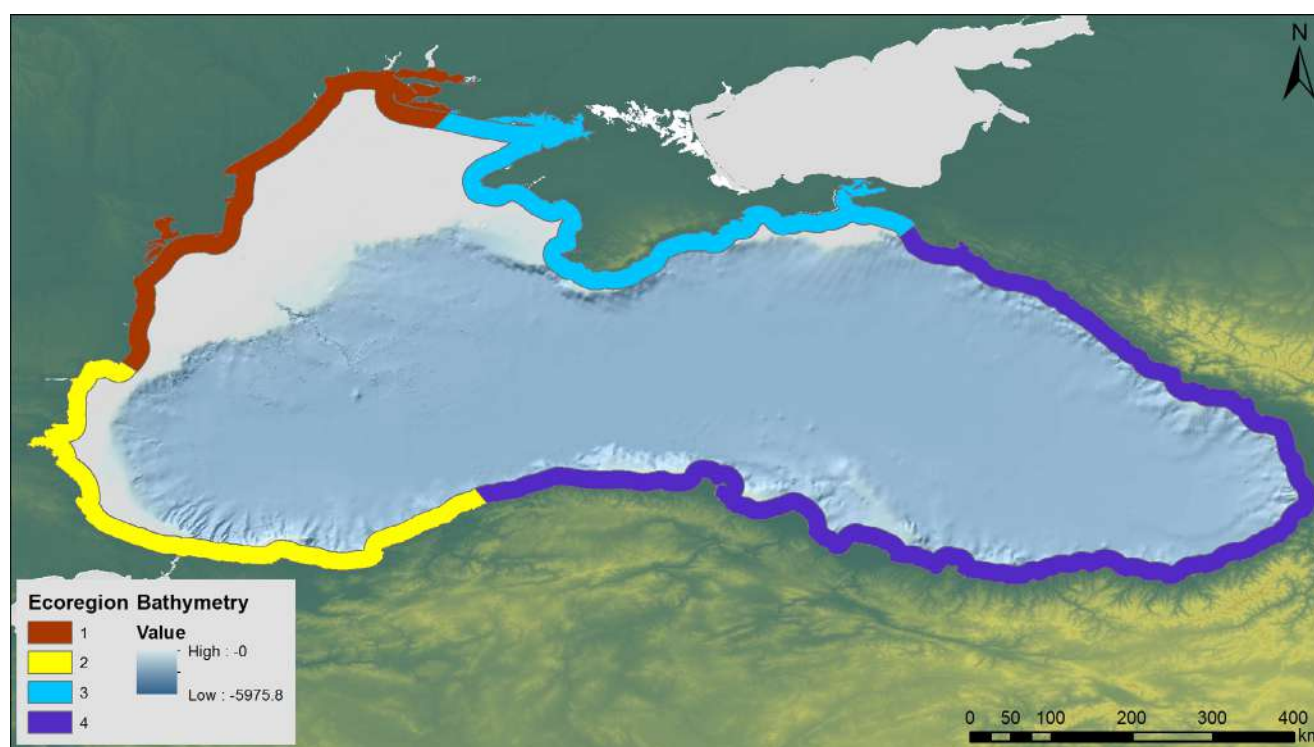
Figure 13. Clustering trend with pelagic phase of 10, 30, 50, 70, 90 days. Colors indicate the extent of coastline habitat clusters (CoCoNet work). For the Black Sea we found the eco-regionalization to be species (trait) dependent, and the figure below is an example. However, our meta-analysis indicated that meso-scale oceanographic features (in our case gyres) were sculpting eco-regions

cold engines) are well known and modelled. These circulations are mostly typical of offshore areas. The irregularities of the coasts (e.g. promontories, capes, inlets, straits, etc.) and of the sea bottom (e.g. canyons, sea mounts, trenches, etc.) determine local situations in which the general circulation patterns might be much altered. These alterations occur at the scale of organisms and are of extreme ecological importance. Canyons, for instance, connect coastal systems with the deep sea and cause intensive production rates. Capes and promontories, moreover, often determine eddies and gyres, connecting coastal with offshore systems. These small scale and mesoscale phenomena occur at ecologically meaningful scales, they are highly variable in time and need to be properly described, understood and modelled, leading to couple physical and bio-ecological processes.

In addition, **extreme events** (storms, sudden temperature changes, etc.) must be considered since they may change connectivity if they either match or mismatch propagule availability. Irregular and extreme phenomena can connect areas that are usually separated by "normal" current regimes. If the timing of propagule production matches with these events, species can disperse in apparent discordance with prevailing 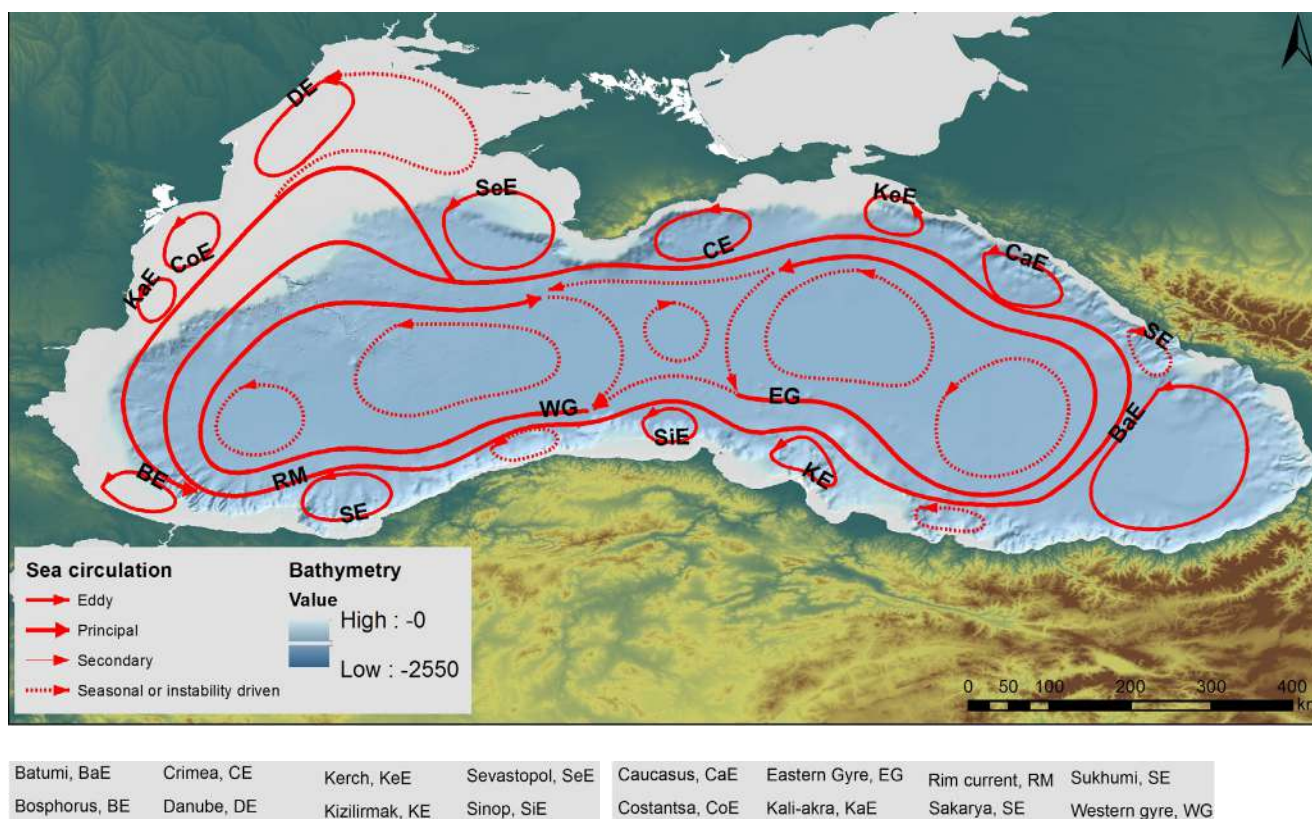water movement. Storms can lead to high fragmentation rates, leading to dispersal of asexual propagules that can travel for very long distances, especially if settled on natural (e.g. drifting algae) or artificial (e.g. floating debris) rafts.

An example of a possible ecological partitioning of the Mediterranean Sea is illustrated in Figure 11. The figure shows a snapshot of currents in the Mediterranean Sea (model output from the joint MIT/JPL project: Estimating the Circulation and Climate of the Ocean, Phase II or ECCO2 (http://ecco2.org/).
Based on oceanographic data (Figure 12) and new modelling involving biological features we end up proposing **five coastline units for the Black Sea** (Figure 13).

Propagules

The **pathways, vectors and impacts of propagule**

pressure of a vast array of species are fundamental to the management of ecosystems. Propagule pressure considers the existence of sets of species living in a given area and that produce propagules that might lead to the colonization of another area, in the presence of conditions that are conducive to dispersal (e.g. canals, unidirectional flows, changes in environmental conditions that favour possible invaders). A good knowledge of species composition in different areas, coupled with a good knowledge of the dispersal potential of each species, is a prerequisite to the understanding of biodiversity distribution.

The **design MPA networks should aim to maintain and encourage indigenous propagule pressure within the network** and control/ monitor non-indigenous propagule pressure. Indigenous propagule pressure promotes dispersal through the network. High gene flows across vast areas lead to healthy populations, whereas isolation can lead to genetic bottlenecks that might be the prelude of local extinction. The exchange in propagules across each network, therefore, must be assessed and encouraged. Following this logic, it may be that the presence of OWFs might enhance connectivity, the basal structures acting as stepping-stones across separated sites. Propagule pressure by NIS is, instead, conducive to alterations in biodiversity composition that might alter ecosystem functioning in negative ways (also by using OWFs). It is then advisable to monitor the corridors and crossroads of NIS introduction, such as harbours, canals, aquaculture farms, etc.

It is necessary to **protect and manage species throughout their life cycles**. Fish occupy different spaces during their life histories: spawning grounds, nursery areas, and feeding grounds. Many species are both benthic and pelagic, in different phases of their life cycle. The knowledge of **life cycles** (the various stages in which species occur) and **life histories** (the timing of reproduction and the quantitative assessment of reproductive processes, in terms of number of eggs, embryos, larvae, juveniles and adults produced by each female) allows managing and protecting species in an integrative fashion, leading to efficient actions. It is not correct to consider species as "adult only", disregarding other life cycle stages. Larval and juvenile mortality is not constant and determines the viability of adult populations. The habitat of a species comprises the various habitats in which it lives during its whole life cycle: protecting

one without protecting the others might lead to mismanagement.

The need to consider asexual propagules is important in clonal species (algae, sponges, cnidarians, bryozoans, ascidians) that, on hard substrates, are the main habitat formers. Connectivity studies usually consider larvae as the main propagules. This is mostly the case for individual organisms (i.e. those that are not able to produce colonies by clonal reproduction), whereas clonal species (most sessile animals and plants) propagate not only through larvae but also as fragments that break off the colonies. Many species produce specialized asexual propagules. Asexual reproduction is underestimated and must be included into connectivity studies also considering that some important non indigenous species (e.g. many invasive algae) spread in this way.

Beta-diversity

Beta diversity is the best measure to evaluate marine biodiversity, the first descriptor of GES. Alpha diversity accounts for the species pool at a given locality (local diversity), whereas Gamma diversity focuses on the species pool of a large region (regional diversity). Beta diversity describes how many distinct speciesn inhabit the same or different habitat types, measuring the level of differentiation of biodiversity across a region. Beta diversity is low if, at several locations placed at different distances from each other, the species composition within the same habitat type is the same, or very similar. This supports the hypothesis that habitats of the same type are highly connected across locations, and that propagule exchange leads to similar species composition across a given space. Beta diversity increases, suggesting a lower flux of propagules across different localities when the set of shared species, within the same habitat, decreases.

Extend beta-diversity analyses to multiple habitats and assemblages. The analyses conducted in the Pilot Projects were focused on a common benthic habitat, because MPAs are mostly defined on the features of benthos. The shift from areas to volumes and from habitats to ecosystems, however, calls for more thorough appreciation of beta diversity, extending investigations to the whole set of habitats that are comprised in a given ecosystem.

Genetics

Genetic diversity can be used as a proxy of fragility (i.e. vulnerability) of target sites for conservation. Connectivity assessments across populations show whether subpopulations from each MPA act as real metapopulations in the network. The identification of metapopulations (i.e. assemblages of populations, each inhabiting different localities) defines the units of management and conservation of target species, whose genetic make-up should be elucidated with the greatest care. If connections are insufficient, gene flows across populations are low: the genetic fragility of isolated populations can be the prelude to local extinction.

Genetic studies are often focused on commercial species (i.e. fish) or on charismatic species (i.e. marine reptiles and mammals) only. **For MPAs it is important to focus on target species with significant ecological roles**, i.e. choose habitat formers to assess connectivity and to explain habitat heterogeneity (the protection of habitat formers is crucial to protect the whole habitat). The functioning of ecosystems and the structure of habitats depend on a great array of species and the representatives of each functional units must be investigated from a genetic point of view, so as to have a more reliable picture of the state of the populations that make up communities, form habitats, and ensure the viability of ecosystem functions.

Similarly, it is **important to study the genetics of species that encompass different levels of vagility** (i.e. the possibility to reach other places with own propagules) since their propagules at a given place have different possibilities to colonize other locations. Gene flows depend on the possibility that individuals of a population can reproduce with individuals of other populations. Vagility is not identical for all species. The populations of low-vagility species should be more isolated from each other than those of high-vagility species. The choice of species for genetic analyses, does not represent the overall gene flow (and hence the connectivity) across different locations, comprising species with very different features, in order to explore the complexity of connectivity phenomena.

The holistic concept of Cells of Ecosystem Functioning

Previous divisions of marine space into presumably homogenous "regions" were based on important features that range from physics to biogeography, focusing on single components: the deep and the high seas are considered in isolation from each other and from coastal systems; the sea bottom and the water column are considered as separate entities; fisheries are extracted from the ecosystems that sustain the stock. Current measures of diversity in terms of species distribution identify homogeneous ecoregions inhabited by species assemblages that differ from those of neighbouring ecoregions. This definition of ecoregions is based mostly on patterns.

MPAs depend on the functioning of larger systems. An MPA-focused management copes with direct impacts inside the protected area, but cannot prevent external impacts (e.g. pollution, and coastal development outside the MPA). Furthermore, indirect impacts such as global warming, the arrival of Non Indigenous Species, or marine litter carried by the currents, call for larger-scale management. CoCoNet proposes a "holistic perspective" and expands protection and management to the space across single MPAs, through the establishment of networks. Ecological processes take place in a volume and organisms move into it and take energy from it: the bottom and the water column are functionally connected and must be considered as a whole. Marine currents connect Marine Protected "Areas" (or, better: "Volumes") and realize connectivity within systems in which benthic and pelagic communities interact.

Based on the appreciation of functional links across the artificial compartments in which we divide the marine realm, CoCoNet introduces the concept of **Cells of Ecosystem Functioning** (CEFs) as ecological units defined by coherent features. The concept of CEFs was elaborated by Boero (2015) and was widely embraced by the CoCoNet consortium during two Synthetic Workshops. The idea inspired the proposal of working in the CoCoNet pilot sites using an **integrated approach** comprising a state-of-the-art suite of tools and models (i.e. oceanography, genetics, beta-diversity and propagule dispersal) that, usually, are used in isolation from each other.

According to the CEF approach, some water masses

are more connected with each other than with other portions. Their homogeneity contributes to the connection of benthic habitats and, altogether, these tightly connected spaces can be considered as Cells of Ecosystem Functioning, both at benthic and pelagic scales. At a smaller scale, the sea bottom topography and the coastline define sub-regional dynamics that do have coherent features: marine canyons are characterised by upwelling currents that trigger phytoplankton production, nourishing the coastal systems (coupled with terrestrial runoffs), whereas coastlines can enhance the formation of gyres and eddies that define specific functions due to concentration phenomena. Vertical phenomena are reduced in the Black Sea, due to anoxic conditions below the surface waters, and the CEF are mostly driven by horizontal circulation (eddies). The definition of CEFs, and of their interconnections, is based on the work of CoCoNet and needs further validation, due to lack of integrative approaches linking the current regimes and the functioning of ecosystems at various temporal and spatial scales.

The physical drivers of the Cells of Ecosystem Functioning

Each basin (in this case the Mediterranean and the Black Seas) is featured by large scale features that regulate its functioning. The physical driver, studied by oceanography, is of crucial importance in determining cells, as described in Figures 14 and 15. Each basin (in this case the Mediterranean and the Black Seas) is featured by large scale features that regulate its functioning. The Mediterranean, for instance, is a miniaturized ocean that can be divided into coherent fractions. The difference in salinity with the Atlantic Ocean triggers a superficial current that enters from Gibraltar and flows to the very end of the Eastern Mediterranean (the **Gibraltar Current**, depicted in orange in Figure 14). Mediterranean waters flow back in the Atlantic as **Intermediate Levantine Current** (depicted in light blue in Figure 14). This flow affects the whole basin defining it as a large body of water. The two currents, however, influence a layer of water that is only 500 m deep. The average depth of the Mediterranean is 1500 m, so the deep part of the basin would suffer from lack of exchange, especially in terms of oxygen supply from the surface. This is compensated by deep-

water formation in the three **cold engines** of the Mediterranean (the Gulf of Lions, the Adriatic, the Northern Aegean).

The sinking of dense waters from the cold engines (light blue arrows and spirals in Figure 14) brings oxygen in the deep sea with a **cascading process** that often occurs through **canyons** (inset A in Figure 14). The water that sinks pushes up deep water (the spirals in Figure 14). The canyons that are not interested by cascading are often generating **upwellings** (inset B in figure 14). **Eddies** and **gyres** (inset C in Figure 14) generate horizontal currents, often determined by the features of the coast and by winds. The basin-scale processes (e.g. the Gibraltar and Levantine currents) are coupled with sub-basin scale processes (the cold engines) and then to even smaller scale oceanographic processes (gyres, eddies, fronts, up and downwellings generated by the features of either the sea bottom or the coast and the prevailing winds).

It is also important to realise that the **history** of the Adriatic and of the Black Sea ecosystems (Figure 15) shows that **stability** does not exist.

Ecosystems change and **evolve**, sometimes due to our direct (e.g. overfishing) or indirect (e.g. global warming, or alien species transport) impacts, sometimes due to organic evolution. The history of life is a **history of change**. It is extremely important to be aware of this feature of living systems, since management and conservation must **state objectives** and if we expect that nothing will change, our objectives will surely not be met.

Identification and role of CEFs for MPA networks

The studies on connectivity, based on the four approaches explained above, identify the drivers that define coherent ecological units. The **holistic approach** that combined the reductionist views of each of the four analyses showed that **oceanography and propagules account for potential connectivity**, while **beta-diversity distributions account for realized connectivity**. Additionally, the distribution of **genetic variability** provides information on the **history of connectivity** that was realized over large temporal scales within the CEFs, thus reflecting the evolutionary history of populations of selected species.

CEFs integrate these approaches from a

functional point of view, based on the efficiency of connectivity: a CEF includes a set of pelagic and benthic habitats that are more connected with each other than with those of neighbouring Cells. **CEFs can equally comprise portions of the high sea, the coast or the deep sea, and are defined both by physical circulation and by the response of the ecosystems to its effects**. The CEFs might have even different extensions for different species, according to their **vagility**. If particular species are to be managed, for instance commercial fish, their use of the **ecospace** must be carefully assessed, both in space and time. **Nursery areas, spawning grounds and feeding grounds** might be different for different species, calling for different management initiatives (e.g. the closure of fisheries in certain periods). Thus, CEFs will

allow ecoregions to be further defined from the point of view of ecosystem processes, leading to sounder units of management and conservation.

The putative **Cells of Ecosystem Functioning (CEFs)** identified in Figures 12 and 13 are the potential units of conservation, whose coherence needs to be tested at both biological and ecological levels. These reconstructions of CEFS, however, consider only horizontal current patterns. The presence of canyons, with upwelling and downwelling phenomena, can lead to specific conditions that, on a small scale (e.g. the coastward mouth of the canyon with the ensuing upwelling current), can have a large influence on ecosystem functioning. The holistic exploration of the water column and of its relationship with the coast and the bottom, in order to define first physically and
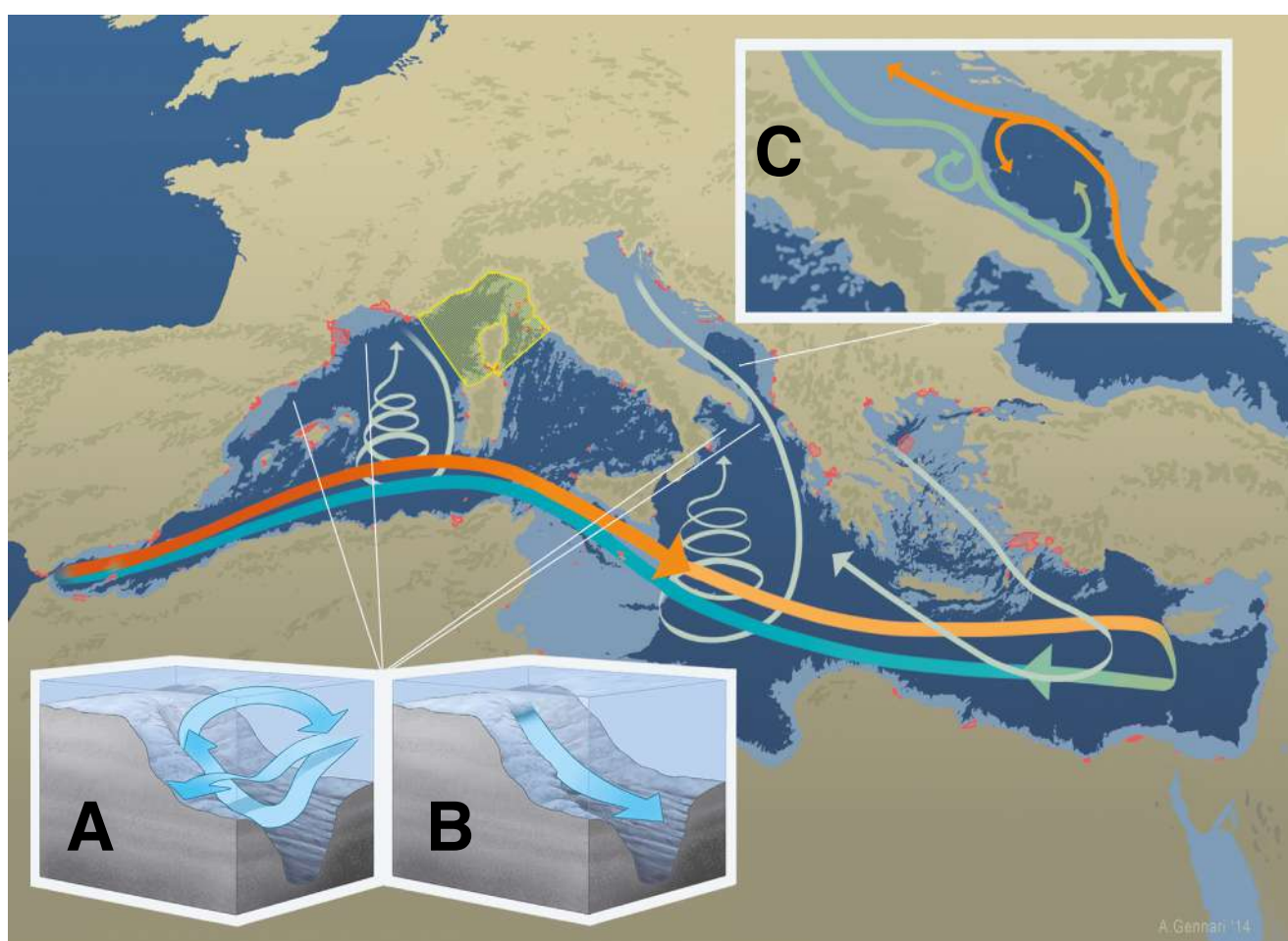

Figure 14. The main circulation patterns of the Mediterranean Basin (artwork: Alberto Gennari)

Figure 15. Both the Adriatic Sea (left) and the Black Sea (right) are characterized by the presence of gyres and eddies that can be considered as putative CEFs. The history of the two basins, with a series of phase shifts, is crucial to understand their current status (Concept: F. Boero; Art: A. Gennari)

then bio-ecologically the CEFs, is still in its infancy and will have to be developed much in the future.

In order to create a network of MPAs, it is advised to identify **coherent flow regions with a high connectivity potential**. These coherent flow regions need to be singled out, as well as the **boundaries** between neighbouring cells. The cells exhibit a **broad variability** in terms of size, boundaries, hydrographic conditions, temporal persistence, possible interactions and/or merging with neighbouring cells. As mentioned above, their main features may range from basin-scale conveyor belts, local sub-basin circulations, mesoscale and submesoscale patterns, temporal variability from decadal to episodic events, typically associated with atmospheric forcing.

Conversely, each network of MPAs must be nested into a CEF, the MPAs being nodes of a complex continuum. Each MPA has specific targets, based on the peculiarities of biodiversity expression within the CEF. The objective of MPA networks is more general than that of MPAs and conveniently coincides with Good Environmental Status, as defined by the MSFD. CEFs, and the networks of MPAs nested therein, are the explicit spaces where management must lead to GES. The legal framework is expressed in the MSFD: all EU states are committed to reach GES by 2020.

The functioning of ecosystems

The definition and measurement of the functioning of marine ecosystems is still rather poorly known and is to be nested into circulation patterns so as to better define the Cells of Ecosystem Functioning.

Figure 16 depicts the main processes that determine the functioning of marine ecosystem. The black circle represents **dead organisms** (from black arrows), that can be incorporated in the sediments (**carbon sink**) or be fed upon by heterotrophic bacteria (the yellow arrows represent a passage across trophic levels), in their turn killed by viruses. Protozoans eat bacteria (and other microscopic beings). The bacteria mineralize the constituents of formerly living matter (white arrows) making them available to primary producers, mostly microalgae: the phytoplankton. This **microbial loop** sustains the rest of the food webs. From the microbes, matter can flow along four main pathways. The shortest one is on top right: microbes prevail, with **algal blooms** that monopolize the standing biomass, even poisoning the other life forms. The most familiar pathway involves **metazoan grazers and vertebrates**. Crustaceans feed on microbes and, in their turn, are the food of larger organisms, first of all fish larvae and juveniles. Once crustaceans and fish grow up, they tend to feed on each other (big fish eat small fish) and, eventually, we feed on them. A third pathway sees the **herbivorous gelatinous plankton**: the thaliaceans "suck" all microbes and deprive crustaceans from their resources, to become marine snow shortly thereafter. The fourth pathway is represented by **carnivorous gelatinous plankton**: jellyfish and ctenophores eat the crustaceans, and also the fish, when they are eggs and larvae. This is what happens in the
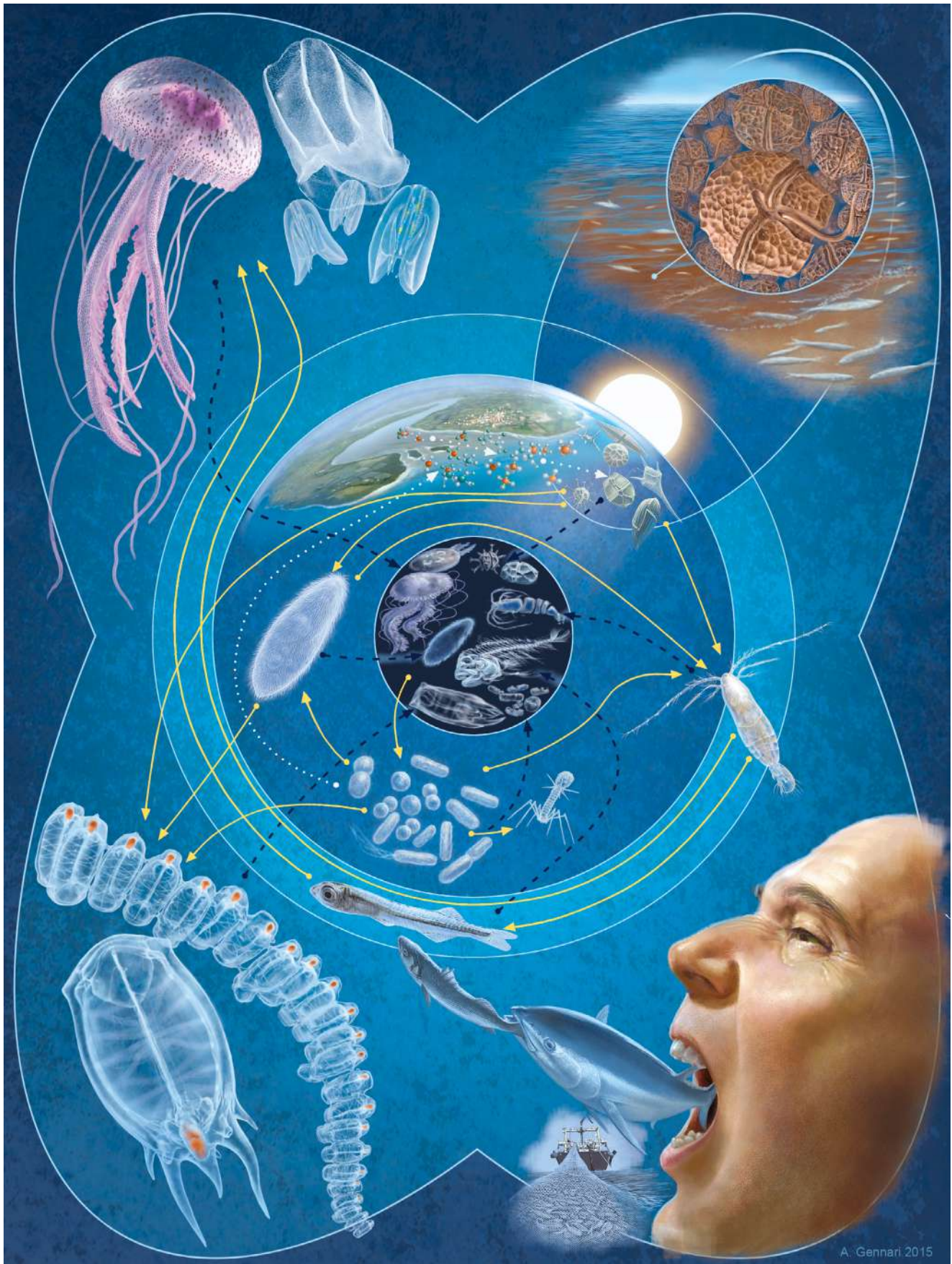
Figure 16. The four main pathways of ecosystem functioning in marine ecosystems (see text for explanation. Concepts: F. Boero; Art: A. Gennari)

water column, the most widespread environment of the planet, the driving machine of all ecosystems. It is our interest to ensure that the fish pathway prevails over the others, but it is inevitable that the other three pathways, every once in a while, prevail over fish.

Holistic conservation and management

The components of marine ecosystems have been studied as separate entities by distinct groups of scientists, and their role in making ecosystems function has not been explored in its entirety. The CoCoNet Pilot Projects showed that **connectivity** is very high into the cells where field work was conducted (the Southern Adriatic and the Western Black Sea) but also showed that they are **connected with neighboring** cells (Figure 8). The **cold corals** that thrive in the Southern Adriatic, for instance, do survive due to the influence of the **cold engine** of the Northern Adriatic and are sensitive to possible threats that might impact on the whole Adriatic basin, since the **cascading** connects the three Adriatic cells along the sea bottom, whereas the **currents parallel** to the two coasts connect them in shallow water. The three Adriatic cells, thus, represent three **units of conservation** (Figure15). Each requires to be managed in a consilient way, since each cell is ecologically coherent and represents the **smaller scale of integrated conservation**. The MPAs in each cell represent **sub-units of conservation** that deserve attention due to **specific expressions of biodiversity**. They must be managed and protected in particular ways, depending on the features of the bio-ecological systems they host inside. This is in accordance with the vision of the **Habitats Directive**, but the new vision of **Good Environmental Status** requires that biodiversity is to be safeguarded through an **efficient functioning of the ecosystems**, and this calls for the inclusion of the MPAs into **larger-scale portion**s of the marine space: the **Cells of Ecosystem Functioning**. The networks of MPAs, thus, must coincide with the CEFs.

3.3 Step 3: identify networks and priority areas

Linking habitats, threats and costs to set conservation priorities

The **concept of CEF**s was not developed when CoCoNet was proposed and is **one of the most relevant outcomes** of the whole project, with a pivotal role in the proposal of the guidelines for establishing networks of MPAs in the Mediterranean and Black Seas. Taking this into consideration, such prospective would lead to combine several previous prospective regarding the Mediterranean and the Black Seas. Each one of these cells has its own specific characteristics and can be considered as relatively isolated from adjacents ones due to physical boundaries (fronts) that avoid a fluid exchange of propagules. The cells are to be considered thus as the true biogeographical regions, each one with its own biological features. Following Boero et al. (2005) and Boero (2015) suggestions, **each of these cells should contain, at least, a MPAs network** in order to preserve the main habitats of each CEF.

Although the CEF approach provides a coherent framework, setting conservation priorities in the Mediterranean Sea is a challenge (UNEP, 2012; Coll et al., 2010, 2011; Mouillot et al., 2011; Oceana Mednet, 2011; Fenberg et al., 2012; Giannoulaki et al., 2013). Several research institutes and groups contributed to fill the gaps in the protection of the Mediterranean and the Black Seas (Table 1).

These proposals consider different aims, conservation features and priorities, invariably stressing the need of passing from single MPAs to networks. Fine scale resolution data on habitat distribution, costs associated with management/ conservation initiatives, and potential threats have to be integrated to support this process. The use of spatial tools such as Marxan, a freely available software (http://www.uq.edu.au/marxan/) are particularly effective in conservation planning thanks to a GIS-based input of a complex variety of information, an efficient algorithm to select protected areas, a flexible interface including considerations on extension and costs of protection and on levels of biodiversity that need to be protected. By encouraging stakeholder participation at all levels, Marxan represents a rigorous approach to MPA design for a diverse

Table 1. Proposed conservation plans in the Mediterranean Sea (Micheli et al., 2013b)

Name of Initiative	Type of Organisation	Motivation	Approach1	Criteria	Planning Tool	Reference	Map viewable in Figure	% included (of tot Med Sea Area)
WWF MedPO/13 key Mediterranean marine areas in need of protection	NGO	unsolicited	Biodiversity driven, Threats	**Biodiversity (species distribution and habitats)**: monk seal, marine turtles, species of whales and dolphins, seagrass P. ocenica and sea-bed heterogeneity to estimate fish species diversity **Threats**: Pollution, urbanization (large harbours and coastal cities)	GIS, Gap analysis	awsassets.panda.org/downloads/ background.doc, 1998	2. a	24%
GFCM/Fisheries restricted areas	Scientific committee for fisheries (MED)	requested scientific advice	Biodiversity driven (emphasis on the conservation of fisheries resources)	**Biodiversity (habitats)**: deep sea sensitive habitats; spawning aggregations	Expert judgement	Recommendations GFCM/2005/1, GFCM/ 2006/3, GFCM/33/2009/1	2. b	58.5% (FRAs: 0.7%; trawling ban >1000m: 57.8%)
Greenpeace/Marine reserves for the Mediterranean Sea	NGO	unsolicited	Biodiversity driven	**Biodiversity (species distribution and habitats)**: Distribution of species (including whales, dolphins, seals and fish); important areas for marine species (such as spawning grounds, nursery areas and nesting beaches); important habitats (such as seagrass meadows); **Geological**: seamounts **Previous initiatives**: SPAMI and Natura 2000 sites	Expert judgement, GIS, quantitative analysis	http://www.greenpeace.org/france/ PageFiles/266559/marine-reserves-med.pdf, 2006	2. c	54.5%
ACCOBAMS/Existing and proposed MPAs for whales and dolphins in the Mediterranean and the Black Seas	Regional Scientific Agreement	unsolicited	Biodiversity driven, qualitative consideration of threats	**Biodiversity (species distribution and habitats)**: Critical habitats for Cetaceans (e.g. feeding and breeding areas); **Oceanographic**: upwelling areas; Geological: canyons	Expert judgement	http://www.accobams.org/images/stories/ Guidelines/mpas%20guidelines.pdf, 2007	2. d	13.5%
Vulnerable habitats	Scientific cooperation	unsolicited	Biodiversity driven (emphasis on the conservation of fisheries resources)	**Biodiversity (habitats)**: Protection of Essential Fish Habitats (spawning grounds, nursery areas, migration routes) and Sensitive Habitats (deep-water corals and cold hydrocarbon seeps). **Geological**: seamounts, canyons	Expert judgement	De Juan and Lleonart 2010	2. e	11.3% (9.6% pelagic; 1.7% demersal)
UNEP MAP RAC-SPA/ Important sea birds areas	Inter-governmental body	Requested scientific advice	Biodiversity driven	**Biodiversity (species distribution)**: seabird species richness and vulnerability **Oceanographic**: bathymetry, sea surface temperature, sea productivity (Chlo-a) **Geological**: seamount proximity, shoreline	Expert judgement, quantitative data and GIS	UNEP MAP-RAC/SPA, 2010. Carboneras and Requena, 2010.	2. f	40.9%
UNEP MAP RAC-SPA and EU/Ecologically or Biologically Significant Areas (EBSAs)	Inter-governmental body	requested scientific advice	Biodiversity driven	**Biodiversity (species distribution and habitats)**: Marine birds, cetaceans, monk seals, marine turtles, sharks, bluefin tuna, deep-sea coral reefs, coralligenous facies, white coral communities, commercial pelagic fishes (spawning and nursery areas); **Oceanographic**: bathymetry, primary productivity, SST; **Geological**: seamounts, canyons, mud volcanoes, hydrothermal vents; **Previous initiatives**: Fisheries Restricted Areas (GFCM); UNEP MAP RAC-SPA/Important sea birds areas	Expert judgement, GIS	UNEP-MAP-RAC/SPA, 2010. UNEP-MAP-RAC/ SPA, 2012	2. g	36.5%
CIESM/Mediterranean Marine Peace Parks	Mediterranean Scientific Commission	unsolicited	Biodiversity driven & intergovernmental collaboration for peace	**Biodiversity (species distribution and habitats)**: endemic & threatened biota (such as unique deep-sea communities, white coral beds, monk seals, rare endemic species, fin whales, spawning grounds of bluefin tuna); **Oceanographic**: surface sites of deep water formation); **Geological**: deep sea canyons, mud volcanoes, seamounts, hypersaline craters	Expert judgement	CIESM, 2011	2. h	target: >10%; no specific boundaries defined
Oceana/MedNet: MPA network proposal for the Mediterranean Sea	NGO	unsolicited	Biodiversity driven, qualitative consideration of threats, administrative and legal considerations, existing proposals	**Biological (species distribution and habitats)**: Key species; CBD criteria. **Oceanographic**: Connection by currents, gyres; Fronts **Geological**: escarpments, seamounts, canyons, trenches, etc.. **Threats**: Illegal, Unregulated and Unreported Fishing; Potential oil and gas prospecting; Pollution; Maritime traffic; By-catch. **Administrative**: Affected by waters of national jurisdiction; Jurisdictional conflicts. **Previous initiatives**: ACCOBAMS; EBSAs; De Juan & Lleonart, 2010; GFCM (FRAs); Greenpeace	GIS, quantitative data and analysis	Oceana 2011	2. i	8.2%
Cumulative Impact Map	Scientific consortium	unsolicited	Biodiversity and Threats	**Biodiversity (habitats)**: 19 habitat types (e.g., rocky reef, seagrass beds, epipelagic areas, deep soft sediments). **Threats**: 18 spatial datasets of human activities and stressors (including fishing, coastal population density, hypoxia, invasive species, pollutants and nutrients, ocean acidification, oil accidents, oil rigs, Sea Surface Temperature change, shipping, urbanization trends, UV change)	GIS, quantitative data and analysis	Micheli et al. 2011 http://globalmarine.nceas. ucsb.edu/mediterranean/	2. j	5.6%
Fish Biodiversity	Scientific consortium	unsolicited	Biodiversity driven and Threats	**Biodiversity (fish)**: total species richness, endemic species richness, IUCN threatened species richness, phylogenetic diversity, functional diversity. **Threat**: fishing pressure	GIS, quantitative data and analysis	Mouillot et al. 2011	2. k	11%
Conservation Concern Areas	Scientific consortium	unsolicited	Biodiversity and Threats	**Biodiversity (species distribution)**: marine mammals, turtles, seabirds, fishes and commercial or well-documented invertebrates; **Threats**: coastal-based impacts, trawling and dredging disturbance, ocean-based pollution, exploitation of marine resources by fisheries, maritime activities and impacts of climate change.	GIS, quantitative data and analysis	Coll et al. 2012	2. l	13.7%

assemblage of users, including conservation scientists, marine biologists, decision makers and groups of interest represented by NGOs. It is widely used worldwide and is a standard tool for conservation and management plans. A training course on the use of Marxan was offered to the CoCoNet community. Its application, however, requires extensive georeferenced information that is not always available.

Introducing connectivity and oceanography into Marxan analysis

The review by Micheli et al. (2013b) of six existing and twelve proposed conservation initiatives highlights gaps in conservation and management planning, particularly within the southern and eastern regions of the Mediterranean and for offshore and deep sea habitats. The eighteen initiatives analysed by Micheli et al. (2013c)

vary substantially in their extent (covering 0.1–58.5% of the Mediterranean Sea) and in the location of additional proposed conservation and management areas. Differences in the criteria, approaches and data used explain such variation. Despite the diversity among proposals, the analyses identified ten areas, encompassing 10% of the Mediterranean Sea, that are consistently identified among the existing proposals, with an additional 10% selected by at least five proposals. These areas represent top priorities for immediate conservation action (Table 1).

In CoCoNet, we refined this analysis by incorporating the following additional data sets:

1 - the information about major circulation patterns derived from the analysis of existing literature (all red lines with arrows in Figure 17, see the legend for details),

2- the 22 regions (white lines) that, according to Berline et al. (2014) are highly connected at short time scale. This subdivision has been obtained by a new regionalization method based on a connectivity approach and is based on an ensemble of Lagrangian particle numerical simulations using ocean model outputs at 1/12u resolution.

The areas destined to conservation according to the Marxan analysis were obtained including habitats, human pressures and management costs assessed in terms of human impacts (https://www.nceas.ucsb.edu/globalmarine/mediterranean).
The optimal spacing among MPA ultimately depends upon both the community and the habitat of interest, the specific geographical domain considered, and the relative position of candidate sites within the ocean circulation system.
Our analysis (presented in Figure 17) shows several areas that might be identified as the physical Mediterranean CEFs, corresponding to spaces into which networks of MPAs could be established, defined by white lines, due to the matching of different descriptors (currents, connectivity measured with genetics, Marxan analyses of protection schemes based on both ecology and human pressures). These areas are mostly based on horizontal oceanographic connections defined as areas of dense water formation, fronts, eddies, principal currents, secondary currents, seasonal currents, and the Bimodal Oscillation System in the Ionian Sea. The upwellings in correspondence

of marine canyons are not covered because their knowledge is too partial to be expressed in a Figure of this kind, but they are presumably crucial for **connections between the deep sea and coastal systems.**
The identification of **priority areas** in which networks of MPAs could be nested is shown by the orange areas in Figure 17.
They were derived from the extended application of Marxan, using fine scale resolution data about habitat distribution, costs associated with management/conservation initiatives, and potential human threats in parallel to the consideration of the potential connectivity between MPAs. These priority areas are well established in the Pilot Areas (Southern Adriatic Sea and Western Black Sea, see Figure 17 insets), where the information on different layers has been completed. The Black Sea networks are only coastal due to anoxic conditions below the surface waters, and are defined as ecoregions, evidenced by different colour patterns along the coast. The rest of the Mediterranean and Black Sea priority areas could be modified after the Geodatabase information layers are expanded.
The need for high connectivity requires the identification of wider spaces, covering both the high and the deep sea as well. The network, however, cannot be based on priority areas only. The very concept of connectivity requires management throughout the network.
Therefore, **these priority areas would take into account a network in which MPAs are less than 100 km apart from any two other MPAs (spacing on average 50 km)**, following the results from CoCoNet and literature analyses**.** This ensures (i) regular protection throughout the Mediterranean and Black Sea areas, (ii) a precautionary principle as for MPA replication and connectivity among them, and finally (iii) a monitoring system divided among the Mediterranean countries according to their coastline.
The map in Figure 17 shows the physical Mediterranean CEFs, corresponding to spaces into which MPA networks could be established, defined by white lines.
The identification of priority areas (orange areas in the insets in Figure 17) is based on the application of Marxan. The map in Figure 17 shows what can be accomplished by using the CoCoNet procedure but it is still preliminary, since the information about species and habitats distributions is still too
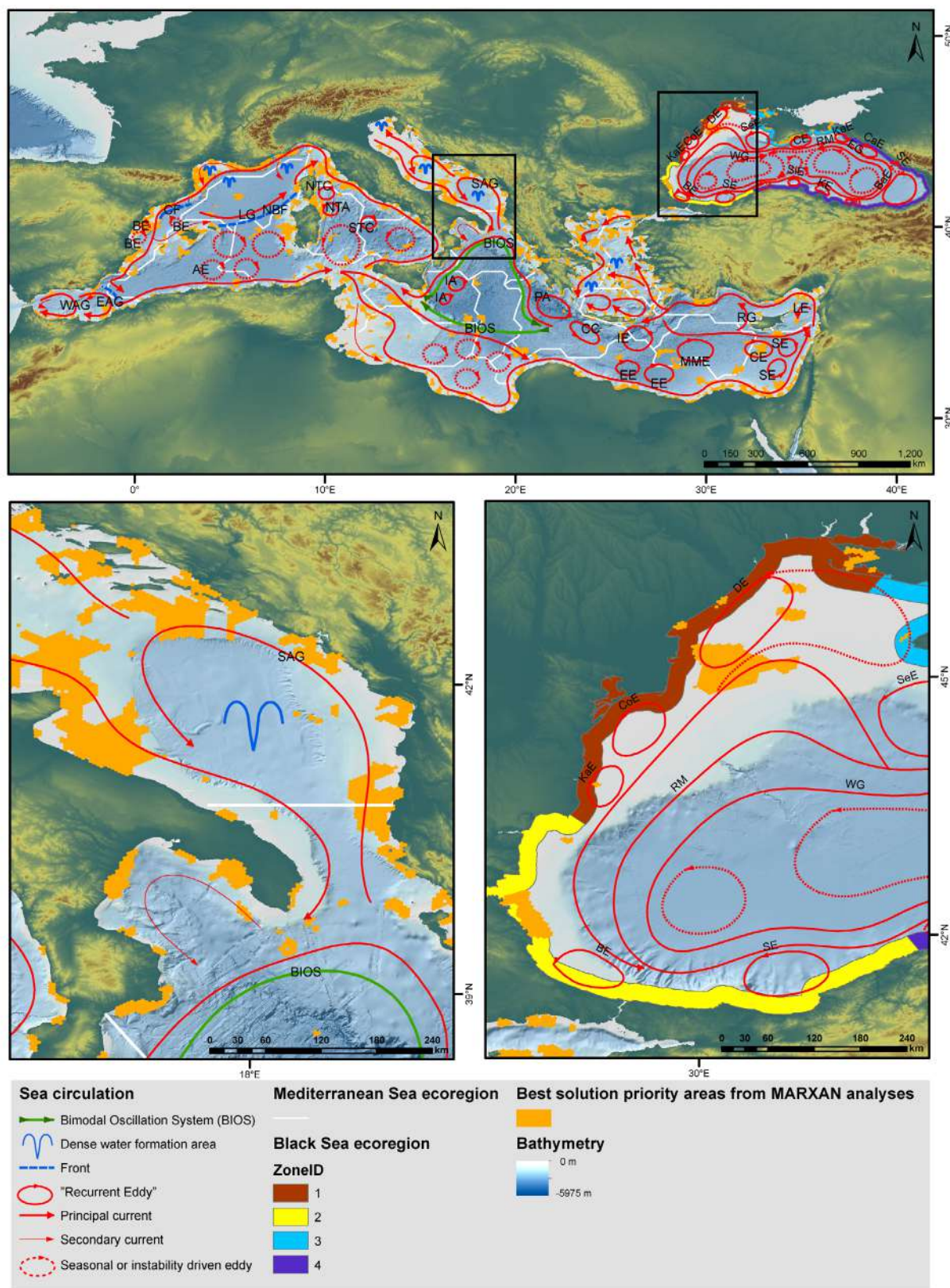
Figure 17. Conservation priority areas in the Mediterranean and the Black Seas. The best solution priority areas from Marxan analyses are the surfaces that could be protected in the 2 regions

limited, as is the appreciation of connectivity. The importance given to biodiversity and ecosystem functioning by the MSFD, together with the definition of GES, is a complete revolution in the way we describe and manage the marine space. This is exemplified by the absence of both biodiversity and ecosystem functioning in current observation systems. This lack of attention to these variables, now recognized as having crucial importance, almost led to the disappearance of the basic science of biodiversity (i.e. taxonomy) from the scientific community. This shortcoming should be filled urgently through a long-term policy of building skills and with substantial investments in taxonomic technologies.

MPA network design from the standpoint of habitat-diversity, threats and conservation targets

Large-scale examples of recovery are almost confined to the institution of MPAs. This is a very strong argument towards the implementation of network of MPAs, increasing the number of protected sites across the Mediterranean and the Black Seas. Previous attempts have also focused on benthic habitats of high conservation importance such as *P. oceanica* seagrass meadows, coralligenous formations, and marine caves (Giakoumi et al., 2014) with the aim of setting priorities at a whole-basin scale. This effort found priority areas mostly concentrated in the Ionian, Aegean, and Adriatic Seas due to the high occurrence of these three habitat types and the relatively low opportunity cost.

The idea developed in CoCoNet is to implement present conservation efforts towards the development of multiple uses scenarios, with an improved representation of habitat typologies, human pressures and management costs assessed in terms of human impacts (https://www.nceas.ucsb.edu/globalmarine/mediterranean).

The results of the Marxan analyses (Figure 18), combine conservation priorities with the need of finding suitable areas for other human uses.

In blue, the best scenario focusing on the conservation of the Mediterranean and the Black Seas includes already existing MPAs (http://www.medpan.org/en/mnp) plus additional areas critical to reach the 10% conservation targets, as

requested by the CBD. It is clearly evident that this scenario largely incorporates wide areas of the North Africa and the deep seas, largely missing in previous efforts. However, even if the deep-sea and eastern Mediterranean basins are better represented in this solution, in some areas are still scarcely represented (i.e. eastern Black Sea) due to limited data availability. This scenario provides indications in terms of where and which size should have the new sites to include in future plans.

In green, the best scenario areas originate from the selection of the Planning Units featured by the highest selection frequency. These Planning Units are of fundamental importance to meet protection targets. They are not replaceable with other Planning Units. Here, urgent protection measures are required.

In pink, the areas originate from the selection of the Planning Units featured by a very low selection frequency. At least on the base of the ecological information we have at this stage, the Planning Units selected for building this scenario are less important to meet protection targets but can be suitable for the installation of OWFs or other human uses (see the Guidelines on Marine Wind Energy in the Mediterranean and Black Seas in the context of suitable Blue Growth).

This piece of information may decrease conflicts and sets the base for a marine spatial planning process. In this framework, the information on **population structure and connectivity** is crucial to design a coherent network of marine reserves but, to date, few studies used information on dispersal patterns to design marine reserves. The lack of spatially explicit knowledge about connectivity at broad ecological scales remains the main obstacle to the adequate incorporation of ecological connectivity into Marxan analyses.

Shanks et al. (2003) reviewed dispersal distances in 32 taxa, concluding that reserves of 4–6 km in diameter should be large enough to contain the larvae of short-distance dispersers, whereas reserves spaced 10–20 km apart should be close enough to each other to capture propagules released from adjacent reserves. Sala et al. (2002), by using optimizathion algorithms to implement a MPA network in the Gulf of California, determined that the distance between adjacent reserves in the Gulf of California should not exceed 100 km, taking into account vulnerable species populations. Melià et al. (2016) show that connections over distances
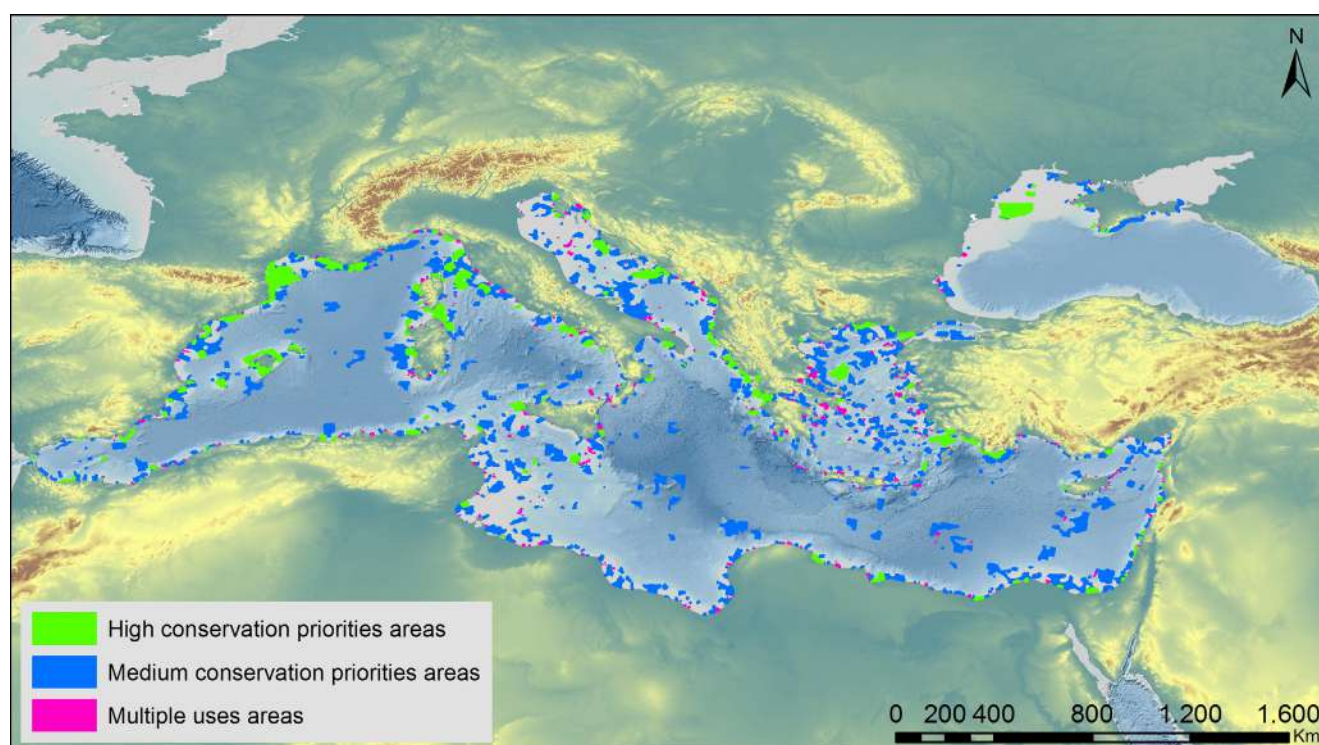
Figure 18. Multiple uses scenarios for informing the marine spatial planning of the Mediterranean and the Black Seas

comprised among 50-200 km can be very effective in the pilot project area of the Mediterranean Sea, at least for the considered model community. Also in the Marxan analyses selected sites are distributed never exceeding this distance. However, despite its power, flexibility and easiness of use, there still remain questions about species persistence and extinction probability and optimal levels of connectivity in networks of MPAs that Marxan cannot address and require a combination of different quantitative approaches.

The optimal spacing of reserves depends on a variety of factors that make it difficult to derive a general rule from specific analyses. **Variability** in ocean currents, spawning seasons, larval life histories, and dispersal distances (from meters to hundreds of kilometres) makes it virtually impossible to obtain a single value to measure connectivity between sites for all taxonomic groups. Seascapes are highly heterogeneous and anisotropic, the optimal spacing among marine reserves depends on both the communities and the habitats of interest, the specific geographical domain considered, and the relative position of candidate sites within the ocean circulation system. There is not a one-size-fits-all formula for network design and every area must be studied in detail before realistic plans can be proposed.

Effective design of reserve networks requires a trade-off between ensuring connectivity and providing an appropriate representation of biological diversity. Studies on Mediterranean MPAs, while professing an attention to biodiversity in general, usually focus just on coastal fish and, even in doing so, they fall short in meeting conservation targets for taxonomic, phylogenetic and functional diversity of the only considered taxon. This might apply also to other ecological compartments, habitats included. To support biodiversity protection, MPAs must be both self-sustaining and linked to each other, so as to promote recovery from local extinctions.

3.4 STEP 4: Formation, management and monitoring of networks of MPAs

The measures and initiatives to protect the marine environment are slowly evolving with the increase of understanding of nature and of our relationships with it. In the Mediterranean Sea, for instance, **Marine Protected Areas (MPAs)** have been mostly established to protect unique places, perceived as having "**inspirational value**" (Boero, 2017). The **beauty** of the landscapes, in this case the seascapes, due to the presence of **charismatic**

faunas and floras, is the main reason for protection, as it happens also in terrestrial parks. The array of measures to protect the marine environment is vast, but it is apparent that MPAs are the most pervasive ones in the Mediterranean area. Several MPAs have been established also in the Black Sea, where conservation policies are developing in a similar way to those of the Mediterranean.

The basic premise of these guidelines, however, is that in order to achieve Good Environmental Status (GES) of the Mediterranean and Black Seas, it is necessary to identify, protect, manage and monitor the units of conservation based on **Cells of Ecosystem Functioning (CEFS)**. The definition of CEFs is extensively described in Step 3 of the guidelines.

For the purposes of this chapter, a **conservation uni**t is considered to be any **geographically defined area** (including the water column) where prescribed measures are implemented in order to achieve GES of the marine environment, as defined by the EU Marine Strategy Framework Directive (2008/56/EC). An appropriate network of conservation units will be needed within each CEF in order to ensure that its natural biophysical processes can continue unimpaired (or be restored to that state). It is of course evident that "conservation unit" covers the concept of **Marine Protected Area** (MPA, which term will be used from now on), and that networks of such areas ought to be **synergistic** in delivering ecological coherence and resilience.

The questions of what actually constitutes ecological coherence, connectivity, representativity, sustainable use and other such concepts, and how to select sites to achieve them, are addressed elsewhere in these Guidelines. Rather, this chapter addresses the question: **if the science informs us of the why and where certain places, areas or regions should be given a particular management regime because of their conservation importance, then how can it be done with the legal and socio-economic tools available?** Furthermore, what improvements can be made to the instruments to improve their effectiveness? It is also important to bear in mind that understanding of the terms "marine", "protected area" and "network" varies considerably among different constituencies such as scientists, politicians, lawyers, managers and users (IUCN-WCPA, 2008).

What is a network of MPAs?

Because of the highly connected nature of the sea, which efficiently transmits substances and forcing factors, a single, relatively **small MPA** which is not part of a connected network of MPAs, is **unlikely to succeed**, due to the transmission of the effects of external human activities (e.g. pollution, litter, introduced species, noise) into the MPA (Kelleher, 2015). The World Conservation Union (IUCN) World Commission on Protected Areas defines an **MPA network** as: "a system of individual marine protected areas operating cooperatively and synergistically, at various spatial scales, and with a range of protection levels, in order to fulfil ecological aims more effectively and comprehensively than individual sites could acting alone. The system will also display social and economic benefits, though the latter may only become fully developed over long time frames as ecosystems recover." (IUCN-WCPA, 2008).

The crucial point of the IUCN definition is the recognition of the likely multi-functional role of networks, while the CBD criteria focus on biological and ecological features and do not cover **socio-economic aspects** (including benefit sharing), which may be vital for effective management of areas and the network as a whole.

In establishing ecologically coherent MPA networks, international best practice currently recognises seven principles as fundamental to design, management and monitoring. These are:

Representativity – the MPA network should represent the range of marine habitats and species by protecting all major habitat types and associated biological communities present in the network boundaries

Replication – all major habitats should be replicated and distributed throughout the network. The amount of replication will depend on the extent and distribution of features within the network

Viability – the MPA network should incorporate self-sustaining, geographically dispersed component sites of sufficient size to ensure species and habitats persistence through natural cycles of variation

Adequacy – the MPA network should be of adequate size to deliver its ecological objectives and ensure the ecological viability and integrity of populations, species and communities (the proportion of each feature included within the

MPA network should be sufficient to enable its long-term protection and/or recovery)

Connectivity – the MPA network should seek to maximise and enhance linkages amongst individual MPAs using best current science. For certain species this will mean that sites should be distributed in a manner to ensure protection at different stages in their life cycle

Protection – the MPA network is likely to include a range of protection levels. Ranging from highly protected sites or parts of sites where no extractive, depositional or other damaging activities are allowed, to areas with only minimal restrictions on activities that are needed to protect the features

Best available evidence – network design should be based on the best information currently available. Lack of full scientific certainty should not be a reason for postponing proportionate decision making on site selection.

The designation of multiple MPA sites according to these principles will confer on them the term "network" which can have a range of inter-related contexts (see Step 3) relevant to their management and monitoring. Moreover, it became evident from the socio-economic research carried out within CoCoNet that different stakeholders held different conceptions of what constitutes an MPA network in practical management terms. Rather than trying to enforce a single one-case-for-all MPA network management vision, we preferred to analyse how the different visions could be accommodated within the overall requirement for ecological coherence and the CEF model and therefore seek ways of **integrating** them in a **holistic** manner as appropriate. As a result, we constructed a framework of seven commonly accepted MPA network "types", which allowed a systematic approach to defining management objectives and monitoring schemes for each type (Table 2). Indeed an analysis of the presence or absence of certain network types (e.g. there is currently no collaborative network for the Black Sea) can suggest strengths or weaknesses in building an effective regional network system.

There are several general characteristics shown across all MPA network types. Some, such as planned or unplanned networks, arise from the process of network formation, usually by legal statute. Others, such as spatial and temporal overlaps, are an emergent property of network

formation itself. These characteristics interact at the site level so that **no MPA will belong to a single network type, but will represent a node in different network types according to its own properties and functions**. This multiplicity of MPA network types is shown schematically in Figure 19.

Accordingly, management and monitoring of individual sites at a network level should be "network-aware", that is, take explicit account of which types of network that site lies within and contributes to. Otherwise, synergistic opportunities may be missed, or worse, important network features eroded because they were overlooked. Effective management and monitoring of MPA networks therefore requires both top-down and bottom-up approaches. In the former, individual sites should be categorised according to the network types relevant to them; and in the latter, site management plans should include specific objectives and activities that ensure they sustain their contributions to those networks (Table 2).

Selection of potential network nodes (actual MPAs)

Although research reported here has indicated the general parameters for building up ecologically coherent MPA networks in the Mediterranean and Black Seas, that still leaves the question of identifying actual sites. To assist in this process, based on literature reviews and work carried out in CoCoNet itself, Table 3 provides a "checklist" of selection factors and their attributes that can help to prioritise potential sites for establishing MPAs. Knowledge has been addressed in Step 1, and scientific justification and risk assessment in Steps 2 and 3. The remaining factors are discussed briefly below.

Applicable legislation for designating MPAs and forming networks

As the marine resources of the Mediterranean and Black Seas are subject to a public law regime, where state control is established (with little or
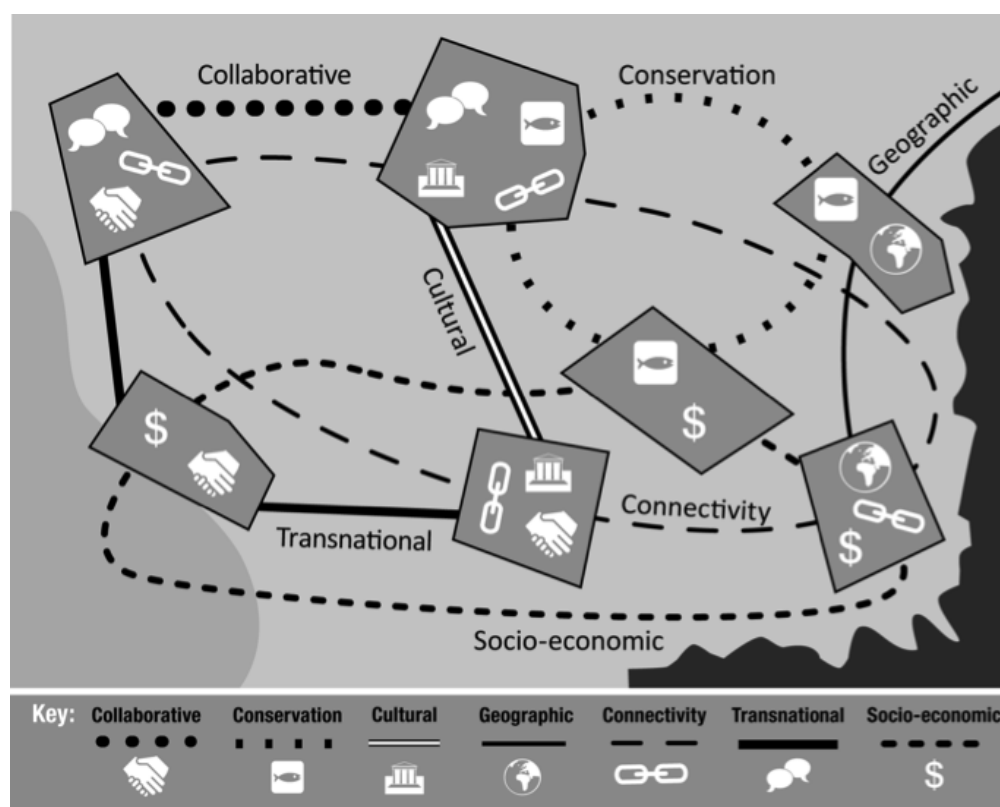
Figure 19. Schematic representation of seven MPA network types (Table 2) showing how they can overlap or be nested within each other (Beal et al., 2017)

no private ownership), ultimately all formal MPAs are designated by a state under the provisions of its own legislation or, in exceptional cases, by an international treaty (e.g. the Pelagos Sanctuary, see below). Informal MPAs, which are managed through cooperatives enjoying customary rights, are rare.

There are no global agreements specifically aimed at the identification, selection and designation of MPAs, let alone networks. Most national maritime legislation is based on a rather broad suite of multilateral international agreements that either have no formal definition of an MPA, or use different definitions and designation criteria.

As a result, MPAs to date have been designated chiefly on an **ad hoc basis arising from a particular combination of ecological and socio-economic factors** including natural resource usage, presence of charismatic or vulnerable habitats and species, legislative conditions, public awareness, cultural heritage, and financial and economic circumstances. Similarly, while some legislation refers to the creation of MPA networks, the meaning is often vague and tenuously rooted in ecological science. Contemporary networks have generally been retrofitted to join up MPAs that have already

been established for different reasons.

These Guidelines are not the place for a **detailed elaboration** of the legislation involved – there are many technical sources for this information. Since there are unique challenges due to differing legal systems, conservation features, socio-economic factors, cultural elements and political aspects, **different legal arrangements** may be required for each site in a network. Coastal states that belong to the European Union, furthermore, have maritime, environmental and energy polices which are **integrated and coordinated** by supranational policies. The aspects considered here, therefore, are the general principles involved.

As these Guidelines concern MPA networks, which imply **transboundary** systems, further discussion of these issues is mainly confined to the **international legal framework**. In designating a site as an MPA, the first consideration is **jurisdiction** (which state or supranational body has the authority, or which instrument provides the legal basis, to designate the site for the intended purpose). The second is to assess the array of **existing legal measures** to determine how these can be best deployed (alone or in combination) to achieve the desired objective(s)

Table 2. MPA network types and appropriate site level management and monitoring actions

Network Type	Network purpose	Management actions required at MPA site level	Monitoring actions required at MPA site level
Conservation	Generally designed to protect features showing the full range of their variation, by representation, replication and adequacy of features, across a range of sites.	1) Identify legal protection measures for features 2) Identify activities harmful to features 3) Identify appropriate restrictive activities	1) Identify features of conservation importance 2) Instigate monitoring programme of features in line with MSFD indicators
Connectivity	To ensure ecological coherence by providing protection to sites between which genetic exchanges are known to occur	No specific measures are likely to be effective at site level	1) Instigate connectivity monitoring programme
Socio-economic	To protect and manage marine resources in a sustainable manner, whilst optimising coastal uses and avoiding conflicts	1) Identify and engage key stakeholders 2) Identify appropriate economic instruments 3) Assess likely success of economic instruments	1) Identify socio-economic activities 2) Instigate socio-economic monitoring programme
Geographic	To achieve conservation and protected area coverage targets within a defined geographical area	1) Identify MPAs sharing features at a range of geographic scales 2) Create links with identified MPAs	1) Identify conservation status of features at appropriate geographic scales 2) Establish monitoring indicator thresholds for features based on geographic scales
Collaborative	To promote interaction among members to effectively plan, manage, implement or monitor area-based management of marine resources and associated uses	1) Identify appropriate collaborative networks 2) Become an active member of collaborative network	1) Identify features of conservation importance 2) Instigate monitoring programme of features in line with MSFD indicators
Cultural	To protect sites and areas where significant historical and cultural features and seascapes are present, by preserving and promoting traditional management practices and preventing harmful activities	1) Identify legal protection measures for features 2) Identify activities harmful to features 3) Identify appropriate restrictive activities	1) Identify cultural features 2) Instigate monitoring programme of cultural features
Transnational	Co-management of natural resources beyond existing political boundaries	1) Identify other sites within transnational network 2) Instigate co-operation programmes with other network members	1) Identify features of conservation importance 2) Instigate monitoring programme of features in line with MSFD indicators 3) Establish appropriate monitoring indicator thresholds

Table 3. MPA selection factors and their attributes for site prioritisation

MPA Selection Factor	Attributes
Knowledge	This covers not only information about the present situation (best available scientific knowledge) but also its historical ecology (how the current situation came about). Unfortunately, it is rare to have such knowledge as there is a general lack of long time series data in the marine environment, but it may be possible to undertake comparative studies to help distinguish features which are artefacts of human influence from those which arise naturally.
Scientific justification	This refers to how well the site accords with accepted ecological criteria (CBD, Habitats Directive), as well as the network contribution e.g. replication and resilience.
Risk assessment	The location of the site should be assessed in relation to shipping lanes, actual or potential industrial development including renewable energy, possible accidental pollution events, attraction of tourists/poachers, colonisation by invasive species, aquaculture or other possible impacts. The potential for mitigating such impacts should be elaborated, for example possible contingency measures to respond to incidents where there is major vessel traffic through the area (Lisovsky *et al.*, 2015).
Political feasibility	Surveys and consultations are needed to confirm stakeholder agreement, from government to civil society at all levels. In particular, any conflict and/or lack of cooperation between environmental and fisheries management agencies will inhibit progress in establishing MPAs.
Legislation applicable and/or available	An audit of the existing local, state and supranational legislation should be undertaken, as well as resource ownership and access, freedom of navigation rights etc. For designation purposes, a check is needed on which littoral states are parties to specific international agreements and how they interpret them in national legislation.
Governance model	The potential governance model (Table 6) should be determined as part of the stakeholder consultation process, and whether and how the site will form part of a network at the international level under the regional agreements.
Management integrity	The site management plan has to be prepared in full collaboration with the relevant stakeholders. The recruitment of suitable staff, planning competence, effectiveness, monitoring and adaptability are other issues to be taken into account.
Economic sustainability	The need and potential for self-financing of the site administration has to be considered. Sustainable financing needs to be put in place in from the beginning, employing appropriate economic instruments based on assessments, valuations and MCDA.
Communication and outreach	The potential role of the site to provide research, education and public awareness opportunities (forming a part of collaborative networks, Table 1) should be considered.
Secular trends	Natural and political worlds operate as complex systems with characteristics which ensure that they will function unpredictably over time. Therefore, the potential for the site and its management to adopt objectives and policies that are adaptable over short, medium, and long-term timescales is an important factor.

and where improvements to that legislation and its implementation could be made.

UN Convention on the Law of the Sea (UNCLOS)

Maritime access and use rights are governed by **UNCLOS**, to which all the Mediterranean (except Turkey, Syria and Israel), Black Sea coastal states and the EU are parties. UNCLOS recognises the sovereignty, sovereign rights, freedoms, rights, jurisdiction and obligations of States within several maritime zones (Figure 20), namely:

1. **Internal waters:** waters on the landward side of the baseline where the coastal state exercises full territorial sovereignty.
2. **Territorial sea**: the zone adjacent to the territory and the internal waters of the coastal State. The coastal state exercises full sovereignty over this zone. The maximum width of the territorial sea is 12 nautical miles.
3. **Contiguous zone**: waters located beyond the territorial sea. The coastal state is allowed to regulate customs, fiscal, immigration and health issues in this zone. Its width may not exceed 24 nautical miles from the baseline.
4. **Exclusive economic zone (EEZ)**: maritime area beyond and adjacent to the territorial sea. Here, the coastal state exercises sovereign rights for the purposes of exploring and exploiting, conserving and managing the natural resources. The breadth of the EEZ may not exceed 200 nautical miles from the baseline.
5. **Continental shelf**: natural prolongation of a coastal state's submarine territory to the outer edge of the continental margin, or to a distance of 200 nautical miles. Over the continental shelf, the coastal state exercises sovereign rights for the purpose of exploring it and exploiting its immobile natural resources In the event that the coastal state does not exercise its rights on the natural resources of its continental shelf, no one else may explore or exploit it without the express consent of the coastal state.
6. **High seas**: the remaining parts of the sea. The High Seas are free for all states and reserved for peaceful purposes.
7. **Area**: the sea and ocean bed and its subsoil beyond the borders of national jurisdiction. The Area and its resources are the common heritage of mankind.

Coastal states of both seas have claimed their rights for a territorial zone, and some contiguous zones have been established for customs, fiscal, immigration or sanitary purposes. In the Black Sea, all coastal states have declared EEZs, meaning that all the waters and sea bed and associated natural resources are demarcated. However, because of its complex geography and relatively small size, there remain high seas areas in the Mediterranean that are much closer to the coast than in other marine areas. Despite the complex situation in terms of maritime delimitations, the Mediterranean Sea has hosted, since 1999, the Pelagos Sanctuary for Marine Mammals, which encompasses waters of France, Monaco and Italy having the legal status of internal maritime waters, territorial sea, ecological protection zone, exclusive economic zone and High Seas. As there are no High Seas in the Black Sea, the designation of marine protected areas remains a responsibility that coastal states may take individually and implement with effective results.

European Union Directives and Policies

EU legislation also applies seaward up to the external limits of coastal waters established by the member state(s) concerned, that is up to the external limit of their territorial waters, EEZ, fishing zones or ecological protection zones (Figure 21). Since no coastal state can claim an EEZ which would affect the rights of another coastal state, it seems reasonable to assume that member states in the Mediterranean will eventually declare EEZs in line with European Parliament Resolution P7_TA(2013) 0403.

EU member states are subject to the EU Directives relevant to establishing marine conservation networks, principally:

1. Birds Directive (79/409/EEC)

2. Habitats Directive (92/43/EEC)

3. Water Framework Directive (WFD) (2000/60/EC)

4. Marine Strategy Framework Directive (MSFD) (2008/56/EC)

The Birds and Habitats Directives (BHD) have, among other developments, led to the establishment of the **Natura 2000 network** of sites where species and habitats of **European interest** (those listed in their Appendices) must be maintained in a favourable conservation condition such that, overall, the species or habitat has a favourable conservation status at
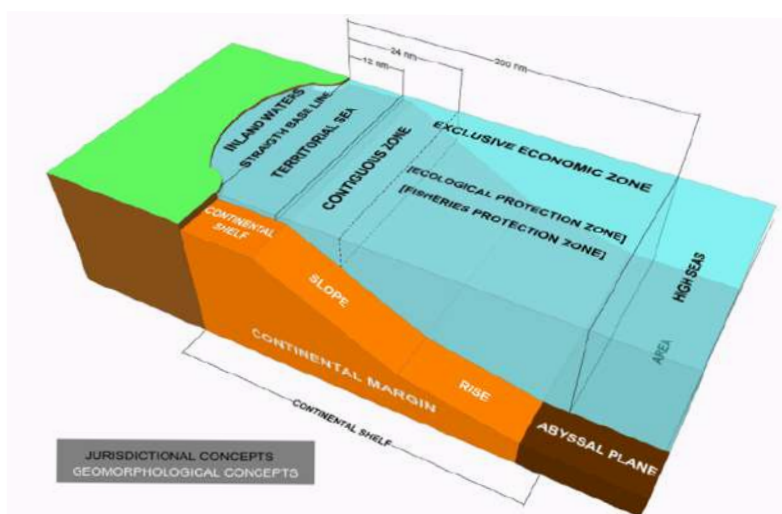
Figure 20. UNCLOS Maritime Jurisdiction Zones (Source: Suárez de Vivero, 2009)
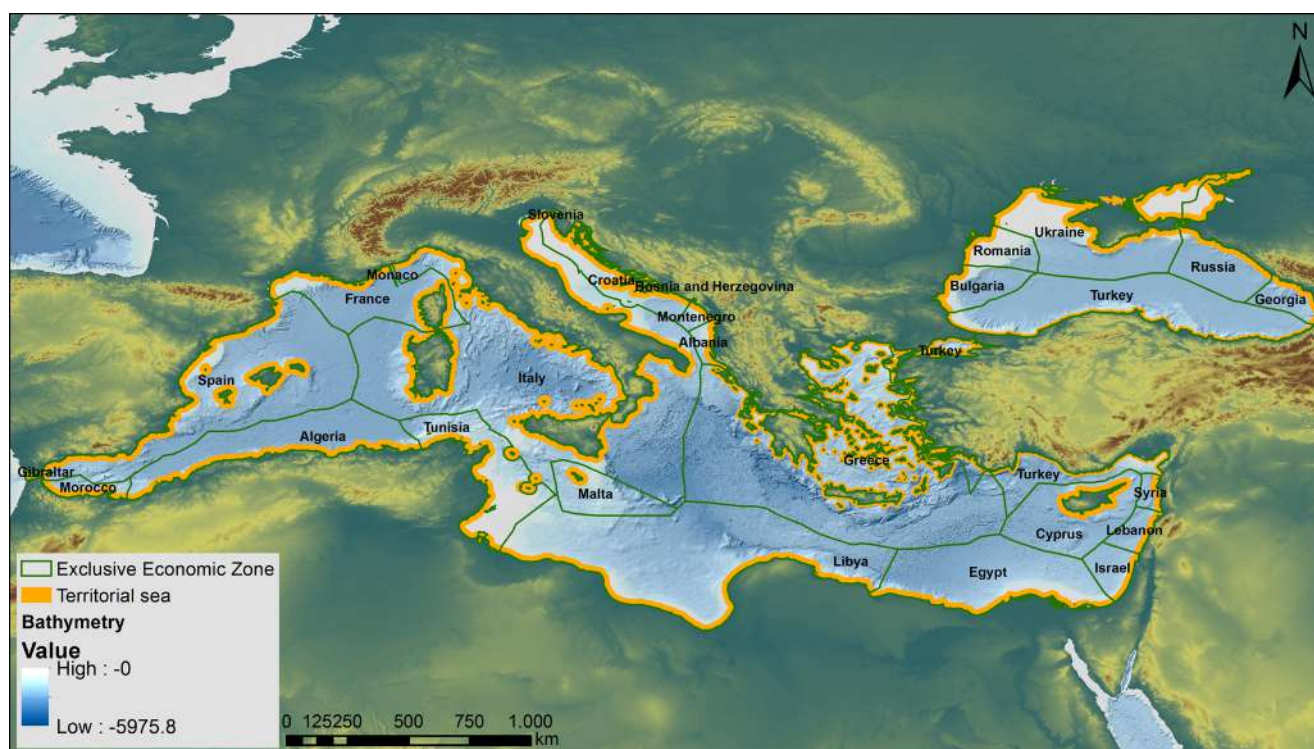
Figure 21. EU members states marine waters in the Mediterranean and Black Seas (Source: European Atlas of the Seas, EC DG Mare http://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/#lang=EN;p=w)

national and biogeographic scales. However, **the Habitats Directive covers only nine marine habitats** and these are mainly coastal and/or have a limited extent, so they do not adequately represent the diversity of marine habitats found in Europe's seas (Fraschetti et al., 2011). In its current form, therefore, Natura 2000 is unable on its own to deliver an ecologically coherent and representative network of MPAs (Reker, 2015) but it is an important element of such a network.

The WFD establishes a framework for the protection of groundwater, inland surface waters, estuarine (transitional) waters, and coastal waters. Open marine waters are not included. However, the WFD is likely to influence the management of marine ecosystems because all land-based inputs of pollutants pass through the coastal zone to the open waters.

The MSFD, which has strong links to the WFD, is the environmental pillar of the EU Integrated Maritime Policy, promoting an ecosystem approach to management and the integration of environmental concerns into different policies, and aims to reaching **Good Environmental Status** (GES) for marine waters by 2020. It requires Member States to develop marine strategies for their own waters, and coordinated strategies with other Member States for marine regions or sub-regions. The MSFD, according to a set of 11 "**Descriptors of GES**" and of the environmental impact of human activities on them, states the desired state of the marine environment. These are then used to establish a series of environmental targets and associated indicators, and to develop a programme of measures in order to achieve or maintain GES. The first, and most relevant MSFD Descriptor for MPAs, states that "**Biological diversity is maintained**: the quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions".

The pillars of GES are **Biodiversity and Ecosystem Functioning**, with a profound revolution in the way environmental quality is defined and assessed (Boero et al., 2015). The MSFD, as a framework directive, leaves the details of programmes of measures to the national and (sub-) regional marine strategies. The coastal states are currently formulating their criteria and the associated monitoring protocols for recognising GES.

This is leading to quite wide disparities of the interpretations of the Descriptors among coastal states, not least in the ecological terminology used (Table 4), and the monitoring programmes also suffer of the same inconsistencies. Furthermore, in the Mediterranean, the MSFD sub-regions and the identified CEF ought to overlap as far as possible, but they probably will not, since the very concept of CEFs is being introduced here, as a result of CoCoNet.

There seem to be only two avenues available to overcome the shortcomings of current directives and legislations: either (i) the **Habitats Directive** is amended to broaden the range of marine habitats covered and incorporate a more contemporary ecosystem approach that includes the water column; or (ii) each member state will have to find **alternative legal arrangements**, alone and in conjunction with other states, to protect key

elements of the cells of ecosystem functioning. The former seems a more efficient solution than the latter.

Multilateral Biodiversity Conservation Agreements

The next level of MPA designation legislation concerns the range of multilateral biodiversity conservation Agreements, at both global and regional levels. Their common feature is that their provisions (especially any on high seas) are not readily enforced (Laffoley, et al., 2014). Those agreements under which MPAs have been designated to date are summarised below.

1. **Convention on Wetlands of International Importance**, Ramsar, 1971.
   Provisions: Parties must include at least one wetland of international importance in the Ramsar List on accession (which may or may not be marine). The Convention applies up to the 6m bathometer.
   Sites declared: 11 on the Black Sea coast and 17 on the Mediterranean coast with marine habitats (http://www.ramsar.org/sites-countries/the-ramsar-sites).

2. **Convention Concerning the Protection of the World Cultural and Natural Heritage**, Paris, 1972.
   Provisions: Parties may nominate sites of global natural importance for inclusion in the World Heritage List.
   Sites declared: Danube Delta, Romania; Gulf of Porto, Corsica, France; Ibiza, Spain (http://whc.unesco.org/en/interactive-map/).

3. **International Maritime Organization** (MARPOL) - Particularly Sensitive Sea Areas
   Provisions: IMO can designate a PSSA in an area that needs special protection because of its significance for recognized ecological or socio-economic or scientific reasons. In consequence, specific measures can be applied to control maritime activities in that area.
   Sites declared: Strait of Bonifacio, France and Italy (http://www.imo.org/en/OurWork/Environment/PSSAs/Pages/Default.aspx).

4. **Convention for the Protection of the Marine**

Environment and the Coastal Region of the Mediterranean, Barcelona, 1976 (amended 1995).

Provisions: Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA/BD Protocol) has led Contracting Parties to establish a List of Specially Protected Areas of Mediterranean Importance (SPAMI's) in order to promote the conservation of the natural heritage.

Sites declared: 26 SPAMI sites are designated (http://www.medpan.org/en/web/database)

5. **Bonn Convention Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area**, Monaco, 1996.

Provisions: ACCOBAMS offers a means to establish marine protected areas, including on the Mediterranean High Seas, in areas which serve as habitats for cetaceans or provide important food resources for them.

Sites declared: 5 sites established on ACCOBAMS recommendations, and 8 more in pipeline. However, the Pelagos Sanctuary for Mediterranean Marine Mammals, declared in 1999, followed an initiative, Project Pelagos, begun in 1990 by Tethys Research Institute and the Rotary Clubs of Europe (http://www.cetaceanalliance.org/cons_Pelagos.htm)

Fisheries management

It is increasingly recognised that conservation and protection of marine areas, both sea floor and water column, are fundamental to maintain sustainable and profitable fisheries (Claudet, 2011). Only recently, however, has the bearing of important ecological phenomena (e.g. **jellyfish blooms**) on the viability of fish populations become appreciated by international organisations such as the **General Fisheries Commission for the Mediterranean** (GFCM) (Boero, 2013).

The **GFCM**, which operates under the **UN FAO**, has adopted recommendations requiring its members to prohibit the use of towed dredges and bottom trawl net fisheries at depths greater than 1000 m. In 2006, three specific areas in the Mediterranean were declared as **fisheries restricted areas**, namely (i) *Lophelia* reef off Capo Santa Maria

di Leuca; (ii) Nile delta area cold hydrocarbon seeps; and (iii) Eratosthenes Seamount (REC. CM-GFCM/30/2006/3). In addition, in 2009, the GFCM established a fisheries restricted area on the continental shelf and slope of the Eastern Gulf of Lions where the use of towed nets, bottom and mid-water longlines and bottom-set nets cannot exceed the level of fishing effort applied in 2008 (REC.CM-GFCM/33/2009/1).

Outside the territorial waters of EU member states, the Commission has exclusive competence for fisheries management measures. The **Common Fisheries Policy** promotes the establishment of **fish stock recovery** areas (Article 8) while taking due account of existing conservation areas and continuing to give additional protection to existing biologically sensitive areas. Different states adopt **restrictions** to fisheries based on **different principles**, if any.

Marine Spatial Planning and Integrated Coastal Zone Management

The range and density of **human uses** around the Mediterranean and Black Seas is growing continually. Already, there is not enough space along the coast for exclusive single use zones and the maritime area is also crowded. **Conflicts** are increasingly common both between and within different sectors for access to suitable areas for their activities, from fisheries to wind farms, recreation to navigation.

Over the last two decades, the technologies for collecting, analysing and sharing spatial information has reached the point where open access basin-wide planning is becoming a reality. These tools are giving an impetus to various initiatives for **spatial planning** in the coastal zone (which includes the immediate onshore belt) and the maritime area of both seas.

Marine spatial planning (MSP) can help to ensure that MPAs and MPA networks protect the most significant ecological areas, while at the same time avoiding areas of high-use as far as possible, and identifying areas for compatible multiple uses. This approach would also extend visibility to so-called "**paper parks**" which have been legally established (often the hardest of the process) but have no management body to control damaging activities.

In the Black Sea, the provisions of the **Bucharest**

Table 4. Definitions for MSFD Descriptor 6 (sea floor integrity) proposed by Mediterranean and Black Sea coastal states. No information from France, Greece, Malta or Romania. (Source: NatureBureau, EC)

SPAIN	ITALY	SLOVENIA
D6.1.1: The distribution area of the biogenetic habitats and/or protected habitats keep positive or stable trends in order to ensure its conservation. D6.1.2: The adverse impacts of human activities of not reach a spatial extension and/or an intensity that risks the maintenance of the benthic habitats. D6.2: The status of the benthic communities evaluated in terms of biomass of the structuring species, richness/diversity, or other related indicators, are kept within the values that ensure its durability and functioning, and the maintenance of the associated characteristic species and key species.	GES is characterized by the absence of significant pressure due to abrasion determined by benthic-impacting fishing gears (trawl, rapid trawl and hydraulic dredge) and sealing (determined by coastal defence structures, offshore structures, pipes, etc.) on biogenic substrates. The biogenic substrates include *Posidonia oceanica* meadows, Maerl beds, Coralligenous biocoenosis (reef) and deep corals.	D6.1: Good condition is achieved when there is no recorded significant physical DNA damage or losses due to the construction in the areas of biogenic substrate. For areas with different substrates the extent to which abrasion, other DNA damage and loss of natural areas occur is smaller than the threshold value of x% of the surface. D6.2: The seabed is in good condition when it is at the level that ensures the protection of the natural structure, scope, distribution and functions of the ecosystem functions, and where there are no long-term adverse effects on the benthic community.
CROATIA	CYPRUS	BULGARIA
In the Croatian part of the Adriatic, distribution, size and state of different marine habitats and associated biocenosis are in accordance with prevailing natural conditions. According to analysis of available long term collected data, expert opinion and applied metrics, GES is reached in the Croatian part of the Adriatic Sea for analysed criteria and indicators of Descriptor 6.	The marine environment of Cyprus is considered to be in good environmental status by the year 2020 if the structure and function of the ecosystem are safeguarded and not adversely affected. Specifically, diversity and productivity are maintained, and any pressures do not hinder the ecosystem components to recover and/or retain their natural diversity, productivity and dynamic ecological processes.	Impacts of human activities do not result in significant damage to the physical substrate and the biological structures on the seabed and deterioration of associated biological communities. The special habitat designated as endangered or vulnerable at the national level or by regional agreements (Bucharest Convention) and European legislation (the Habitats Directive) is effectively conserved by appropriate national and regional mechanisms.

Convention, its Protocols and the **Black Sea Strategic Action Plan** are implemented by the **Black Sea Commission** acting on the mandate of the Parties. The Parties to the **Barcelona Convention** adopted a protocol on ICZM in 2008. It aims to minimize the impact of economic activities on the environment and to guarantee the sustainable use of resources.

For EU member states, the **Marine Spatial Planning Directive** (2014/89/EU) establishes a framework for marine spatial planning and integrated coastal management in order to promote the sustainable growth of maritime and coastal economies and the sustainable use of marine and coastal resources. It may be noted that in the preparation of this chapter, various maps were examined concerning the maritime zones and boundaries in the Mediterranean and Black Seas (among them, Suárez de Vivero (2009) and http://www.marineregions.org/eezmapper.php). However, it was found that none were accurate or up to date. To support the formation of a transboundary MPA network, it will be essential to produce such maps.

Socio-Economic Aspects of MPA Designation and Management

World-wide experience has shown that no MPA can be established successfully without general support and engagement from **local communities** (Kelleher, 2015). General surveys in the project pilot areas conducted by CoCoNet researchers indicate that about two thirds of the general public support the idea that an MPA should be focused on **nature protection**. Nevertheless, in the crowded geographical space of the Mediterranean and Black Seas, an MPA cannot be set up without having **winners and losers**: any action must include an **economic and social analysis** of the benefits and costs of using the marine environment. Furthermore, socio-economic considerations must be taken into account in the development of the MSFD programmes of measures.

It is therefore vital to identify all relevant stakeholders and to **engage** them in MPA delimitation, designation and management. **Stakeholders** are "any individuals, groups of people, institutions or firms that may have a significant interest in the success or failure of a project (either as implementers, facilitators, beneficiaries or adversaries)" (EC, 2004). The main stakeholders are the local, national and international policy makers that should design the networks, the managers of the networked MPAs, the scientific community, and all other types of stakeholders according to the specific features of the networked spaces.

The conventional first step approach is for the MPA proponent to undertake a stakeholder analysis, typically employing a matrix approach, taking care to identify the different sectors, groups and individuals concerned, their authority and depth of interest, level of likely involvement in governance, and their likely stance (positive, neutral or negative) towards an MPA. The proponents of MPAs have to show demonstrable benefits for the stakeholders, or how potential losers can be compensated, in line with the following procedure:

1. **Acquire good knowledge of the system to be protected** before enforcing bureaucratic rules that may be very difficult to modify after MPA institution, leading to perennial mismanagement. Even if this recommendation seems banal, measures are often enforced without adequate knowledge of what is going

to be managed (biodiversity and ecosystem functioning) through the issued regulations.

2. **Convince stakeholders about the value of science-based management.** Rules must be based on solid scientific evidence, leading to carefully planned actions that must be emended in the light of new evidence.

3. **Use the positive examples deriving from good management** to convince stakeholders that networks of MPAs are conducive to also generating economic advantages. Success stories are more convincing than promises about the future.

4. **Assess and prioritize the selection of sites** for designation as MPAs according to a range of factors derived from previous experience.

5. **Convince decision makers that natural rules prevail over human rules.** We must adapt to natural conditions and not vice-versa. The economic costs for not respecting natural rules will be greater than the benefits obtained by not respecting them. Ecology has logical supremacy over economics since natural rules are more stringent than human rules.

6. **Develop views integrating monetary and non-monetary benefits** associated to ecosystem conservation through MPA networks, using both economic instruments and decision-making techniques accounting for multiple valuation perspectives. Actions that ignore natural rules often lead to erosion of the natural capital and, over the medium-long term, to greater economic losses than the economic gains obtained from badly designed actions. Fixing the damage to the natural capital is often left to the states, whereas the profits arising from nature destruction go to private subjects. The costs of nature destruction must be internalized in cost-benefit analyses.

Identifying Socio-Economic Impacts of MPAs

A socio-economic assessment must first elucidate the diverse effects that an MPA may have on the social and economic conditions of the neighbouring coastal communities. Since impacts

will vary between locations, site-specific studies are required to accurately evaluate the overall effects. Ojea et al. (2017) provide a list of the main potential positive and negative impacts expected from MPAs in the Mediterranean and Black Seas (Table 5).

Economic incentives for MPA designation

Some of the main methodologies and conceptual frameworks which are useful for assessing the socio-economic benefits and disadvantages of MPAs (Table 5) on users of the marine environment are:

1. **Socio-ecological Systems** (SES) Approach (e.g. Ostrom, 2009).

2. **DPSIR** framework (http://knowseas.socib.es/lion).

3. **Ecosystem services** and **economic valuation** (Costanza et al., 2014) as set out in Table 6.

Subsequent research and analysis (CoCoNet, 2015) showed that four of the instruments listed in Table 6 potentially perform better than others in both the Mediterranean and Black Seas contexts when considered against the goal of enhancing conservation and livelihood systems in MPA networks, namely: **fishing quotas** (as property rights); **entrance fees** (charge systems); **product taxes** and **subsidies** (fiscal instruments). These are further described in Table 7.

Governance – local, regional, transboundary

The **governance system** proposed for a new MPA, or MPA network, is crucial in terms of delivering the benefits expected by the stakeholders during the formation phase. It is important to distinguish between "**governance**" (which is the strategic, decision making and monitoring process) and "**management**" (which is the executive role of those responsible for implementing the management plan). How an MPA is governed will usually reflect the cultural-political system of the country concerned, ranging from a situation where governance and management are effectively combined in a single authority, to one

where they are fully separated and indeed where both management and governance can be highly diffused among stakeholders.

Except in effective dictatorships, pure **top-down** methods will never work. Equally, attempts by local communities to establish protective measures without the support of appropriate levels of government will often end in their rules being broken by **outsiders**. Therefore, in developing MPAs, it is necessary to obtain the formal **support** of both **local communities** and **governments** (Kelleher, 2015). Indeed, it is becoming increasingly common to view MPAs as planned areas with concerted management where the MPA serves as a forum for users and experts, rather than as an administrative district controlled by a body of law enforcement officials.

It is often in users' interests to minimise the size of an MPA, or to establish several MPAs, where they can exert maximum influence. This will act as a constraint on designating MPAs purely on scientific / biodiversity criteria where larger sites might be preferred but would then involve intervention by central, or even international, authorities (Table 8). As a result, the identification, classification and development of MPA **governance models** are currently a growing field for socio-ecological research (Feral, 2012; Jones, 2014; Kelleher, 2015).

Current management of existing Mediterranean and Black Sea MPAs

The **anthropogenic factors** that threaten marine ecosystems are many, complex and often act cumulatively or synergistically or in antagonistic ways. Some of them (e.g. the effects of climate change) are difficult to solve with local measures such as MPAs, while others can be tackled with complex management measures based on different approaches at different spatial scales, including the implementation of MPAs.

Well-managed MPAs lead to increases in the biomass of natural resources, also favouring fisheries around their perimeter, and the conservation of littoral habitats. However, although most of the good results yielded by the Mediterranean MPAs come from well enforced no-take zones, these represent only **0,01%** of the total sea surface (202 km^2). **Fishing is allowed** in at least 94% of the MPAs of the world, and in more than 99% of the total ocean area (Costello and

Table 5. Potential Socio-economic Impacts of MPAs (Source: Ojea et al., 2017)

Type of Activity	Sub-type of Activities	Potential Positive Impacts on Users	Potential Negative Impacts on Users
Fisheries	Artisanal fisheries / small scale	Improved catch mix. Income and job increase, for professional and pleasure fisheries and for diving Exclusive access (less competence)	Closure of areas to fisheries If retention rates inside the MPA are high (dispersal ability is low comparing to MPA size) there might be no benefit for nearby fisheries
	Commercial fisheries / large scale	Improved catch mix Increased catch ("spillover effect" and also by the "recruitment effect") Income and job increase, for professional and pleasure fisheries and for diving Increased biomass (reserve effect) Increased fish size (reserve effect)	Closure of areas to fisheries If retention rates inside the MPA are high (dispersal ability is low comparing to MPA size) there might be no benefit for nearby fisheries
	Recreational fisheries	Income and job increase, for professional and pleasure fisheries and for diving	Closure of areas to visitors If retention rates inside the MPA are high (dispersal ability is low comparing to MPA size) there might be no benefit for nearby fisheries
Aquaculture	Offshore aquaculture (longlines)	Economic benefits of employment and income	Impacts on local ecosystems
	Offshore fish-farms	Economic benefits of employment and income	Impacts on local ecosystems
Navigation and Communications	Commercial shipping	NA	Effect on shipping lanes Increase transport time by reducing speed limits
	Ports & harbour service area	NA	Negative effects of anchoring on seabed (e.g. seagrass)
	Communication cables	NA	Limitation of allocation
Mineral, Water and Energy Resources	Offshore oil/gas platforms, resources extraction, pipelines and cables	NA	Limitation of extraction and allocation
	Offshore wind-farms	NA	Limitation of allocation
	Sailing	Increase sailing visitation; increase in tourism demand	Damage to ecosystem from tourist congestion (e.g. anchoring)
	Marine cruising	Increase in marine cruises relating to cetaceans or seabirds sightseeing	Negative effects of anchoring on seabed (e.g. Seagrass)
	Diving, snorkelling, nautical activities	Increase in divers' visitation. Income and job increase, for professional and pleasure fisheries and for diving	Damage to ecosystem from tourist congestion Negative non-consumptive divers impacts on the natural environment Closure of areas
	Cetacean and seabird watching	Increase in demand	Negative effects on cetaceans
Management	MPA management	Economic benefits to scientists and biologists (budget for their research, projects, etc.)	Economic cost for public finances of administration, supervision, monitoring, scientific information policies, prohibitions with financial compensation

Ballantine, 2015). Although there is an increasing number of MPAs in the Mediterranean (from 94, in 2008 to 170 in 2012), only a few can be considered as really effective (Gabrié et al., 2012). The main flaws are:

1. Poor management and lack of surveillance prevent most MPAs from fulfilling their mission to protect the environment (Guidetti et al., 2008; Sala et al., 2012).

2. Landscape considerations and political opportunism: most MPAs have been established where and when it was opportunistically pos-sible, without consideration for ecology.

3. All-purpose MPAs rarely ensure adequate management measures and the ecological conditions to achieve goals that can even be opposite to each other (e.g. conservation vs. spill-over). Most MPAs seem to be "cure-all" areas aiming at the conservation of biodiversity, favouring artisanal fisheries and sustainable use of resources.

4. Lack of representativity and ignorance of what is to be protected (no species lists, habitat mapping and baselines from which to test the effects of protection).

Table 6: Valuation techniques available for economic valuation of ecosystem services in MPAs (Source: Ojea et al., 2017). NFI = Net Factor Income; PF = Production Function; MP = Market Price; TC = Travel Cost; CV = Contingent Valuation; RC = Replacement Cost; HP= Hedonic Pricing; AD = Avoided Damage

Value	Ecosystem function	Ecosystem good or service	Common valuation technique
Use value	Direct use value:		
	Provisioning or production services	Production of valuable food and fibre for harvest	NFI, PF, MP
		Pharmaceuticals	NFI, MP
		Raw materials	NFI, MP
	Cultural services	Recreational opportunities	NFI, TC, CV, CE
		Education and scientific knowledge	CV, CE
	Indirect use value:		
	Regulating services	Water quality control	NFI, RC, CV, HP, CE
		Waste treatment	NFI, RC, HP
		Flood control and storm buffering	NFI, RC, AD
		Biological regulation	CE, CV, PF
		Human disease control	NFI
	Supporting services	Climate regulation	RC
		Nutrient cycling	RC
	Option value:		
	Option value	Future benefit for direct and indirect uses	CV, CE
Non-use value	Existence value	Intrinsic value of species, habitat, biodiversity	CV, CE

Table 7. Economic instruments recommended for MPA development in the Mediterranean and Black Seas (Source: CoCoNet, 2015)

Economic Instrument	Category	Description
Fishing quotas	Property rights	Fishing rights are property rights given to an individual fisher or a community over a period of time in order to exploit the natural resource sustainably.
Subsidies	Fiscal instruments	Subsidies are given to individuals or groups to promote better environmental practices and/or decrease the environmental damage of their activities.
Product taxes	Fiscal Instruments	Environmental taxes charge users for the environmental damage of a given activity to encourage limit that damage through demand management.
Entrance fees	Charge System	Entrance fees are a charge system for users of an environmental good, with the aim of investing that money on conservation in the area.

5. Long-term monitoring programmes are absent in most MPAs.

6. Bias towards economic interests (e. g. tourism) diverts some MPAs from their original objectives.

7. Deep sea and open sea habitats (with the exception of the cetacean-oriented Pelagos Sanctuary in the NW Mediterranean) are not protected, since most of Mediterranean and Black Seas MPAs are in coastal areas.

8. A pronounced northern bias in the protection of Mediterranean Sea (Figure 22).

The Natura 2000 initiative only protects the coastline, with obvious limits that, in some cases, can give a false image of protection. The 507 sites of the Natura 2000 network (Figure 22, top) make up most of the 677 Mediterranean protected spaces. However, only 25% have some kind of management (Gabrié et al., 2013), under the jurisdiction of national and regional governments. In some countries (e.g. France, Spain), the Natura 2000 sites (many of which have no management) are considered to meet target 11 of the Convention on Biological Diversity (CBD) Aichi Biodiversity targets, that "...at least 10% of coastal and marine areas must be conserved and equitably managed effectively through systems by 2020..." (Meinesz and Blanfune 2015). Spain, for instance, has integrated some of its Natura 2000 sites in a brand new "network" of MPAs (the so-called RAMPE: Spanish Network of MPAs; http://www.mapama. gob.es/es/costas/temas/proteccion-medio-marino/biodiversidad-marina/espacios-marinos-protegidos/red-areas-marinas-protegidas-espana/red-rampe-integracion-espacios.aspx), grouping several areas with very different management levels. The **representativity, replication and connectivity** among MPAs are not considered in that network. In short, this indicates that the Aichi target 11 will be met in some countries, but only **artificially**.

However, the Italian policy towards MPAs does not include its Natura 2000 sites in the Aichi target, being based on the establishment of 29 designated MPAs (Meinesz and Blanfune, 2015). Italy and Greece share a model of MPA zoning, with one or more **no take** areas surrounded by one or two "**buffer**" areas where prohibitions concern mainly recreational or industrial fishing (http://www.minambiente.it/pagina/aree-marine-istituite). Areas outside MPAs boundaries but inside the network could be considered as **complementary** zones for protection where regulations and monitoring programs could be promoted and adopted to ensure the protection of a representative proportion of species and habitats from surrounding threats.

In the Black Sea there are up to 54, mainly coastal, MPAs, but only 14% enjoy some form of management, while the rest do not have adequate financial and human resources. None of these MPAs include a no-take zone.

In spite of the EU Directives, many European MPAs hardly qualify as effective MPAs. In this regard the EU should evaluate both the existing and future

Table 8. Categories of MPA governance approach (source: Jones, 2014)

MPA governance approach	Characteristics
Governed primarily by the state under a clear legal framework	Decisions are taken by the state with some deconcentration or delegation of power to lower level government and quasi-independent government organisations, which generally only consult local users and other stakeholders on decisions taken at a higher state level
Governed by the state with significant decentralisation and/or influences from private organisations	Implementation is decentralised too lower level government, quasi-independent government and private organisations along with the delegation of some decision-making powers; central governments maintain some degree and form of control over implementation and decision-making
Governed primarily by local communities under collective management arrangements	MPAs instigated on a bottom-up basis by local users, with implementation and decision-making mainly delegated to local users/organisations, but often requiring some degree of state support for enforcement
Governed primarily by the private sector and/or NGOs who are granted with property rights and associated management rights	MPAs instigated by organisations who may, or may not, represent local users who are granted with the majority of decision-making powers and implementation responsibilities, but often still requiring some degree of state involvement for enforcement and oversight
No clearly recognisable effective governance framework in place	Paper MPAs with no effective incentives to promote the achievement of MPA objectives or fulfilment of related obligations

MPAs based on some criteria such as serious management and means to ensure the effective protection of marine ecosystems. The minimum requirements for any coastal MPA to be approved by the EU would be similar to those proposed by Meinesz and Blanfune (2015):

1. **A representative no-take area** in all networked MPAs, in which fishing is absolutely banned. A buffer zone in which a limited fishing could be allowed, excluding the more harmful modalities, in order to preserve the local artisanal fishery.

2. **Effective enforcement of protection** measures with a sufficient number of wardens and the means that allow an efficient surveillance.

3. **Clear objectives of protection**, avoiding abuses and diversions due to other interests (i. e. enhancing tourism).

Future management: moving from single MPAs to MPA networks

Although Mediterranean MPAs with good surveillance and enforcement are few, several international organizations are nowadays promoting ecologically coherent networks of MPAs that have to meet the minimum requirements of **representativity, effectiveness, replicability and connectivity** (IUCN-WCPA, 2008). However, to create a network, **individual MPAs must have sufficient management and enforcement** to ensure a good protection level. Laudable initiatives, such as the Strategy of the MedPAN Mediterranean MPA Network (http://www.medpan.org/en/network-strategy-2013-2017), and the Mediterranean MPAs Roadmap (http://www.medmpaforum2012.org/en/node/2554) do not impose minimum requirements of management and effective enforcement for the networked MPAs. Assembling a number of "**paper MPAs**" (based solely on written rules that are not enforced) into a nominal network will not improve the situation. On paper, in fact, the assemblage of Natura 2000 sites, at least the whole northern side of the Mediterranean Sea, already seems a vast network of MPAs (Figure 23).

Building up ecologically coherent MPA networks

Despite the drawbacks of current single MPA management and network formation mentioned

above, there is a clear direction of travel for establishing effective ecological MPA networks, resulting from the CBD Aichi Biodiversity Targets, and the GES requirements of the EU MSFD.

IUCN-WCPA (2008) defines Networks of MPAs as "a collection of single MPAs operating co-operatively and synergistically at various spatial scales and with a range of protection levels that are designed to meet the objectives that a single MPA cannot achieve". "Synergistically" implies that the benefits of a network of MPAs outweigh the sum of benefits of single MPAs. This requisite, however, is difficult to test and, in fact, has almost never been checked. However, 'synergy' is absent in the IUCN guidelines, in which the most important goals of the network are:
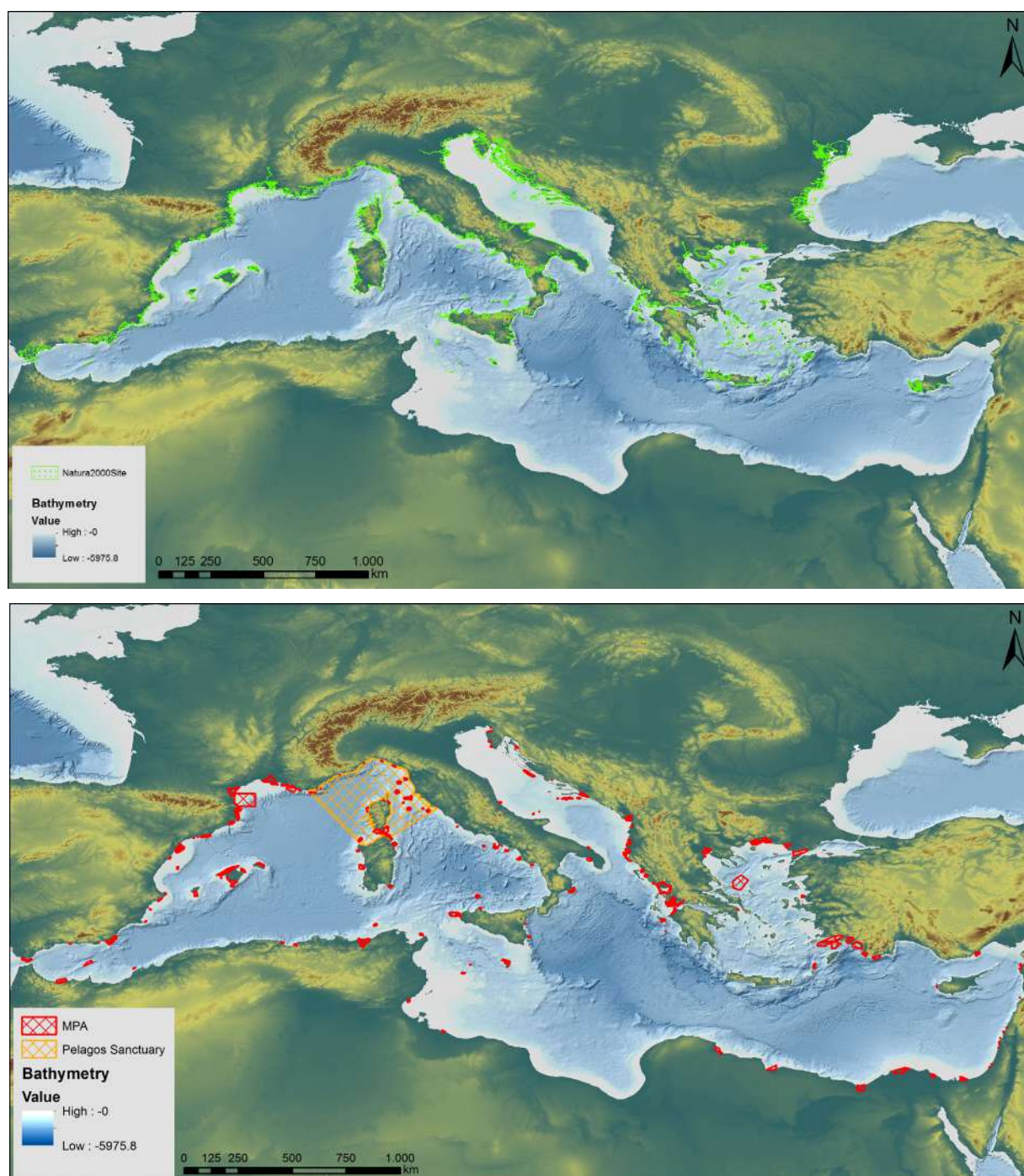

Figure 22. Top: Distribution of the Natura 2000 sites in the Mediterranean basin. Bottom: distribution of MPAs (MAPAMED datbase, 2014) in the Mediterranean basin. In orange the Pelagos Sanctuary, a marine area subject to an agreement between Italy, Monaco and France for the protection of marine mammals

1. **Include full range of biodiversity** present in the biogeographic region **(representativity and replication).**

2. **Ensure ecologically significant areas** are incorporated in the network **(replication).**

3. Maintain long-term protection (**resilience**).

4. Ensure ecological linkages (**connectivity**).

5. **Ensure maximum contribution** of individual MPAs to the network.

The first four of these goals do not require statistical testing and must be ensured during the network design, based on preliminary studies including:

1. **Extensive studies of biodiversity,** with special attention to the most vulnerable habitats depending on the specific goals of the network (goals 1, 2).

2. **GIS mapping** of the surface of all habitats of candidate areas to be integrated into the MPA network (goal 2).

3. **Oceanographic characteristics** of the area (current and wind conditions) are to be studied, so as to infer about the possible drift of propagules (goal 4).

4. **Genetic studies** - preferably on vulnerable populations- comparing different areas to check whether subpopulations of each area act as metapopulations within the network environment (goal 4).

5. **Home range and possible migrations** of mobile organisms (e. g. fishes, crustaceans) studied by means of radio tracking or tagging in order to see if their subpopulations are connected

6. **Systematic monitoring** of habitats and species, in order to ensure that the above goals are met.

A large part of the benefits attributed to the networks (representativity, replication and connectivity) are based on the **integrity of the design**, which must meet the objectives and require regular and long-term monitoring to check both the status of habitats and species, and also the possible changes due to natural or man-made threats.

Management Objectives of MPA Networks

MPA networks are likely to have broadly-drawn objectives due to their size and scale. Nevertheless, it is essential to set clear objectives for MPA networks (by mutual agreement or arrangement between the management authorities of their component sites) in order to elicit site-based management actions that can be used to measure progress and results. Network-level objectives should focus on the following aspects:

1. **Purpose** – ensuring that the underlying rationale for the MPA network is explained. The objectives of MPA networks cannot be inferred as the conflation of the objectives of single MPAs (the nodes of the network). MPAs are usually aimed at protecting unique expressions of biodiversity, identified as charismatic species and/or habitats. The networks must enhance, first and foremost, the ecosystem functioning processes that guarantee the existence of MPAs.

2. **Features/uses** – a common list of features and/or marine resource uses of network interest should be compiled; the required management activities are focused on maintaining the designated features and reduction of external impacts (including by enforcing applicable regulations at all jurisdictional levels). MPA networks should implement strategies, inclusive of monitoring and spatial plans (i.e. zoning), aimed at achieving GES, accounting for cumulative impacts on biodiversity and ecosystem functioning, with a 'learning by doing' approach.

3. **A common core management** of MPAs. This should include, at least, a representative no-take zone (where appropriate), a buffer zone, and economic support to guarantee enforcement. The EU must certify well-managed MPAs to be integrated into future networks.

4. **Monitoring and assessing network effectiveness** – indicators relating to maintaining the features/uses that contribute to the network purpose should be defined, taking account of temporal, spatial and governance aspects. Appropriate monitoring protocols for each indicator that are consistent across each site in the network should be formulated. Including extra-network sites in the monitoring programme can help to determine whether the network is performing better than having no network.
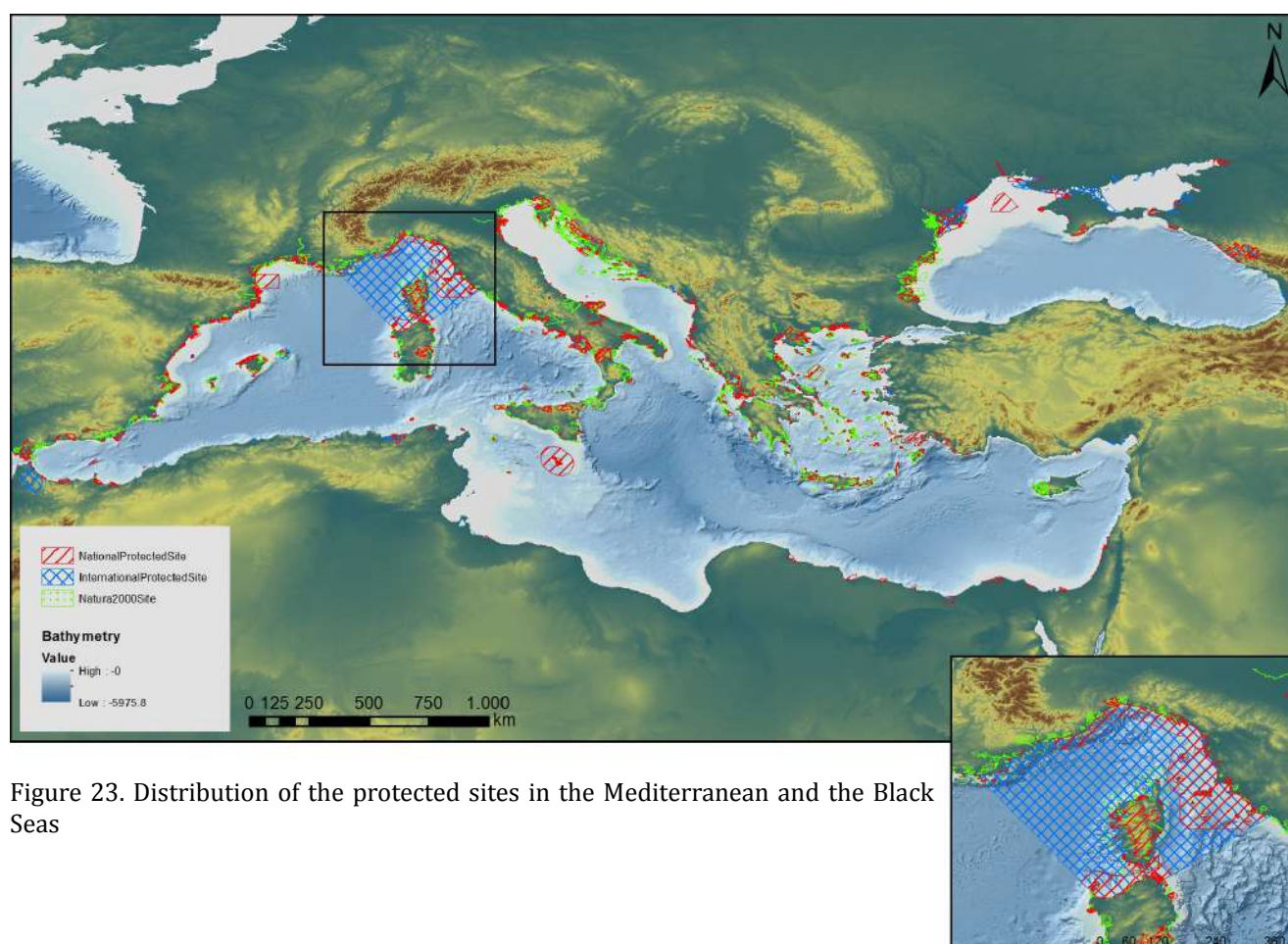
Figure 23. Distribution of the protected sites in the Mediterranean and the Black Seas

5. **Governance** – the network governance structures will generally flow from the site administration up to a multi-national body, with responsibility for the design, coordination and assessment of management and monitoring delegated to the lowest appropriate level. The overall governance structure is responsible for issues such as:

A. Establishing the common features/uses of the network

B. Identifying gaps and adding/designating new sites in the network

C. Developing standards for monitoring conservation features/uses

D. Ensuring data quality and control, and sharing information within and beyond the network)

E. Developing 'Best Practice' codes for site and network managers, including emergency response procedures

F. Sharing resources between network members for enforcement and monitoring activities

G. Promoting stakeholder engagement across the network

H. Raising public awareness of the network

K. Developing national and multi-lateral legislation to strengthen the network.

Monitoring MPA networks

MPAs protect habitats and species on a small scale, with limited impacts on ecosystem functioning at regional scale. MPA networks can have larger impact than single MPAs, and fit perfectly with the visions of the MSFD and its definition of Good Environmental Status (GES). MPA networks, if nested into Cells of Ecosystem Functioning (CEFs), are the instrument to reach GES and the MPAs are the ideal locations to test for management efficacy. Equally, MPA networks can serve as evaluation sites of GES and the test sites to fulfil by 2020 the objectives of GES defined by the 11 descriptors of the EU MSFD (Table 10). For example, some GES Descriptors are direct measures involved in MPA

management, namely: biodiversity is maintained; the population of commercial fish and shellfish species is healthy; elements of food webs ensure long-term abundance and reproduction; maintain the sea floor integrity that insures functioning of the ecosystem. Although MPA networks can do little to improve some descriptors (e.g. permanent alteration of hydrographical conditions, marine litter, etc.), they are linked to environmental management at large.

Assessment is crucial to test the efficacy of management and adjust actions, in accordance with the stated objectives. Representativeness requires that the protected portions within the network represent the diversity in biodiversity expressions, first of all in terms of habitats. Replication requires that the same habitat type is protected at several locations, so as to test if changes are global (when they occur throughout the replicates) or are due to contingencies (when they occur at some sites but not at others).

Clearly, mandatory long-term observation systems of MPA networks and of their effectiveness must be established in order to measure the attainment and maintenance of GES.

Monitoring and assessing the "synergy" in MPA networks: challenges and emerging issues

The main problem posed by MPA networks is how to check that the **synergy** among MPAs actually exists, that is, if the MPA network effects outweigh the sum of the effects of isolated MPAs. Just one example of such a design exists, showing the positive effect of a MPA network (Grorud-Colvert et al., 2014), but the evaluation is based on a single fish species and is insufficient to assess the adequacy of management in general. After Grorud-Colvert et al. (2011), a weighted meta-analytical approach going beyond Before-After-Control-Impact (BACI) designs can address this issue: the MPAs within the network would act as the impacted locations (with adequate space nested factors to assess not only the MPA variability, but also the variability within-MPA), and the MPAs outside the network would act as multiple controls.

Claudet et al. (2008) used a meta-analysis of Mediterranean and Atlantic no-take zones looking at the influence of distance to the nearest neighbouring MPA on the effectiveness of single MPAs in the north-west Mediterranean. There was

no effect of distance to neighbouring MPA on the response of commercial fish species richness or mean densities, suggesting that the distance *per se* to the nearest neighbouring marine reserve did not play any significant role. MPAs of different sizes and ages and with different zoning were included in this study. But it is likely that these MPAs meet the other objectives set by the IUCN-WCPA (2008), in terms of representativeness, replication and connectivity.

Monitoring the conservation goals and the effects of stressors in MPA networks

It often expected that, once protection of habitats and species is ensured in an MPA network, these will always evolve favourably. That could be true for the species that are very **sensitive to fishing** where and when exploitation ceases. However, some habitats and populations show an extremely **parsimonious rate of change** under 'natural' conditions (e. g. submarine caves, *Posidonia oceanica* meadows, coralligenous habitats)*.* Abrupt changes in these cases are likely to be related to unpredictable extreme events, such as severe storms (Mateo and Garcia-Rubies, 2012), poaching on *Corallium rubrum* (Linares et al., 2012) or mass mortality of filter-feeders due to increasing sea surface temperature and the deepening of the mixed layer (Coma et al., 2006; Rivetti et al., 2014). The effects of siltation in coralligenous habitats, and human frequentation in highly vulnerable habitats such as coralligenous formations and submarine caves (Hereu et al., 2012), or the effects of invasive species, induce more **progressive** changes.

Long-term monitoring is needed in case of either sudden or progressive change in the descriptor, and also to prove the extent of the losses and the resilience of these descriptors inside the MPA networks. The establishment of **long-term observation systems** must ensure both the state and the evolution of protected habitats and populations, and the severe or progressive changes caused by multiple stressors throughout the network. In both cases it is advisable that observing systems are applied **inside and outside** the MPAs of the network, ideally following a "beyond BACI" design (Underwood, 1997), considering the effects of different combinations of threats to document if the magnitude of the changes affects

or not all MPAs in the network, and whether there are differences between the MPAs and non regulated areas. Sampling methods of monitoring should be adapted to each descriptor and can be broadly classified into "detailed" or traditional sampling, and quick "coarser" sampling, such as photographic methods (Kipson et al., 2011). Detailed sampling involves a comprehensive qualitative and quantitative characterization of the most sensitive habitats included in the network.

Use of Site Descriptors

Monitoring schemes must be set according to the **objectives** of managed systems (Gleason et al., 2013). The cases of **long-term monitoring** in current Mediterranean MPAs are few, due to **lack of economic support** to monitoring. The selection of **descriptors** can apply to different criteria that are related to protection (Table 9). Descriptors are **specific** for each MPA, but cannot apply to networks: a **general set** of descriptors should be employed throughout the networks (see below).

Monitoring Large Scale Effects of MPA Networks: the Good Environmental Status (GES)

The **effectiveness** of MPA networks must be tested in terms of **representation**, **replicability** and **connectivity**. One possible way to evaluate the proper functioning of the networks would be to test the effect in some region-wide **environmental quality index** (e.g. ecosystem functioning in the CEFs). The **MSFD** prescribes the achievement of **GES**, defined as: "*the environment status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are intrinsically clean, healthy and productive and the use of marine is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations.*" To give context to this definition, 11 descriptors of GES are provided in the MSFD (Table 10).
The Descriptors which are directly addressed in MPAs and MPA networks are listed in Table 11. Of these, Descriptors 1, 3 and 4 have been shown to perform favourably in Mediterranean MPAs (Hall et al., 2012); the possibility that MPA networks might address descriptor 2 is yet to be determined, since the role of MPAs in limiting the proliferation

of non indigenous species seems rather small so far (Otero et al., 2013).
The rest of GES descriptors depend only in part on the degree of protection of a given area because the source of the problem might lie well outside the area of influence of the MPA network. Descriptors 6 and 7, on sea floor integrity and alteration of hydrographical conditions respectively, however, might be invoked as an objective in a network, and also marine litter (descriptor 10) might be dealt with some management. The limitation of eutrophication and contamination pertains more on the impact of land-based activities on marine systems.
In most EU countries the criteria for implementing GES are still **unclear**, with **lack of harmonization** of methods between countries (Hummel et al., 2015). Thresholds, data availability, and the knowledge of some descriptors (D2, D7 and D11) and methodologies are still unclear. There are differences in the implementation of GES in different countries (Borja et al., 2013). Furthermore, there are no baselines to assess some of the GES descriptors and there is the need to assess the natural variability of the variables/indicators we use to assess if the status of a system is good. For example, what is the biodiversity that has to be maintained? Is it the high diversity in pristine habitats? Do pristine habitats exist in a given region of the Mediterranean and Black Seas? In some case the values of some descriptors in effectively managed MPAs could be good references areas. The rationale behind some of the concepts included in the MSFD is sometime difficult to quantify. Despite the attempt to provide a holistic approach to the assessment of the status of the marine environment, the proposed definition of Good Environmental Status, the identification of clear-cut targets and the proposed approach for threshold evaluations handles with difficulty the complexity of the response of the ecological systems to multiple stressors. Multiple controls and structured experimental designs can address the variability of natural systems, and can help us to identify critical situations and the good environmental status. The MSFD should be perceived as challenge and an opportunity for the whole European scientific community, whose role in providing guidelines for the monitoring of the marine environment should be fully recognized.
The role of MPA networks could be important in the attainment of GES in a given region if their state could be integrated in an index that could

summarize the scores (weighted or not) of all descriptors, as suggested by UNEP (2012). Although MPA networks can do little to improve some descriptors, they can play an important role in others (Tables 9, 10, 11). If the number of MPA networks is going to be high, the GES could be reached in many cases. One possible way to evaluate the performance of the networks of MPAs would be testing the effect in some region-wide environmental quality index such as the Ocean Health Index (OHI), applied to the West Coast of the United States featured by an Ecosystem Approach to Management (EBM) (Halpern et al., 2012). The OHI contains some **ecosystem services**-oriented descriptors that can be also improved by an MPA network, such as Food Provision, Natural Products, Carbon Storage, Coastal Protection, and Tourism and Recreation.

It is expected that GES descriptors, due to general management, would improve within MPA networks. Management must be **tailored according to the features of each CEF**, in connection with the management of the single MPAs making up the nodes of the network.

Gaps in Monitoring / Observation Systems for CEFs and MPA Networks

The Descriptors of GES are all based, directly or indirectly, on **Biodiversity and Ecosystem Functioning**. The goals of MPAs and of their network is just to warrant Biodiversity and Ecosystem Functioning. So the overall objective of the networks is GES. The networks, thus, will be the **natural areas** where the attainment of GES is to be assessed and the measures to obtain it are enforced, either directly or indirectly. And they will be conducive to establish new forms of observation platform, so as to complement current ones (Figure 24).

The knowledge acquired on Mediterranean and Black Sea ecosystems is great, but its fragmentation is hindering holistic approaches. Although the key role of connectivity in marine systematic conservation planning is well established (Beger et al., 2010), the **paucity of empirical data** has prevented effectively incorporating connectivity into conservation planning (Hodgson et al., 2009). The management of the seas, including their protection, must be ecosystem-based and

Table 9. Some examples of descriptors taken into account in the Medes Islands MPA monitoring programme according their role in the ecosystem, the interest, the main threats and vulnerability, and the sampling methods that can be used

Descriptor	Role	Interest	Main threats	Vulnera-bility	Connec-tivity	Sampling methods
Coralline-nous habitat	'Key' habitat	Ecological Landscape	SST warming Siltation Invasive species Erosion	High	????	Classical sampling Quick surveys (point-intercept, photographic surveys)
Algal cano-pies	'Key' habitat	Ecological Landscape	Overgrazing Invasive species	High	Low (e.g. *Cystoseira* spp)	Classical sampling Quick surveys
Submarine caves	'Rare, exclu-sive' habitat	Ecological Landscape	Erosion	Very High	Presum-ably low	Sampling
Targeted fish spp	Preda-tors	Ecological Economical Iconic	Fishing	Medium	High	Visual counts Experimental fishing (in buffer areas)
Corallium rubrum	Building species	Economical Landscape Iconic	Fishing	Very high	Very Low	Classical sampling (density, height, and width of the colonies Quick surveys
Paramuricea clavata	Building species	Ecological Landscape	SST Warming Erosion	High	Very low	Classical sampling (density, height, of the colonies, partial mortality) Quick surveys

Table 10. Descriptors of Good Environmental Status in the MSFD

Descriptor 1	Biodiversity is maintained
Descriptor 2	Non-indigenous species do not adversely alter the ecosystem
Descriptor 3	The population of commercial fish species is healthy
Descriptor 4	Elements of food webs ensure long-term abundance and reproduction
Descriptor 5	Eutrophication is minimised
Descriptor 6	The sea floor integrity ensures functioning of the ecosystem
Descriptor 7	Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
Descriptor 8	Concentrations of contaminants give no effects
Descriptor 9	Contaminants in seafood are below safe levels
Descriptor 10	Marine litter does not cause harm
Descriptor 11	Introduction of energy (including underwater noise) does not adversely affect the ecosystem

integrative, with holistic views that are still missing in the scientific community. Some of the most important gaps are set out below.

1. **CEFs are management and conservation units**, their spatial definition in the Black and the Mediterranean Seas calls for detailed, crosscutting and integrative appreciation of the connections that characterize the marine space, i.e. the **holistic approach**. The scientific community is still reductionist: disciplinary barriers prevent effective communication across the various approaches; such cultural and operational hindrance must be removed by focused **talent building**. Large technological infrastructures produce enormous amounts of information and require technologists to operate the machines, but this led to lack of properly trained scientists, able to **transform**

information into knowledge. This challenge will require the elaboration of a solid strategy, since marine sciences are still too fragmented.

2. **Change is the trademark of life,** the understanding of the evolution of these highly dynamic systems calls for **long-term series**. Conditions change **annually** (seasonality) and **interannually**: a **long-term approach** to the study of environmental features is required, especially in a period of fast change as now. Long-term series of ecological observations, instead, are being dismissed.

3. **Current observation systems** mainly focus on the water column and consider mostly physics and biogeochemistry. They do not cover **biodiversity and ecosystem functioning**, the pillars of GES, calling for a thorough **upgrade**. Observation systems can be based

on a monitoring strategy, but must be more **flexible**. Monitoring should cover three aspects: baseline (surveillance/observation), targeted (management intervention impact) and unexpected events (recording as much as possible in the short time they take place, and then included in surveillance and/or targeted). If unexpected events occur, they must be reported and measured: the dedicated personnel must be ready to face them. In case of episodic

Table 11. List of descriptors and indicators of GES that can be addressed by MPA networks

Descriptor	Criteria	Indicator
1.Biological diversity	1.1. Species distribution	1.1.1. Distributional range
		1.1.2. Distributional pattern within the latter
		1.1.3. Area covered by the species
	1.2. Population size	1.2.1. Population abundance and/or biomass
	1.3. Population condition	1.3.1.Population genetic structure
	1.4. Habitat distribution	1.4.1. Distributional range
		1.4.2. Distributional pattern
	1.5. Habitat extent	1.5.1. Habitat area
		1.5.2 Habitat volume when relevant
	1.6. Habitat condition	1.6.1. Condition of the typical species and communities
		1.6.2.Relative abundance and/or biomass
	1.7. Ecosystem structure	1.7.1. Composition and relative proportions of ecosystem components (habitats/species)
2. Non-indigenous species	2.1. Abundance and state of non-indigenous species, in particular invasive species	2.1.1. Ratio between invasive non-indigenous species and native species
	2.2.Environmental impact of invasive non-indigenous species	2.2.1. Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem
3. Exploited fish and shellfish	3.1. Level of pressure of the fishing activity	3.1.1. Fishing mortality
		3.1.2. Catch biomass/ratio
	3.2. Reproductive capacity of the stock	3.2.1. Spawning Stock Biomass (SSB)
		3.2.2. Biomass indices
	3.3. Population age and size distribution	3.3.1.Proportion of fishes larger than the mean size of first sexual reproduction
		3.3.2. Mean maximum length across all species found in research vessel surveys
		3.3.3. 95% percentile of the fish length distribution observed in research vessel surveys
		3.3.4. Size at first sexual maturation
4. Food webs	4.1. Productivity of key species of trophic groups	4.1.1 Performance of key predator species
	4.2. Proportion of selected species at the top of the food webs	4.2.1. Large fish (by weight)
	4.3. Abundance/ distribution of key trophic groups/species	4.3.1. Abundance trends of functionally important selected groups/species

events of wide scale, the frequency of observations must be increased. Each state has its own monitoring networks, according to internal regulations. The shift from monitoring to observation should be encouraged and sustained economically, in the framework of the MSFD. The data from **fisheries** should become part of observation systems.

4. **Sea bottom mapping** mostly considers geological features, and much is still to be accomplished to **define the distribution of benthic habitats**. The **functional links** across the portions of the marine environment, determining ecosystem functioning, are not well elucidated yet.

5. **The water column** is mistakenly considered as a simple medium and the lack of recognition that it is **a suite of habitats** is a major gap: the definition of CEFs calls for its **mapping**. The Habitats Directive (and, hence, the Natura 2000 sites) and the siting of MPAs are based on the distribution of benthic systems. The very concept of "area" must shift to focus on "**volume**".

6. **Fill the serious gap in the coordination and homogenization** of observation systems, which are often run by single states. On the contrary, we need a **basin-wide strategy** that allows the collection of consistent and comparable data, to be stored into comprehensive data bases, following the model of the CoCoNet Geodatabase. The involvement of non-EU states in CoCoNet is a wise policy in this direction. The BlueMed Initiative is an important step in this direction and is being substantiated under Horizon 2020 in the 2016 Work Programme of SC2.

7. **Regime shifts** are increasingly observed in marine coastal habitats in response to intensifying human activities and global change, resulting in significant **loss of ecosystem services**. Improving the ability to prevent these transitions has profound implications for management and conservation of coastal marine ecosystems. Yet, our knowledge of regime shifts is still too limited to underpin management decisions. We lack understanding of how resilience is built-up in ecosystems. This requires focused research on thresholds and better knowledge of the mechanisms that determine resilience.

8. The knowledge of **Non Indigenous Species**

is still limited, as is the assessment of their effects on ecosystem structure and function. Eradication systems are highly ineffective, as are prevention systems. Conservation of habitats must include the detection of NIS and their management.

9. **Promote training curricula in holistic sciences**. The training of scientists is reductionistic. The holistic view is not simply the sum of the reductionistic approaches. Curricula in integrative marine sciences are missing. There are big enterprises in reductionistic sciences (e.g. physics or molecular biology) but the study of complex natural phenomena, such as those that pertain to the marine environment, are still fractioned. Practical solutions to specific problems are often offered, with a lack of overview and theory. This usually leads to short-term solutions that are followed by medium- to long-term problems. The scientists that study the various compartments of the marine space rarely communicate (Thiede et al., 2016).

10. **Co-ordinate research actions**. National and international research is still fragmented. The bits of information are rarely transformed into knowledge. The CoCoNet Geodatabase achieved this result that, however, must be strategic and not linked to contingent programmes.

11. **All benthic habitats must be mapped**, as the Corine Landcover system did with terrestrial ones. This is will require field studies, so as to identify both geological and bio-ecological aspects. CoCoNet produced a protocol to classify habitats. A lot of data are available for *Posidonia* meadows and bioconstructions: this is to be extended to all marine habitats. Mappings are to be repeated so as to evidence seasonal and long-term changes.

12. **Map pelagic habitats**. The definition of CEFs requires this mapping that, however, is not as precise as that of benthos. Seasonal and annual changes in current regimes can lead to variations in the spatial distribution of such mappings which do not pertain to patterns only but that comprise also ecological processes. The protocol used in CoCoNet to identify CEFs (based on physical oceanography, propagule dynamics, beta diversity distribution, and genetics of key species) is to be further improved with measures of production.

13. **Merge benthic and pelagic habitats into**

Figure 24. Observations systems currently cover mainly physics, chemistry and biogeochemistry. In order to face the requirements of GES evaluation, observation systems must be upgraded so as to cover also Biodiversity and Ecosystem Functioning. Networks of MPAs and Marine Stations will have a prominent role in this upgrade

maps that link patterns and processes, so as to identify the CEFs within ecoregions. This mapping will be crucial to implement sound marine spatial planning, based on biodiversity and ecosystem functioning.

14. **Revive taxonomy**. Expertise on biodiversity is vanishing from the EU scientific community. Phenotypes are as important as genotypes since ecosystems function due to their action. The EU is losing an important component of biodiversity expertise (Thiede et al., 2016).

15. **Promote projects on the fauna and flora of EU waters**. Updated monographs of the EU biodiversity are lacking. The European Register of Marine Species lists the species, but the knowledge regarding their morphology, genetics, ecology, biology, phenology, etc. has not been assembled. It is futile to infer about biodiversity and ecosystem functioning if we do not know the components of the system and how they are related with each other. This is an absolute priority that is invoked from many tribunes but that is invariably left behind.

16. **Set up harmonized long-term observation systems**. These must be carried out at all MPAs and also in other zones, according to national monitoring plans of the various States. This monitoring is already envisaged by the MSFD in the light of GES, but there is an apparent lack of consistency in the way the various states are planning it. Furthermore, it has to be encouraged also in non-EU countries when their jurisdiction falls within shared CEFs.

17. **Coordinate the long-term series at marine stations** with assessments at wide geographic scales that can use information of past knowledge as benchmark to evaluate recent conditions.

18. **Organize task forces to study episodic events of ecological relevance** (e.g. swarms of gelatinous organisms, harmful algal blooms, mass mortalities, etc) that are of short duration. Monitoring networks detect these events but when they occur extra efforts are necessary.

19. **Upgrade current observation systems so as to fulfil the scopes of the MSFD**. Huge resources have been invested to set up observation systems based on remote sensing of key variables that, however, do not cover the eleven descriptors of GES. Key variables are still considered with low-tech approaches, whereas high tech approaches are dedicated to background variables that are extremely important but that do not help much in defining GES.

4. The future: where to go next with MPA Networks

Declines in biodiversity occur at unprecedented rates, calling for systematic conservation actions, encompassing planning, implementation and management of conservation initiatives (Margules and Pressey, 2000). The irreversibility of biodiversity loss, and the reduction in ecosystem services affect the food security and livelihoods of many people. Conservation planning (Margules and Pressey 2000) develops theory and guidelines to effectively and efficiently conserve biodiversity. MPA design theory is a subset of conservation planning that specifically addresses guidelines for MPA network design (e.g., spacing, size, replication) to enhance effective protection of biodiversity (Sala et al., 2002; Lubchenco et al., 2003). The expectation is that this theory – conservation planning generally, and MPA design specifically – will help inform implementation of conservation actions (Margules and Pressey, 2000; Balmford et al., 2003; Knight et al., 2006) leading to marine sustainability (Thiede et al., 2016). In order to do so effectively, however, conservation planning theory needs to evolve based on the latest relevant ecological and social science advances, taking **natural history** into consideration (Ricklefs, 2012).

Systematic conservation planning requires improvement: its theory and guidelines represent known and mapped biodiversity elements (e.g., species, habitats), and adopt generic design criteria such as replication (e.g., ensure that biodiversity elements are represented in more than two MPAs). In most cases, patterns of biodiversity are **implicitly assumed as static** (Pressey et al., 2007).

In contrast to the reality of community-based MPA implementation, most of the theory and practice of systematic conservation planning has been based on developing regional-scale, "**top-down**" plans. One of the perceived strengths of the top-down approach is the ability to ensure that MPAs within the network are well connected to each other. **Both local and regional approaches are important**, but there is **difficulty** in making the two

approaches work together. A strong understanding of MPA **connectivity** requirements can act as an effective **bridge** by guiding the implementation of **bottom-up** community-driven efforts to meet regional goals, thereby **reconciling** the strengths of systematic conservation planning with the need to be responsive to locally driven opportunities.

All states invariably call for policies aimed at sustainable development. The increase of the economic capital will be sustainable only if the natural capital will not be eroded. The neworks of MPAs will hopefully play a prominent role in promoting marine sustainability (Thiede et al., 2016).

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6. OFFSHORE WIND ENERGY IN THE MEDITERRANEAN AND BLACK SEAS:

THE SMART WIND CHART

6.1   Rationale

The necessity to increase the share of the offshore renewable energy resource in the energy-mix strategies is a top priority in the EU. To date, offshore wind energy combines a number of attractive aspects, from technological maturity to economic viability that may further enhance its dominance, provided that offshore wind energy projects are developed with deference to the marine environment. To this effect, the CoCoNet project has undertaken among others a two-fold task: i) to assess offshore wind resource under the current and future climate conditions at the Mediterranean and Black Seas, two basins with many particularities where no offshore wind farm has been constructed yet, and ii) to develop the Smart Wind Chart, i.e. a multilevel tool for the identification and pre-evaluation of potential sites for offshore wind farm development taking into consideration different viewpoints, namely technical restrictions and environmental considerations.

As regards the development of offshore wind farms in the Mediterranean and Black Seas, one of the primary concerns is the identification of appropriate candidate areas. This is a complex and multifaceted procedure, encompassing a variety of different parameters and considerations (technical, environmental and socio-economic) that are often not aligned. To start with some gross technical parameters, offshore wind resource (or wind speed) evaluation is the most important one. At the basin scale, long-term and high resolution gridded wind data are necessary, while appropriate methods should be applied in order to estimate inherent uncertainties and increase accuracy. Moreover, future climate change may affect wind energy economics and therefore should be also considered. Additional technical parameters that are analysed are the bottom depth, the distance from shore, the proximity to ports, the electrical grid infrastructure and the type of bottom sediments. A common feature of the abovementioned characteristics is that they define to a great extent the wind energy economics. On the other hand, the environmental considerations illustrate not only the present ecological status of the examined basins but also the future one by predicting potential (positive and negative) effects on the surrounding (biotic and abiotic) elements. From this point of view, the environmentally restricted and sensitive areas that are considered are: National protected areas/marine protected areas, Ramsar/Natura 2000 sites, coralligenous and maërl, deep sea corals, *Phyllophora* fields and *Posidonia*/sea grass meadows.

In order to reveal candidate areas that deserve further in-depth assessment for offshore wind farm development, the consideration and evaluation of the technical parameters is achieved firstly through the implementation of a factor rating table that assigns ranks to particular ranges of these parameters. Then, the importance of each parameter is quantified by applying a relative weight and, through a linearly weighted methodology, the candidate areas are evaluated. The obtained results are integrated, along with the environmentally sensitive areas, in a Geographic Information System platform. This final tool is called the Smart Wind Chart. The results of the Smart Wind Chart are presented for both the basin scale and two pilot sites, while some notes of caution are also provided in order to avoid potential misuse or misinterpretation of the results.

The detailed description and the analytic results as regards the themes presented here are contained in the following deliverables/milestones of the project:

1. D5.1: Report on existing and in-progress technologies of offshore wind farm elements and wind turbines;

2. D5.3: Offshore wind power potential for the Mediterranean and Black Seas;

3. D5.4: Statistical analysis and comparison of the offshore wind power potential;

4. D5.5: Smart wind chart for the Mediterranean and Black Seas;

5. M24: Wind data for the Mediterranean and the Black Seas;

6. M25: Atmospheric model results for the Mediterranean and Black Seas.

7 Approaches and potential obstacles for offshore wind energy development in the Mediterranean and Black Seas

Reduction of the dependence on fossil fuel and emissions from carbon sources, decoupling energy costs from oil prices, improvement of competitiveness with an internal energy market and reassurance of a secure energy supply arise the imperative necessity of renewable energy sources. Finding new suitable onshore sites to install wind farms is becoming increasingly difficult in Europe (Soukissian, 2013); therefore, offshore wind energy is an attractive alternative solution offering many advantages (higher, more frequent and less variable marine winds than inland). Offshore wind farms (OWFs) are already much developed in the North and adjacent seas, but no OWF has been developed yet in the Mediterranean and Black Seas. The EU holds the leading position of OWF development worldwide, mainly in the UK and Germany. Along with its economic viability, offshore wind energy offers many advantages, which explains its steady growth worldwide. The wind potential in the Mediterranean and Black Sea basins, although not ample, is sufficiently high and exploitable, while the offshore wind industry is mature enough to expand in these two basins like in the Northern European seas. According to Gaudiosi and Borri (2010), the total wind energy production (offshore and onshore) could cover 10% of electricity demand of the Mediterranean countries by 2030.

Besides the evident benefits of wind as clean energy source, proper site selection and construction of an OWF might even have **positive impacts** on the marine environment. The wind turbine **foundations**, for example, if properly designed, can be **habitats** for hard bottom

Figure 25. Coupling wind energy with environmental features should be common practice for every OWF development. If properly designed, their bases can be stepping stones increasing connectivity into the cells of ecosystem functioning where they are placed (Concept: Ferdinando Boero; Art: Alberto Gennari)

species, favouring the **connectivity** among Marine Protected Areas (MPAs) separated from each other by large extensions of soft bottoms (Figure 25). Furthermore, OWFs can have a large potential as "areas of opportunity" for fisheries management. With the prevention of fishing activities (e.g. trawling) inside OWFs, these refuge habitats may evolve in the future into important ecological systems on a larger scale (Bergström et al., 2013). Moreover, development of synergies/multi-uses in offshore wind projects will increase acceptance of OWFs. For instance, the foundations can be used to implement **sustainable aquaculture**, especially of filter feeding bivalves, such as mussels; this perspective will provide various technical, economical and, above all, environmental benefits, while simultaneously will optimize the use of marine space (Lacroix and Pioch, 2011; Westerberg et al., 2013).

One of the most important problems in the design and development of an offshore wind project is the **identification of appropriate areas**, which is directly related with the planning of the wind farm with regard to other marine uses of the area. The selection of appropriate sites is neither simple nor a straightforward process. On the contrary, the determination of the suitability of an OWF site is a multilateral and complex procedure that comprises technological, socio-economic and environmental considerations, which are not always aligned. On the other side, cost reduction of offshore wind projects is a major challenge in the sector. Apart from wind availability, **distance from shore and bottom depth** are currently among the most important technical and financial constraints in the selection of sites for OWF development, especially in the Mediterranean Sea. Short distance from shore may cause **visual disturbances** in coastal areas and favour the "not in my backyard" (NIMBY) attitudes. To avoid visual disturbances, France has recently considered developing OWFs based on **floating wind turbines and therefore this perspective is also taken into consideration**. Moreover, the current European trend is to **move away from the coastal zone** to far offshore (EWEA, 2015a), a perspective that is expected to reduce the above limitations when the relevant floating turbine technology reaches the appropriate technology readiness level (TRL). Under the current conditions, conflicts between different uses of the same marine space are also expected to occur mainly due to the **very**

well developed tourism industry, fisheries and aquaculture, rendering the development of OWFs in the Mediterranean and Black Seas a delicate task. In this connection, a basin wide marine spatial planning (MSP) is expected to greatly facilitate this aim.

The **Smart Wind Chart** (SWC) aims to integrate some of the most important quantifiable factors in order to identify and evaluate potential locations for OWF development in the Mediterranean and Black Seas by taking into account environmental considerations. Let it be emphasized beforehand that **the identified locations in the Mediterranean and Black Seas should not be considered as direct suggestions for future OWF development; they rather comprise a set of potential areas which are favourable** *candidates*. **Final decisions and strategies as regards the development of OWFs in particular sea areas are feasible only after a detailed assessment of the local technical, socio-economic and environmental features at the finest possible spatial scale.**

Since the most important parameter, as regards the evaluation of locations in the Mediterranean and Black Seas for potential OWF development and the viability of offshore wind projects, refers to the assessment of the wind climate and of the available wind resource, in the next section the offshore wind climatology of the examined basins is presented.

8   Offshore wind climatology and wind power potential in the Mediterranean and Black Seas

8.1   The role of wind in the marine system of the Mediterranean and Black Seas

Ocean surface **winds** have an important effect on the world **climate**. Wind is the main driver of both changes in air masses and humidity fluxes from sea surface evaporation, and also induces storm surge and wave dynamics, which are **key elements** in the determination of **coastal risks**. The sub-basins of the Mediterranean Sea have different wind regimes; Figure 26 shows a summary of the

usual wind names for the Mediterranean region. The Black Sea has a much **simpler** topography, compared to the Mediterranean: its atmospheric circulation is dominated by northerly winds. During winter months, stronger Northern winds define a rim current with two gyres whilst, during summer, the wind attenuates causing the breakdown of the rim current into a series of eddies.

8.2   Wind data sources and relevant uncertainties

Wind climate assessment and resource evaluation are the main prerequisites for the **identification of candidate OWF locations**. For the detailed spatial assessment of offshore wind resource at the basin scale, long-term results from high-resolution numerical atmospheric models were utilized, namely **Eta-SKIRON** for the Mediterranean Sea (Papadopoulos et al., 2011), and **WRF-ARW/SeaWind II** (Skamarock et al., 2008; Menéndez et al., 2014) for the Black Sea. The **European Centre for Medium-Range Weather Forecasts** provided the initial conditions for both models. Gridded satellite data from the **Blended**

Sea Winds (Zhang et al., 2006) and the **ERA-Interim products** (Dee et al., 2011) were also used for comparison purposes (Soukissian et al., 2016). All these alternative wind data sources are characterized by different measuring principles and errors, devices and configurations; therefore, various types of **uncertainties** are inherently present, and they should be properly considered and, if possible, quantified. Due to the lack of accurate long-term wind measurements from meteorological masts or Lidar (Light Detection and Ranging) instruments, the evaluation of the aforementioned wind data sources and the estimation of the relevant uncertainties was based on *in situ* measured wind data for the Spanish and Greek Seas (obtained from buoys) and the Italian coasts (obtained from coastal stations). The analysis' results suggested that the **evaluation and identification of uncertainties of wind data should never be overlooked and necessarily should be taken into consideration when site-specific studies are made for potential OWF development**; see also Soukissian et al. (2014); Soukissian and Papadopoulos (2015). In the latter work, a sophisticated and effective **calibration procedure** is described and applied for specific
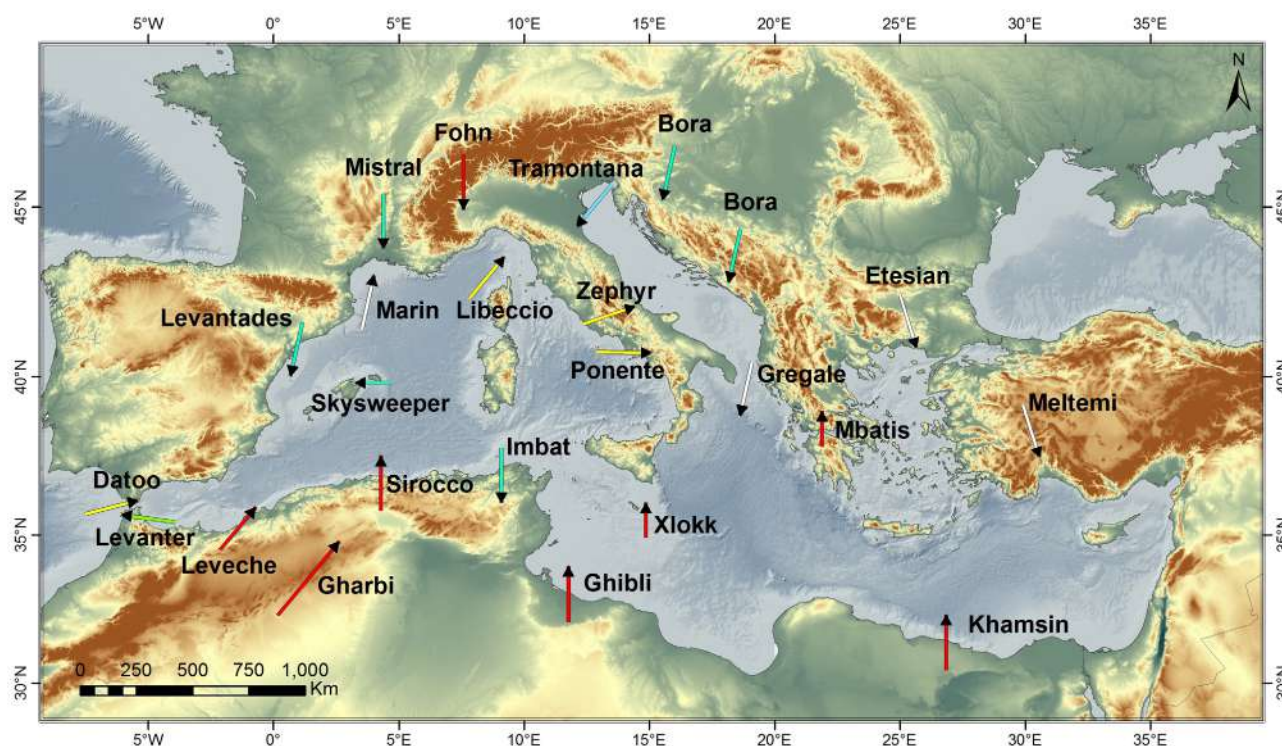

Figure 26. Winds of the Mediterranean Sea

locations of the Mediterranean Sea. However, **it is not advisable to apply a single calibration relation in extended spatial scales**, since the performance of the calibration methodology is, in general, site-dependent.

8.3   Wind climate and wind power density for the Mediterranean and Black Seas

At the Mediterranean basin scale, the analysis of wind climate and offshore wind power potential is confined to the spatial distribution of various long-term quantities, such as mean value, standard deviation, coefficient of variation at the annual and seasonal (monthly) subscales, along with the mean annual and the inter-annual variability. The results of the **Eta-SKIRON** model reveal that the **Gulf of Lions and the Aegean Sea** are the **windiest** areas (mean annual wind speed reaches values up to 7.5 m/s at 10 m height above sea level), as well as all the **major straits** of the basin (Figure 27). December, February and March are the **windiest** months in the Mediterranean Sea, and August, June and September are the **calmest** ones. A detailed analysis of wind climate and its variability for the

Mediterranean basin is provided in Soukissian et al. (2017). The mean annual wind power density at 10 m height above sea level reaches values up to 560 W/m^2 encountered offshore the Gulf of Lions, and up to 480 W/m^2 at some locations in the central and southern Aegean Sea.

For the Black Sea, the **SeaWind II** results reveal that the mean wind speed spatial distribution is characterized by a clear diminishing northwest-southeast gradient (Figure 28). The highest values of mean wind speed are found along the **Ukrainian coasts** of the Black Sea and in the **Sea of Azov** (about 7 m/s). December, January and February are the **windiest** months while May, June and July are the **calmest** ones. The mean annual wind power density at 10 m height above sea level reaches values up to 400 W/m^2 encountered offshore the western coasts of Sea of Azov, while in the western coasts of Black Sea it reaches values around 330 W/m^2.

The detailed analysis of the wind climate and wind power density in the Mediterranean and Black Seas is presented in the deliverable report D5.3: "Offshore wind power potential for the Mediterranean and the Black Seas on a monthly, seasonal and annual basis", and the milestone reports M24: "Wind data for the Mediterranean and the Black Seas" and M25: "Atmospheric model results for the Mediterranean and Black Seas".
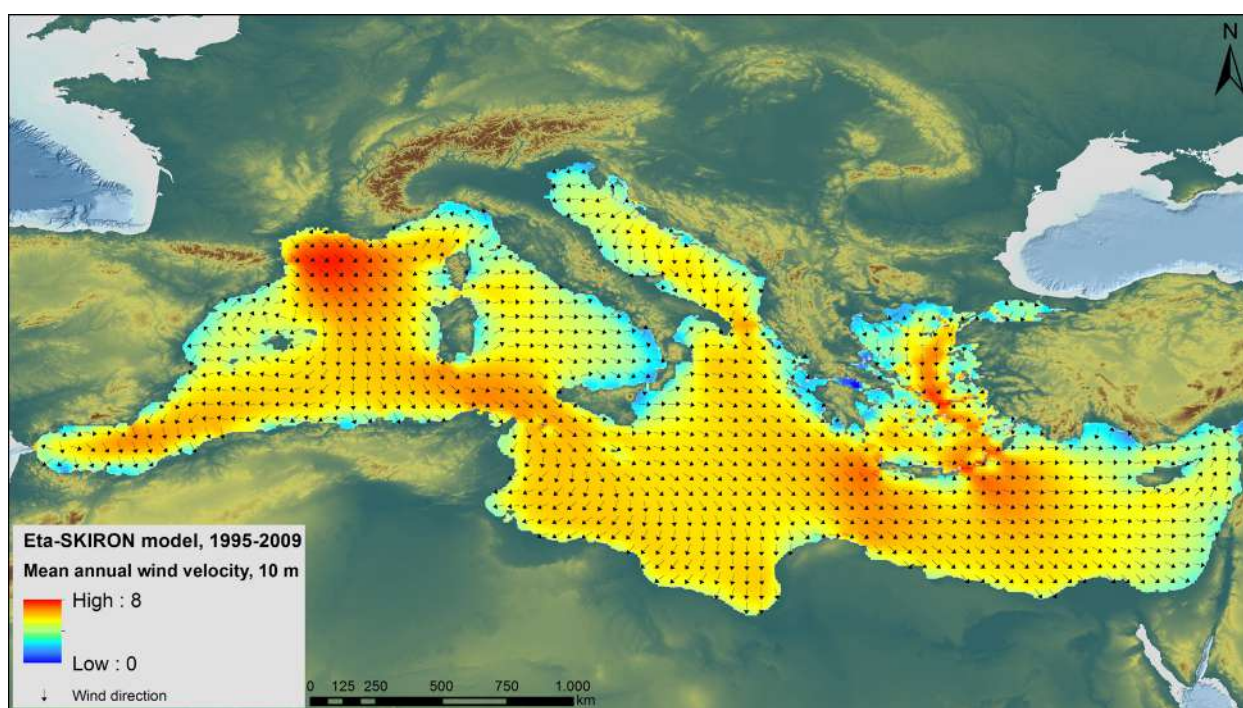

Figure 27. Mean annual wind speed (m/s) and direction for the Mediterranean Sea obtained from the Eta-SKIRON model (1995–2009)
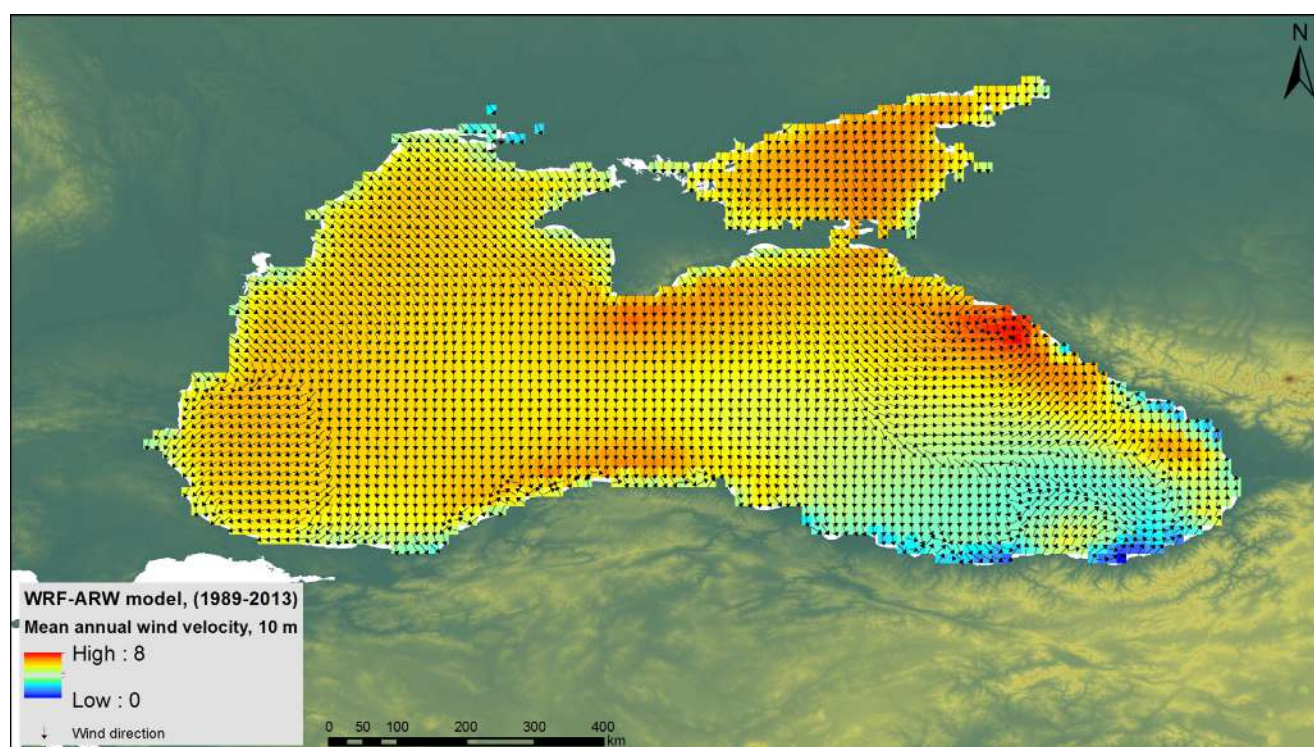
Figure 28. Mean annual wind speed (m/s) and direction for the Black Sea SeaWind II, obtained from the WRF-ARW model (1989–2013)

8.4   Offshore wind power under global climate change scenarios

Wind energy and the relevant economics are also susceptible to global climate change, since they rely upon components of the climate system. Wind speeds over Europe are expected to **change** during the 21st century as a result of the increased **greenhouse** gas conditions, (Rockel and Woth, 2007) and, therefore, a critical question for the offshore wind industry is **what impact could a global climate change have on the wind energy production**?

Aiming to provide quantitative estimates to the above question, an extended analysis has been made, based on global climate change scenarios and data from the EU-funded ENSEMBLES project, http://ensembles-eu.metoffice.com/.

The combinations of available regional and global models evidence **high levels of uncertainty** as regards future wind conditions; hence a **consensus rate** was adopted to estimate each future period: i) a threshold of 5% change in wind power potential between current and two future periods is considered, then ii) the percentage of ensemble members that satisfy this threshold is calculated. According to this metric, for the period **2021–2050**, wind power is projected to **increase more than 5%** over the **Aegean Sea** and the **southwest Black Sea** and expected to **decrease more than 5%** over the maritime areas of North Africa and Middle East. In the period **2061–2090**, an **increase of wind power** is expected over a large part of the Aegean Sea as well as over the western **edge of Alboran Sea (nearby Gibraltar Strait)**, while a **decrease exceeding 5%** over a large part of the central and easternmost Mediterranean Sea is also anticipated. **For the Gulf of Lions, no clear future change signal was detected**; see also Koletsis et al. (2016).

An updated analysis using a more realistic extrapolation of hub-height wind speeds and with data from the latest RCPs of the CORDEX project, available from the website https://esg-dn1.nsc.liu.se/projects/esgf-liu/, indicate that there will be no significant change in the wind power density over the Black Sea as a whole under either the RCP4.5 or RCP8.5 scenarios (Davy et al., 2017). Although we may expect a small increase in the N and NE of the Black Sea (RCP4.5 scenario for the period 2021–2050) and a small decrease in the S and SE of up to 10%, for the period 2061–2090, for both the RCP4.5 and RCP8.5 scenarios. The main changes are anticipated along the coastline in the E and

SE of the sea for the period 2061–2090 for the RCP8.5 scenario, namely, a decrease of wind power density of up to 20%

The detailed analysis of the potential impacts that a global climate change may have on the wind energy production is presented in the deliverable report D5.4: "Statistical analysis and comparison of the offshore wind power potential for the Mediterranean and Black Seas for two different IPCC scenarios with the current conditions".

9 Off Shore Wind Farms and the marine environment

In this section, the potential impacts of OWFs on marine biota are described along with the potential role of OWF installations in relation to MPAs.

9.1 Impacts of OWFs on marine biota: Lessons from Northern European Seas

The lack of OWFs in the Mediterranean and Black Seas constrain the assessment of marine biota responses to OWFs. Predictions can be built only on the existing knowledge from elsewhere (e.g. North and Baltic Seas). Few investigations **assess OWFs impacts** on marine biota (Andersson and Öhman, 2010; Bergström et al., 2014). Most studies are focused on the **operating period**, dealing with impacts to biota related to **noise**, addition of **hard substrate** and **electromagnetic fields**. For the **construction** phase, impacts are mainly related to **noise** and addition of **hard** substrate. The effects of **decommissioning** have not been assessed yet. The effects of OWFs on marine biota depend on the **life history traits and settlement requirements of the impacted species**, and on their **tolerance** to noise and electromagnetism. In general terms, significant negative effects for **birds** at population level have been found, through collisions, barrier effects and habitat loss. The main **shifts** in species compositions and spatial redistribution will be occurring at the area closer to the OWF (Bergström et al., 2014). Newly introduced hard substrata within OWFs can play an important role in the establishment and the expansion of the population of **non-indigenous species** (NIS) (De Mesel et al., 2015). To date, there are no studies valuing monitoring programs to detect variability in the status of the marine environment at OWF sites (Franco et al., 2015).

The main stressors fall under the **Descriptor 11** of Good Environmental Status (GES) in the Marine Strategy Framework Directive (MSFD), pertaining the **introduction of energy** in form of **Noise and Electromagnetism**.

The **construction** phase generates **high levels** of **underwater noise**, although in the **operational** phase noise is **negligible**. Scarce knowledge exists on the behaviour of **fishes** under different noise levels, and the impact seems to be limited near the wind turbines with differential influence at increasing distances depending on fish sensitivity (Wahlber and Westerberg, 2005). Marine **mammals** are temporally displaced outside the OWFs due to the noise during the installation phase (Gilles et al., 2009; Brandt et al., 2011).

Electromagnetism generated by OWFs represents a **new field** for studies, since response of different organisms might vary depending on the species sensitivity and the intensity of the electromagnetic field (Gill et al., 2012). Based on theoretical studies, **cetaceans** are temporally displaced from the OWF area, while **seals** do not seem to be affected. Scarce information exists on the effects derived from the newly generated electromagnetic fields, with consequences ranging from cellular to behavioural level. **Elasmobranchs** are probably affected by magnetic fields (Jordana et al., 2011).

In addition, **hard substrate** availability causes possible **redistribution** of marine biota in relation to the OWF. **Habitat loss** affects infaunal species that exhibit lower abundances, diversity and community structure. In the OWFs intermediate area, several community parameters such as recruitment, diversity and abundances remain stable if the sediment conditions are not altered. OWFs offer **new habitat** for **macrobenthic communities**, favouring the colonization of hard bottom species, with **increases in both diversity and biomass**. Vertebrates are favoured by the availability of food and refuge that hard substrates provide (Wilhelmsson et al., 2006; Stenberg et al., 2015).

9.2 The potential role of OWFs in MPA networks

Networks of MPAs represent an integrated system of protected areas, designed to conserve regional

biodiversity and ecosystem functioning. One of the key goals in establishing such a network is making it "**ecologically coherent**" (Figure 29).

Environmental impact assessments, monitoring programs and scientific studies have highlighted the wide-ranging and extensive impacts that OWFs have on the local marine environment. OWF presence can **interact** with the objectives of MPA networks by affecting: biodiversity, ecosystem functioning, and site resilience.

Changes in **biodiversity structure** on and around the OWF installations, e.g. biofouling abundance (Kerckhof et al., 2010), dominance of particular species (Langhamer et al., 2009), and introduction of NIS to the region, (De Mesel et al., 2015), will significantly affect **source/sink larval populations** of MPA networks. Source/sink populations are essential for MPA network connectivity and provide the larval supply for ecologically coherent MPA networks. Alterations in **predator-prey** relationships due to the **attraction** of higher trophic predators to OWF sites (Russell et al., 2014), or the **exclusion of fishing practices** within the region (Inger et al., 2009), will **modify food web trophic links** and **ecosystem functioning**. In turn, these

modifications to **ecosystem function** will also impact MPA source/sink populations, and the ecological processes related to the **connectivity** of the MPA network.

Considering the future introduction of OWF foundations in the Mediterranean Sea, the impacts on marine life at a larger scale should be closely linked to **currents**. On a regional scale, wind turbine foundations may allow for **sustainable aquaculture** and act as **stepping-stones** enhancing **connectivity** among MPAs. Moreover, OWFs can have a large potential as "**areas of opportunity**" for fisheries management. With the **prevention of fishing activities** (e.g. trawling) inside OWFs, these refuge habitats may evolve into important ecological systems on a larger scale (Bergström et al., 2013). OWF foundations, however, might favour the presence of NIS (so falling under **Descriptor nr 2 of GES**) and noxious species in general (substrate for polyp settlement, enhancing jellyfish blooms).

Environmental aspects of OWFs are also presented in the deliverable reports D5.1: "Report on existing and in-progress technologies of offshore wind farm elements and wind turbines" and D5.5: "Smart wind chart for the Mediterranean and Black Seas".
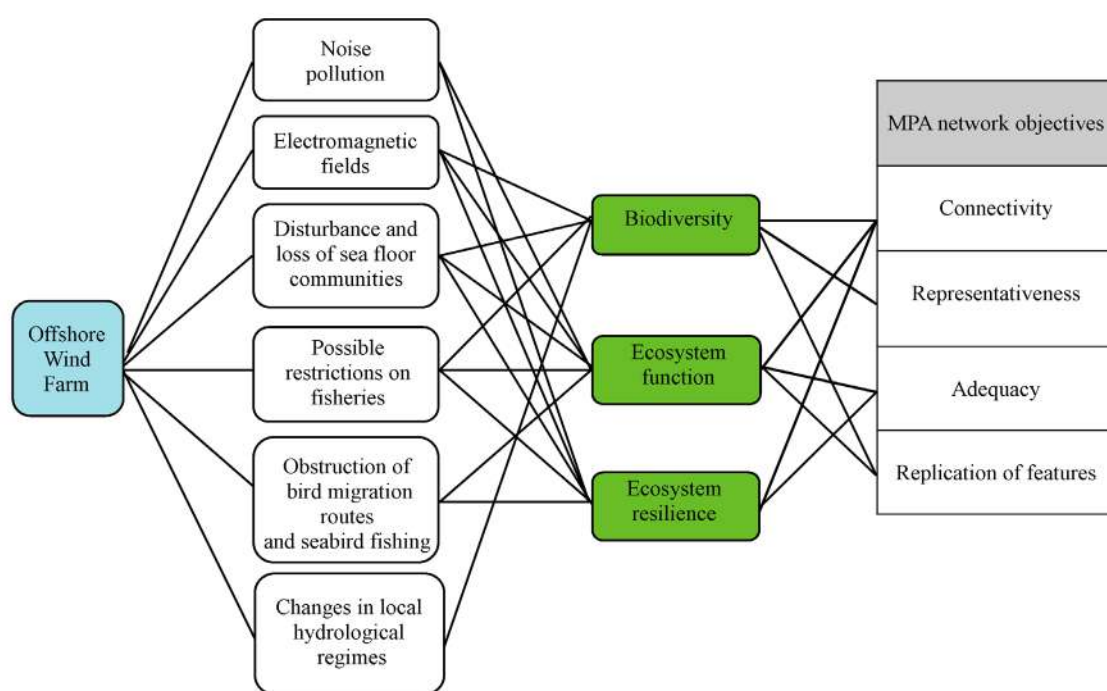

Figure 29. Interactions between OWFs and the objectives of MPA networks

10   The Smart Wind Chart

10.1   Methodological background

One of the most important problems for the development of OWFs is the optimal planning for identifying eligible areas appropriate for the exploitation of offshore wind energy. The determination of OWF site suitability is a multilateral and complex procedure that comprises technological, socio-economic and environmental considerations that include *inter alia* the following (see also Figure 30):

1.   The **geotechnical/engineering framework** that refers to the feasibility, development and installation phases of an offshore wind project. The technical terms define and characterize spatially OWF developments, like energy efficiency of offshore wind, bottom suitability (e.g. depth, slope, morphology, sediments), distance from shoreline and inland infrastructures (harbours, airports, railways, highways), existence of underwater connecting grids and shore-based stations, etc.

2.   The **socio-economic framework** that identifies the diverse effects that an offshore wind project may have on the social and economic conditions of the neighbouring coastal communities. Issues related with this extended framework are, *inter alia*, European and national legislation, coastal and marine activities, marine spatial planning (MSP) and marine space uses, marine cultural heritage, tourism, shipping lanes, etc.

3.   The **environmental framework** that focuses on the mitigation of negative and the enhancement of positive consequences of OWFs on the biotic and abiotic elements of the area. The environmental terms include the sensitive marine habitats and protected areas, the potential effects and impacts on seabirds, fish and marine mammals, the disturbance of the seabed mainly during the construction and decommission phases, the underwater noise during the operation phase and the potential effects on coastal geomorphology and the hydrodynamic status of the area.

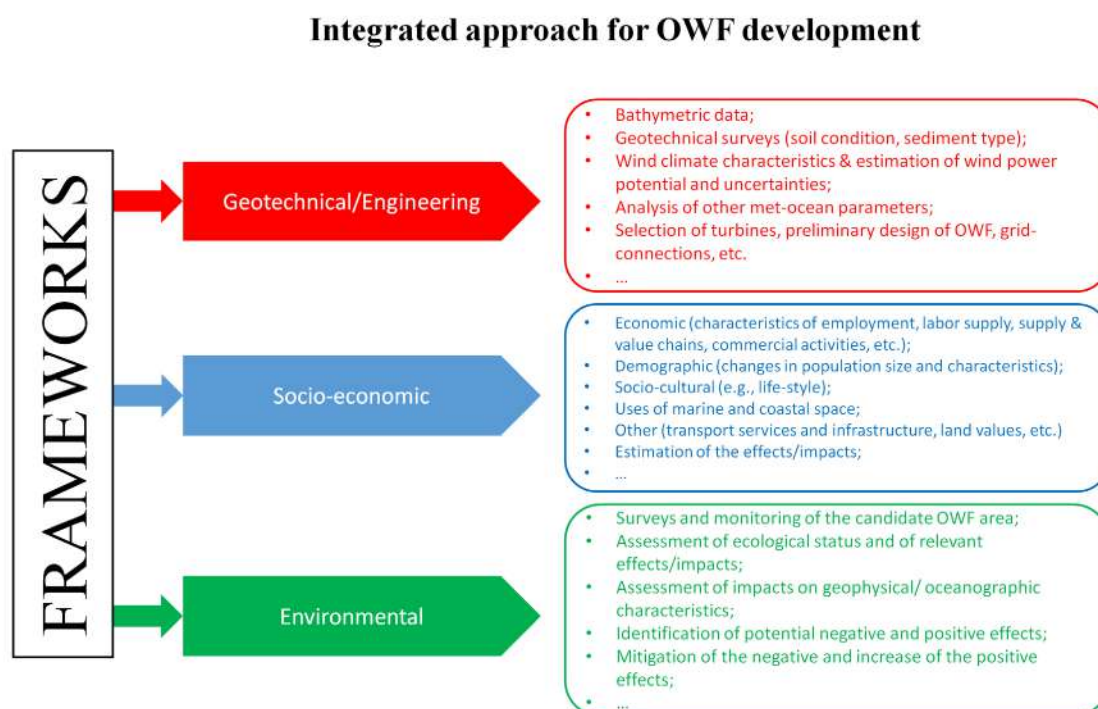These frameworks refer to different, yet highly

Figure 30. Integrated approach for OWF development

interrelated, aspects of OWF design, development and operation and relate various groups of stakeholders with different requirements and priorities; therefore, ideally, they should be jointly considered; see also Grassi et al. (2012). A rational way to effectively deal with the **preliminary identification and comparative pre-evaluation of favourable sites for OWF development in rather extended regions**, such as the Mediterranean and Black Seas, is based on GIS technology and consists in the **development and implementation of the Smart Wind Chart (SWC)**. SWC itself is a marine **planning tool** rather than a decision-making platform and the favourable locations, resulted from this procedure, should be regarded as **candidates deserving further in-depth assessment** in the context of local detailed studies.

The comparative pre-evaluation of potential locations as regards OWF development is based on quantifiable multi-parameter eligibility criteria, and is implemented by using GIS tools taking into account environmental considerations and restrictions. Specifically, for wide spatial scales like the Mediterranean or the Black Sea, the information included in the evaluation refers to the most important quantifiable gross technical parameters/factors namely, **the mean annual wind speed, the bottom depth, the distance from shore, the proximity to ports, the electrical grid infrastructure and the type of bottom sediments**. This information is combined with spatial information regarding the most important environmental restrictions. For the evaluation, a linearly weighted methodology was used providing the following important advantages: i) it can be easily adopted in various situations; ii) the considered weights can be redistributed to the various factors; iii) parameters/factors can be easily added or removed, according to new constraints and requirements of the end-users, technological progress, etc. Let us note, though, that *the locations evaluated through this approach should not be considered as direct suggestions for future OWF development; they rather comprise a set of potential areas, which are favourable candidates deserving further in-depth assessment in the context of detailed studies at the local scale*.

The development of the methodology and the derivation of the SWC is performed at two major steps (see also Figure 31):

1. **Preparatory actions** to assess the most important **quantifiable factors** (technical parameters), the **factor rating table** and the identification of **no-go and restricted areas**, i.e. areas that are either definitely excluded from further consideration or are under important restrictions;
2. **Processing phase**, with the implementation of the aforementioned features and the final ranking for each location.

During the **preparatory actions**, the above mentioned technical parameters are categorized and rankings from 1 to 5 are provided for each category with the highest number corresponding to the most feasible site for OWF development. Then, each parameter is assigned with a weight corresponding to its relative value to the final ranking scheme. The decisive parameters along with their relative weights are the following: **wind speed** 0.35, **bottom depth** 0.25, **distance to shore** 0.15, **distance to power grid** 0.15, **type of sediments** 0.05 and **distance to ports** 0.05. It seems that in the relevant literature, there is no uniform established methodology for assigning weights to the above mentioned parameters, notwithstanding that the rationale seems to be analogous (i.e. it depends on the relative importance that each criterion has on the feasibility of an OWF development). Let us also note that detailed local socio-economic and environmental considerations may alter the above mentioned weighting scheme. A futher step in the preparatory actions is the identification of the "no-go/restricted" areas. In this step, the exclusion/restriction of an area is primarily based on environmental restrictions, namely National protected sites/MPAs and Natura 2000 sites, areas characterized by meadows of the seagrass *Posidonia oceanica*, fields of the alga *Phyllophora*, biogenic habitats such as coralligenous and maerl, and deep sea coral formations. The latter important habitats along with migratory bird routes areas are considered as no-go areas.

In the **processing phase**, the mean annual wind speed at 10 m above sea level is evaluated for all grid points and the corresponding bottom depth is extracted. If the combination of wind speed and bottom depth satisfies the adopted specifications (see next section), then the point (area) is characterized as *"potentially go"* area. These areas are subsequently graded according to
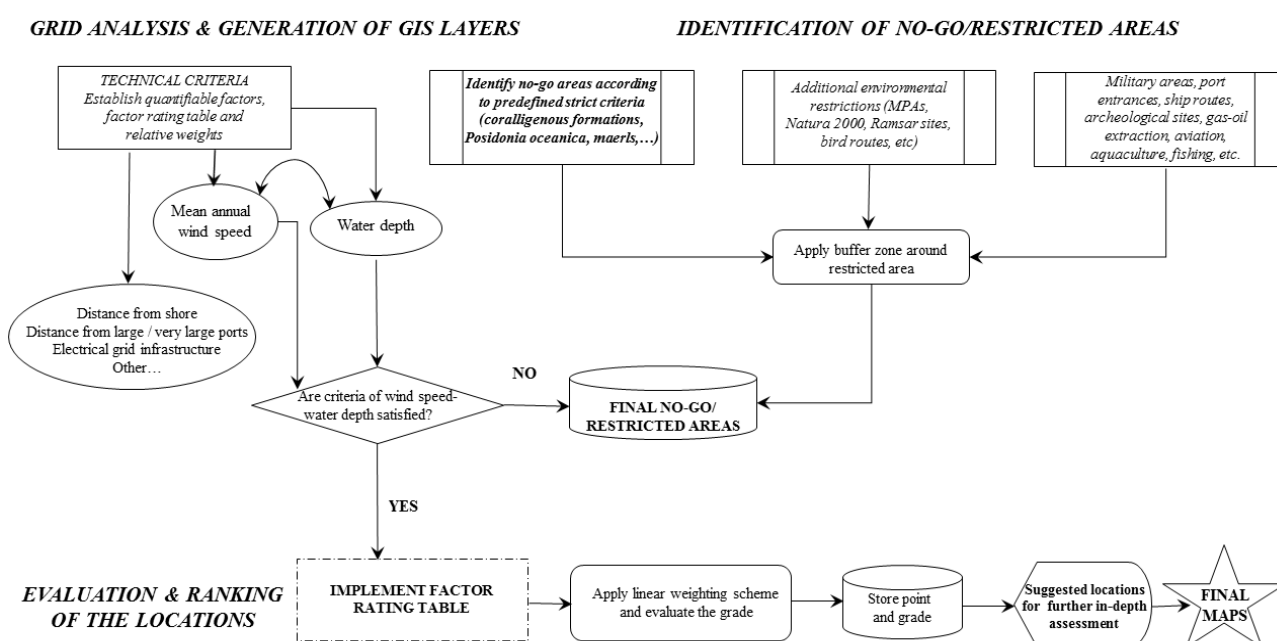
Figure 31. Development of the Smart Wind Chart

all examined parameters and relative weights, so that the final rankings of the locations are derived. Summing up, the final results of the SWC refer to the identification of **"no-go" and "restricted" areas for OWF development** and the **evaluation of the suitability of "go areas"**.

All the corresponding spatial information is depicted in the form of separate GIS layers. At the end of the analysis, the most suitable sites worth further assessing for OWF development are identified. In the following section, a more detailed presentation of the factors and rankings adopted in the SWC are provided.

10.2 Technical parameters and rankings for potential locations for OWF development

The technical parameters (factors) that were used for the evaluation of potential locations for OWF development along with the corresponding categorizations and rankings are shown in Table 12. From these factors, wind speed, water depth and distance from shore are of particular interest for different reasons explained thereafter.

Wind speed: In the relevant literature, there is not a uniform way to rank the **wind resource**

availability (as well as the other technical parameters). For the final decision, the local particularities of the Mediterranean and the Black Sea have been taken into consideration. The rather low limit of 4.1–4.9 m/s, at 10 m above sea level, corresponds to mean annual wind speeds of the order of 5.1–6.0 m/s, at 100 m height above sea level. The reason for including this low limit is due to the fact that the model wind data set used in the analysis underestimate (sometimes significantly) the wind speed with respect to buoy measurements and satellite data; see Soukissian and Papadopoulos (2015). Moreover, all the examined data sources are characterized by larger or smaller location-dependent deviations compared to the reference data source. In order to be on the "safe" side and avoid accidentally exclusion of areas that may be proved favourable for OWF development, we have eventually decided to include the particular wind speed limits. Clearly, areas with low wind resource are graded by lower grades accordingly.

Water depth: Three critical **water depth** ranges have been considered, namely 10–40 m ("shallow waters"), 40–70 m ("intermediate" waters"), and 70–200 m ("deep waters"). Shallow and intermediate water depths refer to monopile, gravity-based, tripod, jacket, and triple supporting structure, while depths

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between 70–200 m refer to floating wind turbines technologies, including tension leg platform. Up to date, the installed foundations correspond to fixed structures because of their established commercial steadiness. However, as is emphasized in EWEA (2013) with regard to the Mediterranean Sea: *"There are currently no offshore wind farms in the Mediterranean, because the water is deep, and current commercial substructures are limited to 40 m to 50 m maximum depths. This restricts the potential to exploit offshore wind development in the Mediterranean".* The future trend is to move to deeper waters, and consequently, more distant to the shore, and to larger turbine sizes. This shift seems to be boosted by the floating substructures with a possible 7% market share based on worldwide project announcements up to 2020 (Smith et al., 2015). Moreover, in deeper water depths, the available offshore wind resource is higher and steadier, visual impacts and environmental stress (e.g. from pile driving) are mitigated while the **high population density**, mainly in the coasts of the Mediterranean Sea, and **the intense maritime activities may limit the available places with shallow waters**. In this respect, water depths greater than 70 m (and up to 200 m) are ranked with a medium score in order to illustrate and foresee this trend. On the other hand, a grade of 1 was assigned to 40–70 m water depths zone, since this zone is not well adapted to both fixed offshore foundations and floating foundations for wind turbines. Fixed foundations are, in general, not suitable for depths greater than 40 m and the dynamic behaviour of floating foundations in waters with a depth smaller than 70 m remains a complicated technical issue, which can be solved only using heavier foundations and anchoring systems, leading thus to higher costs and less reliable solutions. Let us also note that

despite the fast advancement of the floating wind turbine technology, it has not reached yet TRL 9. The locations that jointly satisfy the minimum wind speed and the appropriate bottom depth requirements are shown in Figure 32 for the Mediterranean and in Figure 33 for the Black Sea.

Distance from shore: it is related with underwater electrical grid connections, installation and maintenance activities and the visual impact of offshore turbines. **Distance from shore is, at least for the Mediterranean Sea, the most intriguing parameter to deal with**. A short distance from shore minimizes all the costs related with the technical infrastructure, installation and maintenance activities (i.e. capital and operating expenditures). On the other hand, a short distance from shore maximizes visual noise. Moreover, there are specific constraints in certain areas of the Mediterranean Sea where distance from shore may be affected by external parameters (e.g. issues related with national territorial waters). Therefore, an attempt was made to assign weights by following a compromise procedure: the ideal distance from shore (as regards an equilibrium between economic and visual disturbance reasons) is 10–20 km; the second best choice is 5–10 km. There is a not-severe visual disturbance and the costs are low. For example, this is a typical distance for some scheduled OWFs in Greece. The distance 20–100 km raises the costs and eliminates visual disturbance, while 0–5 km and >100 km are two range distances that should be recommended to be avoided (the former due the severe visual disturbance and reduced capacity factors -because of lower winds-, and the latter due to the higher cost).

Table 12. Ranking score of technical parameters (factors) regarding the suitability of OWFs' establishment

Wind speed (m/s)	Depth (m)	Distance from shore (km)	Sediment type	Distance from large/ very large ports (km)	Voltage capacity (kV)	Rank
> 6.9	10–40	10–20	Sand	0–100	> 400	**5**
6.3–6.9	-	5–10	-	100–200	225–400	**4**
5.7–6.3	70–200	20–100	Mud	200–300	36–225	**3**
4.9–5.7	-	0–5	-	300–500	< 36	**2**
4.1–4.9	40–70	> 100	Rock	> 500	Distribution grid	**1**

10.3 Environmental considerations

The environmental considerations deal *inter alia* with the assessment of the ecological status of the candidate area in order to predict long-term potential positive and negative effects that an OWF may have on the surrounding biotic and abiotic elements. Among the environmental restrictions, the most common are the following: MPAs, Ramsar and Natura 2000 sites, cetacean sanctuaries, areas considered as migratory bird routes, areas characterized by meadows of *Posidonia*, fields of *Phyllophora*, and other priority habitats (e.g. coralligenous, maerl and deep-water white coral formations). The identification of ecologically important areas can be based ideally on *in situ* surveys or can be estimated from habitat models. The environmental requirements formulated within the EU Directives provide additional guidelines for the protection and conservation of the marine environment. National protected areas/MPAs and Natura 2000 sites may belong to either "restricted" or "no-go areas"; they can be definitively characterized as no-go areas only after detailed *in situ* assessment. Chapter 5 of the relevant EU guidance (European Union, 2011)

provides a step by step procedure for wind farm developments affecting Natura 2000 sites. An appropriate assessment should be made if an OWF site is part of the Natura 2000 network, while compensatory measures are necessary in order to protect the overall coherence of Natura 2000 sites if there are negative impacts with no alternatives. Regarding the seagrass *Posidonia oceanica*, it is widely distributed in the Mediterranean coastal waters and is used as a tool for the evaluation of ecological status and the assessment of the water quality. Moreover, the presence of seagrass influences the water flow, such as wave and current attenuation and alternation of nearshore sedimentary patterns. Therefore, *Posidonia oceanica* is considered among the aquatic ecosystems requiring monitoring and enhancement based on the objectives of the relevant EU Directives. In this respect, any human activity that may threaten the conservation of *Posidonia* (and, consequently, the marine ecosystem) shall be limited, while the installation of offshore wind parks shall also be prohibited in these areas. On the other hand, *Phyllophora* beds supply benthic primary production and water oxygenation in the circalittoral zone, and provide
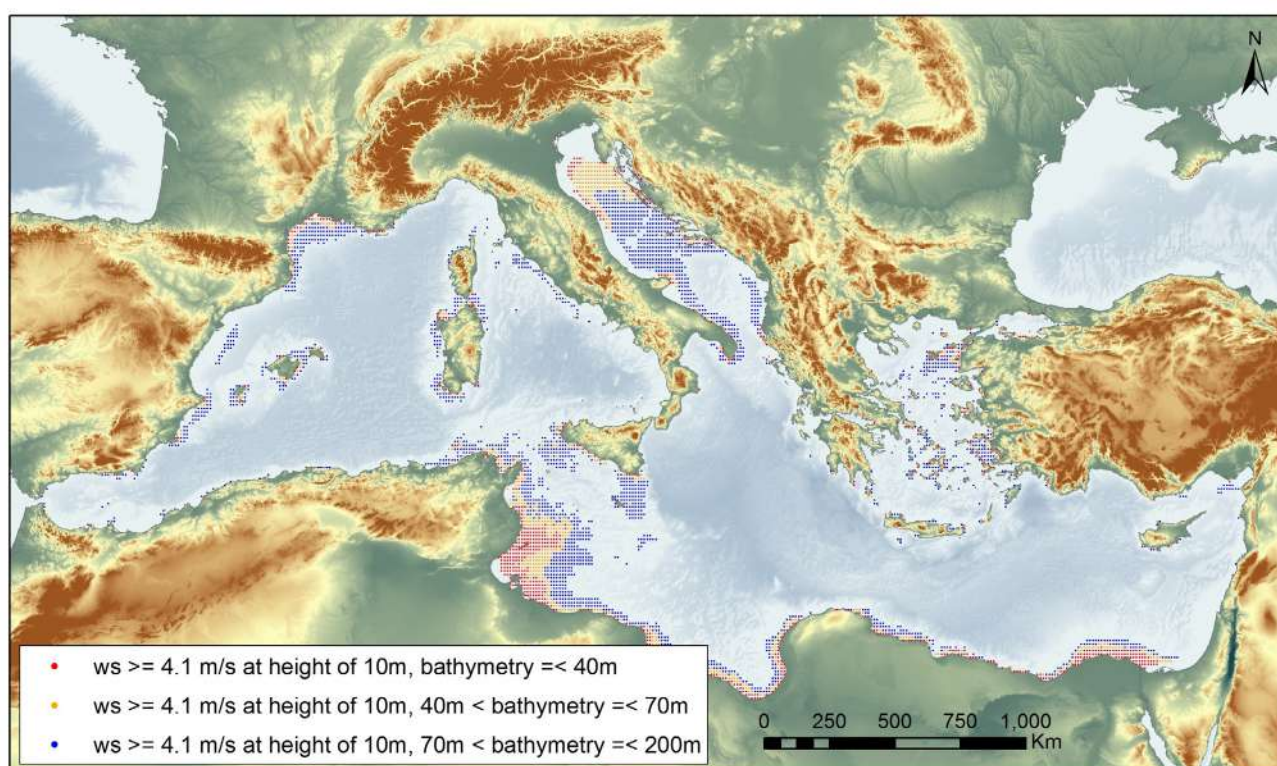

Figure 32. Potentially go areas for OWF development in the Mediterranean Sea (upper panel) and Black Sea (lower panel). Red, orange and blue dots correspond to locations with water depths up to 40 m, 40–70 m, and 70–200 m, respectively

- ● ws >= 4.1 m/s at height of 10m, bathymetry =< 40m
- ● ws >= 4.1 m/s at height of 10m, 40m < bathymetry =< 70m
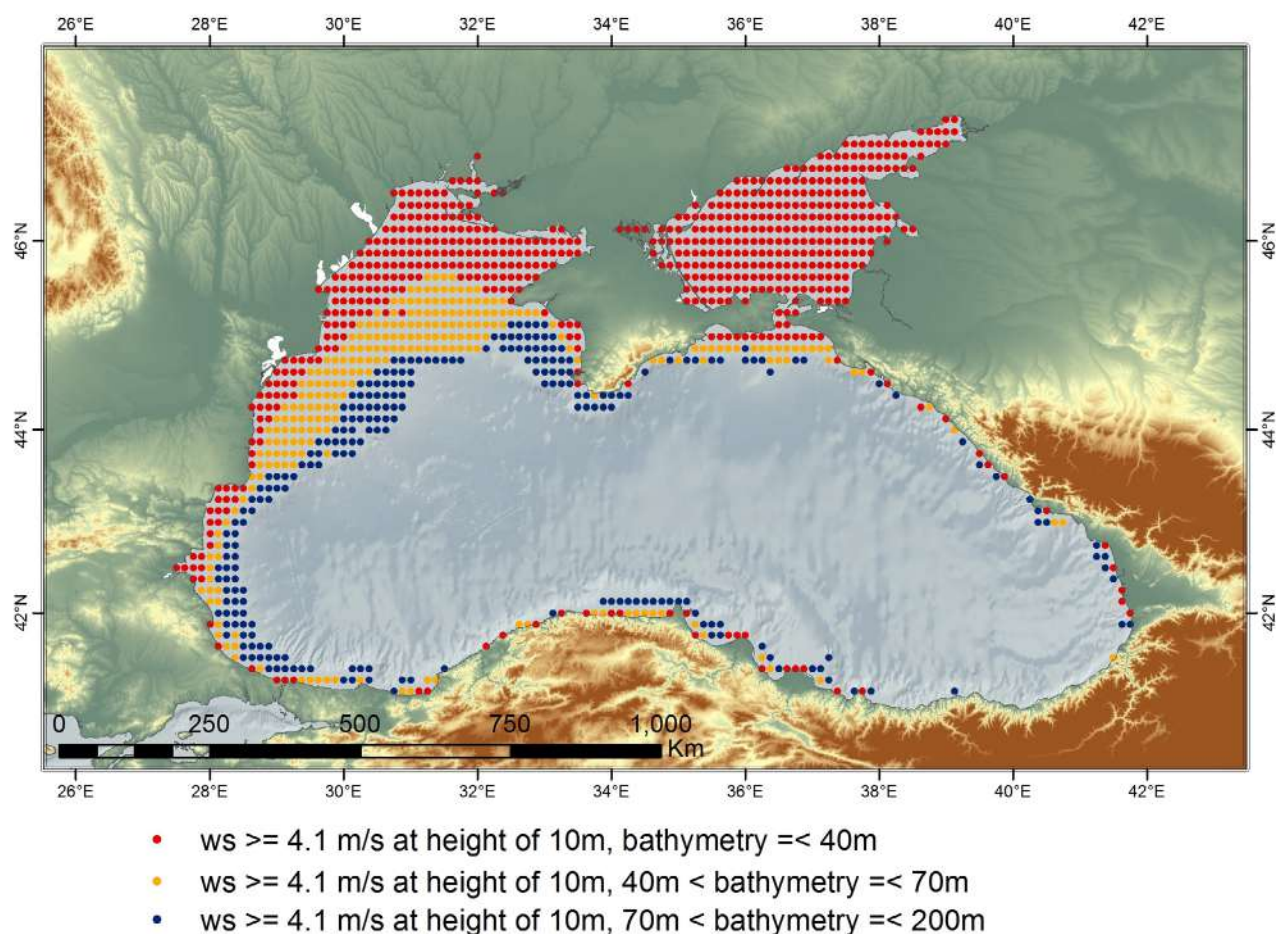- ● ws >= 4.1 m/s at height of 10m, 70m < bathymetry =< 200m

Figure 33. Potentially go areas for OWF development in the Mediterranean Sea (upper panel) and Black Sea (lower panel). Red, orange and blue dots correspond to locations with water depths up to 40 m, 40–70 m, and 70–200 m, respectively

breeding and feeding grounds, and nursery for diverse invertebrate and fish species (Salomidi et al., 2012). Thus, similar restrictions hold also for this case. Regarding the impacts and threats of OWF installations in birds and seabird habitats, they are site- and species-dependent. Although the main information regarding protection of birds is provided by the Birds and Habitats Directives, more focused aspects on these issues can be found in the guidance document of the European Union (2011). In this respect, the appropriate sitting of an OWF is of crucial importance. This implies the necessity for rational and appropriate assessments of the wider area in order to meet the principles of the above Directive and result in a reasonable decision. To this end, "integrated and sustainable form of spatial planning" is demanded.

Summing up, although there is a large debate in progress as regards the feasibility of developing OWFs in environmentally important areas (recent

evidences indicated that OWFs that are properly designed and deployed are generally not a threat to marine biodiversity), a rational solution in order to avoid or minimize environmentally related conflicts is to **avoid sites with sensitive marine and seabird habitats, and migratory bird routes**. In this connection, MSP and coastal zone management are prerequisites for efficient OWF project implementation from a sustainable perspective. In any case though, mutual understanding, transparency and confidence attitude between the involved key players is necessary for efficient offshore wind energy development in the Mediterranean and Black Seas. Bearing in mind the above discussion, in Figure 34, the no-go/restricted areas for OWF development are presented for the two basins. Specifically, **biogenic habitats (coralligenous and maërl), deep sea coral, *Phyllophora* fields and *Posidonia*/sea grass meadows are considered as no-go sites**, while **National protected areas/MPAs and Na-**

tura 2000 sites are, in principle, considered as restricted areas for OWF development. The no-go/restricted sites for the two pilot areas (Othoni Isl. in the Ionian Sea and Costinesti in the western coasts of Black Sea) are shown in the bottom panels.

After the analysis that was performed (see Deliverable D5.5) it is concluded that a rather limited part of candidate OWF locations is excluded due to environmental restrictions. Note also that the definitive exclusion of these areas should be justified only after *in situ* assessments and monitoring studies.

10.4   Integration of the acquired information

Taking as an example the Mediterranean Sea, the described approach is schematically depicted in Figure 2 (the Geodatabase). Each of the presented layers corresponds to a particular technical parameter along with its ranking (shown in Table 12). Taking into account the relative weight of each parameter, the final layer with the overall scores for the two basins is obtained. Superimposing this layer with the no-go/restricted areas due to
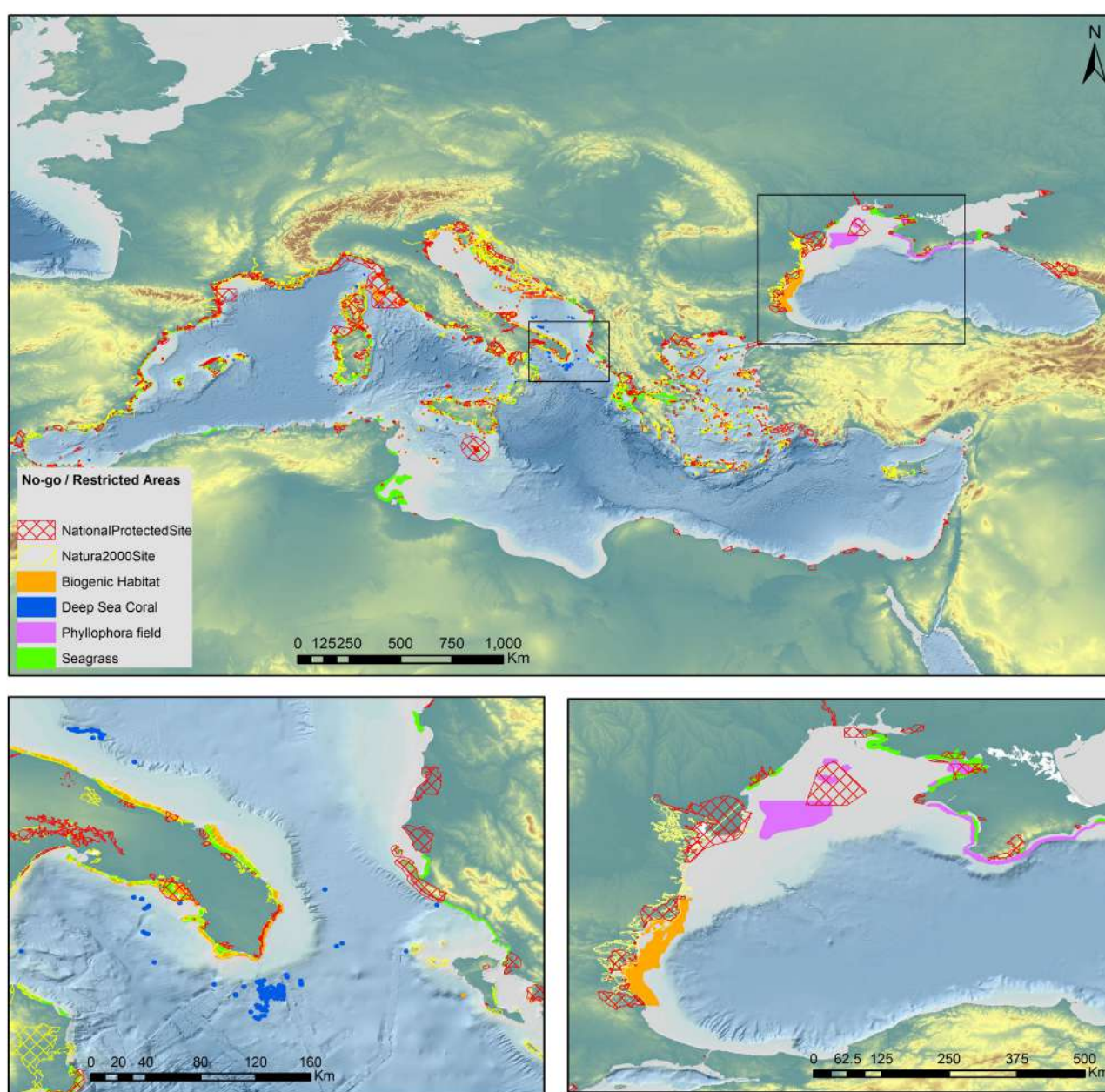

Figure 34. Upper panel: No-go/restricted areas for the Mediterranean and Black Seas. Lower panels: No-go/restricted areas for the pilot sites

environmental considerations ("environmental considerations" layer depicted in Figure 35) results to the Smart Wind Chart. The detailed description of the entire methodology is made in the deliverable report D5.5: "Smart wind chart for the Mediterranean and Black Seas".

The final results of the SWC are depicted in Figure 36 for the Mediterranean and Black Seas (upper panel) and the pilot project areas (lower panel). The environmentally restricted/no-go areas that are depicted in the chart are only those that overlap with potentially go areas for OWF development. A more detailed, high-resolution analysis can be found in the WebGIS environment of the CoCoNet project (http://coconetgis.ismar.cnr.it/).
A multitude of different features are shown in these maps; thus the reading and "translation" of the results of the SWC should be made with great care. The first main feature of the SWC refers to the designation of areas that are either **no-go** or **restricted**. Specifically, black colour denotes the no-go areas and brown colour denotes areas that are, in principle, restricted for OWF development, but may not be necessarily no-go areas. The second

main feature of the SWC refers to the designation of areas that are favourable for OWF development, after excluding the no-go and the restricted areas. The "degree of favourability" of these areas is designated by an overall score along with the corresponding colour, i.e.:

1: very bad (red colour, overall score 1.70–2.00);

2: bad (orange colour, overall score 2.01–2.50);

3: fair (yellow colour, overall score 2.51–3.00);

4: good (green colour, overall score 3.01–3.50);

5: very good(azure colour, overall score 3.51–4.00);

6: excellent (blue colour, overall score 4.01–4.50).

Let us note that:

1. all the evaluated areas, even the "very bad" ones, are, in principle, candidates for further assessment as regards OWF development;
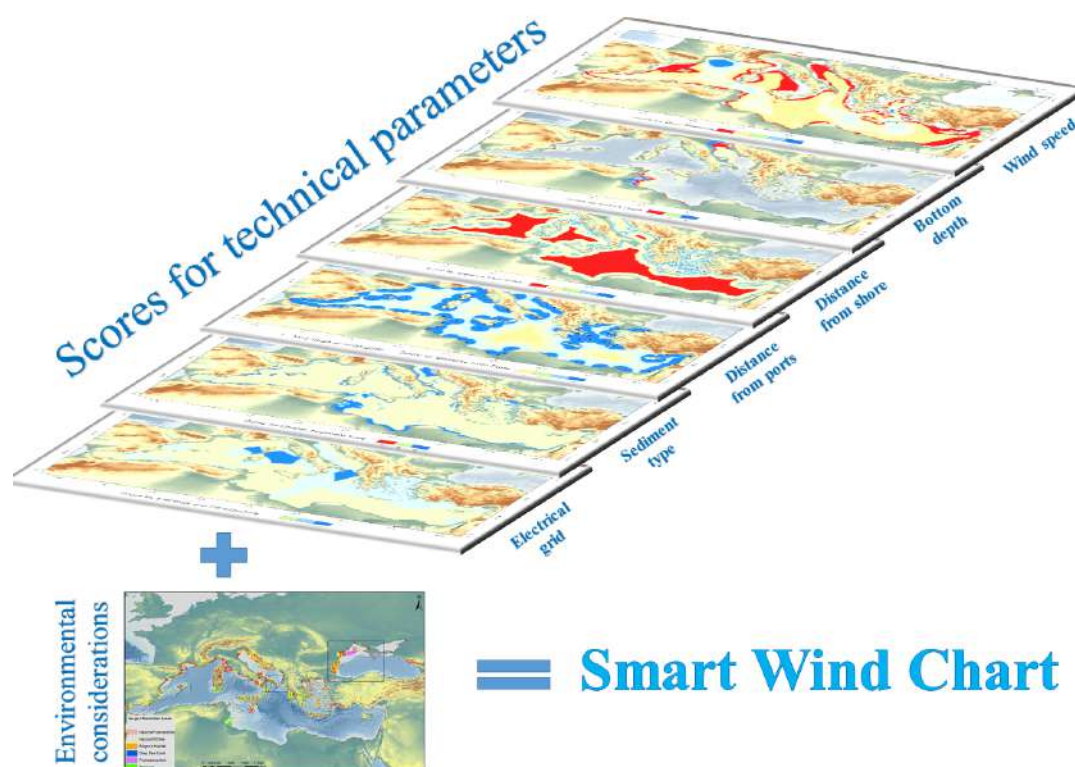2. a location characterized as "excellent" or "very

Figure 35. Layers of technical factors along with rankings (scores) and environmental restrictions taken into consideration for the analysis of the SWC in the Mediterranean Sea

good" in the Mediterranean or the Black Sea is such in a relative way, i.e. with respect to the other examined locations of the entire basin; for example, a location in the North Sea, with the same technical characteristics, could be characterized as "fair" or "good", compared to other locations in the wider area;

3. for the areas with the highest possibility for offshore wind energy projects, further in-depth analysis is necessary with combined use of site-specific detailed input data;

4. areas that were not rated in this analysis correspond to the current technological limitations and may be considered as future favourable sites for OWF projects as the offshore wind industry is developing.

10.5   Results at the basin level

Based on the results of the SWC, some favourable areas for OWF development are revealed. Regarding the Mediterranean Sea, extended areas characterized as "very good" (azure colour) are located in the **Gulf of Gabes and the northern part of the Gulf of Tunis (Tunisia), the Gulf of Lions (France), the Aegean Sea (Greece), the eastern part of the Gulf of Sirte (Libya), the area close to the Arabs Gulf in Egypt and in the coastal and offshore area of Otranto city (Italy) in the Adriatic Sea**. Extended favourable areas characterized as "good" (green colour) are also encountered in the same areas as above, as well as in **the central Adriatic Sea, and the southwestern part of Sicily**. Overall, the most extended areas in the Mediterranean that are, in general, favourable for OWF development are the **North African coasts (from Tunisia up to Egypt) and the Adriatic Sea**. **The spots that are characterized as "excellent" (blue colour) in the Mediterranean Sea are all located in the Aegean Sea (Karpathos Isl., Mykonos Isl. and the straits between Ikaria and Samos Isl.)**.

Regarding the Black Sea, the results are much more uniformly distributed. Specifically, the entire western part of the basin hosts very favourable locations for OWF development. The most promising locations are extending **across the Romanian and Ukrainian coasts and at the entrance of the Sea of Azov**. The **southwestern part of Crimea and the area extending across the Turkish and Bulgarian coasts** are characterized as "good". The entire eastern part of the Black Sea seems to be not promising for OWF development. The Sea of Azov was not included in the final analysis due to the lack of bottom sediment data.

10.6   Results for the Mediterranean and the Black Sea pilot sites

The **Mediterranean pilot project area** (Othoni Isl. in the northern part of Corfu Isl.) is a characteristic representative of the basin's coastal areas since: i) it does not belong to the few top ranked areas (according to the wind resource availability), ii) the wind and wave climate is rather mild, iii) a Natura 2000 site is designated very close to the examined area, and iv) the wider area is well developed as regards tourism and fisheries, which comprise two of the most characteristic marine uses in the Mediterranean Sea. For this site, the mean annual wind speed (at 10 m above sea level) is marginally appropriate for potential OWF development. On the other hand, bottom depth is characterized by the highest score. The score for distance from shore parameter fluctuates between 2 and 4 in the wider examined pilot area, while the score for distance from ports is very good. The existing electrical grid infrastructure, as well as the bottom sediment type are optimum, since there is an electrical grid infrastructure and the sea bed composition is sandy. One Natura 2000 site is present at the close neighbourhood of the examined location and therefore in-depth environmental assessments are necessary for the final selection of this site for OWF development. This site is overall characterized as "fair". A more detailed analysis of the Mediterranean pilot project area is presented in Soukissian et al. (2016).

Regarding the **Black Sea pilot project area**, (Costinesti – Cape Aurora) the choice was made heuristically: in the inshore area there is a Natura 2000 site, which supports a variety of habitats; on the other hand, the entire western coastal area of the Black Sea is very favourable for OWF development due to the fair wind availability and the appropriateness of the bottom depths. Moreover, in this area large facilities exist onshore (such as the major harbour of Constanta, a well-developed highway system and tourism

OWF suitability

Score of candidate locations

- 1,7 - 2 Very bad
- 2,0 - 2,5 Bad
- 2,5 - 3 Fair
- 3,0 - 3,5 Good
- 3,5 - 4 Very good
- 4,0 - 4,5 Excellent
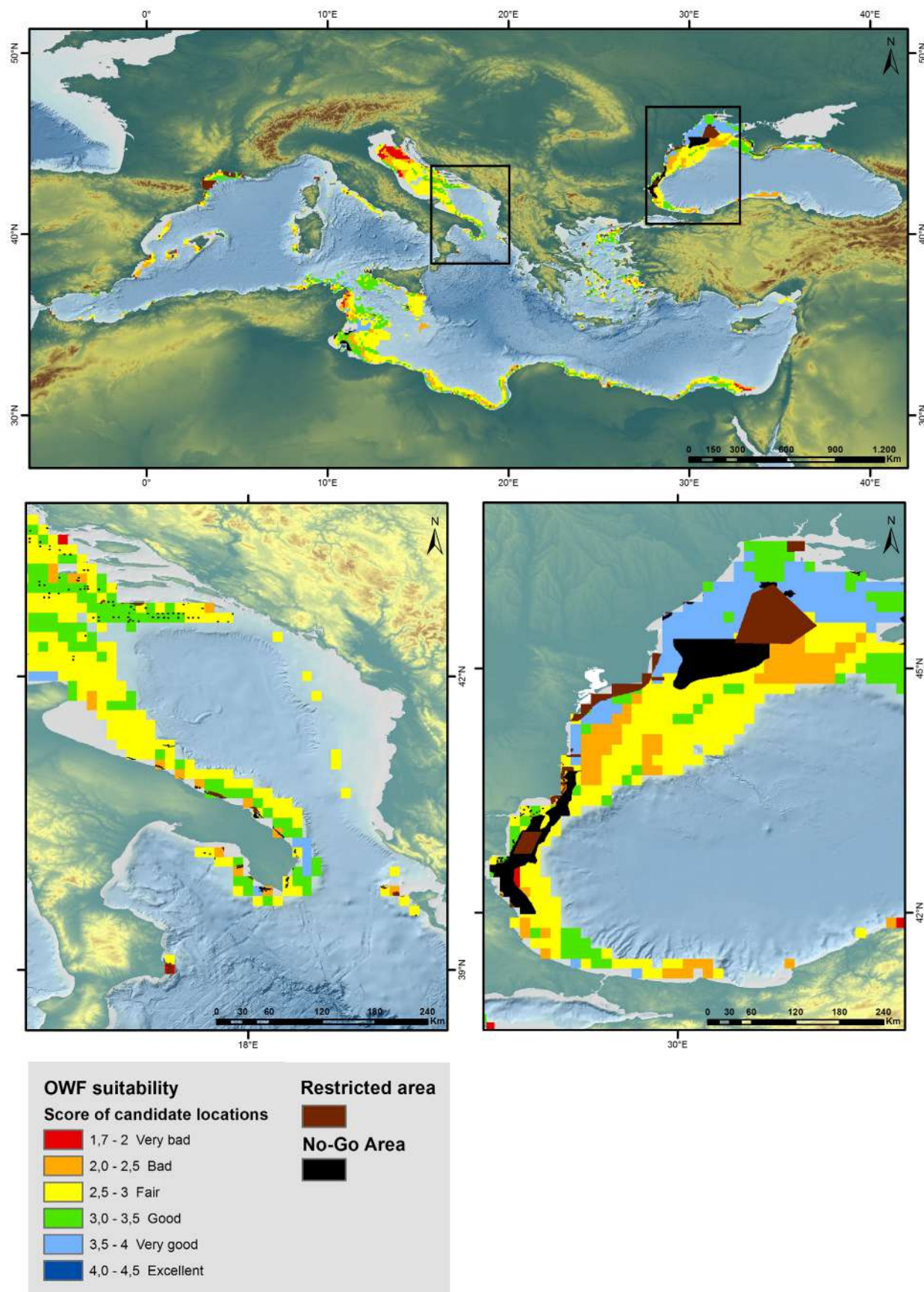
Restricted area

No-Go Area

Figure 36. The Smart Wind Chart for the Mediterranean and Black Seas (upper panel). The Smart Wind Chart for the pilot areas of the Mediterranean and Black Seas (lower panel)

industry), the neighbouring countries (Romania and Bulgaria) are members of the EU and the site had an ideal distance from shore (regarding visual disturbances), around 14 km. The wind resource of the area is high enough for potential OWF development, while the degree of suitability for bottom depth receives the best score. The score for both distance from shore and ports is also maximum. The existing electrical grid infrastructure contributes to a rather high score for this pilot site, while the type of the bottom sediment is not ideal for potential deployment of offshore wind turbines due to the muddy composition, contributing to a medium score. From the analysis it was also found that the main shipping lanes are relatively far from this pilot site. This site is overall characterized as "very good".

10.7   A word of caution on the SWC results

The indiscriminate and direct use of the evaluation results without further in-depth and site-specific assessment may lead to unexpected situations. Two characteristic examples of the potential misuse of these results are provided herewith. The first example refers to an offshore area in the northern part of the Mykonos Isl. in the central Aegean Sea, where the conflicts between different uses of the same marine space are expected to occur in any future attempt for OWF development. This area has received the best overall score regarding the technical criteria for the Mediterranean Sea. On the other hand, tourism is a very important pillar of the local economy and the island is world famous as a touristic attraction. Furthermore, the Cyclades plateau is one of the most important fishing grounds for trawl fisheries in Greece, and the marine transportation is highly developed. From these points of view, the consideration for an OWF development in the area is expected to be a very controversial and debatable task, and a quite complicated procedure with many hindrances, obstacles and conflicts as regards social acceptance, visual disturbance and uses of the marine space. The second example refers to a location in the Sea of Azov. Although the Sea of Azov is characterized by very high wind resource and an excellent suitability of the water depth, the sea icing and the instability of the geomorphological features of the area render the

development of an OWF a very difficult task.

The complete analysis of all SWC aspects, the relevant methodology and the detailed results are presented in the deliverable report D5.5: "Smart wind chart for the Mediterranean and Black Seas".

11   Conclusions

The entrance of offshore wind energy industry in the Mediterranean and Black Seas is a **very promising prospective**; however, it is *terra incognita* from several viewpoints, let alone that relevant projects will increase in scale and complexity as wind industry is expanding offshore with larger turbines.

Aiming to integrate some current important aspects of offshore wind energy development in the Mediterranean and Black Seas, the SWC has been developed. SWC is a multilevel tool that identifies and pre-evaluates potential favourable locations that deserve further in-depth assessment as regards OWF development, taking into consideration environmental constraints. The assessment of the available offshore wind power potential was based on high-resolution numerical atmospheric models, while additional important technical factors were also evaluated (bottom depth, distance from shore, proximity to ports, electrical grid infrastructure and type of bottom sediments). Bottom depth was limited to three groups ranging within 0–200 m due to the current limitations of the relevant offshore wind technologies. For the future, i.e. when floating turbine technology reaches the appropriate TRL, the analysis revealed that floating structures may be dominant for the offshore wind exploitation in the examined basins (due to bottom topography and distance from shore issues). The SWC results project that the Gulf of Lions, the Tunisian Plateau, off the coasts of Alexandria, the Adriatic Sea and sporadic locations in the Straits of Sicily and the Aegean Sea are favourable locations for in-depth assessment as regards OWF development in the Mediterranean Sea. In the Black Sea, the extended regions of the Ukrainian and Romanian coasts seem to be prominent for offshore wind projects. Although the areas with the highest possibility for offshore wind energy projects were identified, further in-depth analysis is necessary with the

use of site-specific data. Areas that were not rated in this analysis correspond to the current technological limitations and may be considered as favourable sites for OWF projects as the offshore wind industry is developing.

Nevertheless, one potential yet important problem, expected to be revealed in future implementations of OWFs in the examined basins, refers to the **conflicts with other uses of the same area** (coastal or marine). For the Mediterranean Sea and, in a lesser degree, the Black Sea, potential conflicts between marine and coastal space uses, refer mostly to **aquaculture, tourism and recreational activities, fishing and fisheries** and also to underwater antiquities, aviation, coastal works, areas of military exercises, oil/gas exploration and production sites, ports and harbours, telecommunication cables, shipping, etc. In this regard, **implementation of MSP**, **simple and homogeneous licencing and permitting procedures, governance support and financial stability** will contribute to the mitigation of potential conflicts regarding marine and coastal space use and boost offshore wind energy projects.

Evidently, the most effective way to avoid or mitigate the conflicts between different marine space uses is **through a detailed MSP** at local and regional level. An indicative example of the need to assess the feasibility of OWF development in finer planning scales, is the marine spatial plan for the Gulf of Lions, in southern France. See the relevant document (in French), accessed on April, 2015: http://www.dirm.mediterranee.developpement-durable.gouv.fr/IMG/pdf/Document_de_planification_pour_transmission.pdf.
This plan, apart from the most favourable areas for OWF development, includes a variety of detailed spatial information (no-go areas due to other marine uses, bird protection zones, electrical grid infrastructure, radar coordination zones, limit zones of 10 km, 7 mi, 12 mi and 20 mi, isobaths of 50 m and 100 m, potential zones for aggregate extraction, etc.). According to this plan, all suggested sites for OWF development are located at distances greater than 10 km from the shore and at water depths greater than 50 m. It is evident that the information contained in this plan cannot be included nor depicted in a basin-wide context; it can only be assessed in the fine-local spatial scale. In this respect, **results of the evaluation

methodology can only provide preliminary suggestions for potential OWF development**, mainly through indicative zones; further site-specific data and detailed assessments are required for localised cases, where such projects are supported. The example of Gulf of Lions could also serve as a road map in order to efficiently deal with local spatial planning issues.

In conclusion, **very important and specific benefits of investing in offshore wind energy in the Mediterranean and Black Seas are anticipated**. Apart from the **general benefits that offshore wind energy provides** (clean, non-polluting, renewable and reliable), there are also anticipated **positive socio-economic effects for the coastal areas of the two basins** (economic prosperity of the candidate areas, creation of new jobs and increase of employment, supply chain opportunities, community benefit contributions, and promotion of social, economic and environmental benefits). As is noted in EWEA (2015b) *"Offshore wind has more potential to create local employment and a positive GDP impact than almost all other energy sources"*. **Co-utilization of the same marine space and connectivity enhancement among MPAs are also very positive perspectives**.

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13   Acronyms - glossary of key terminology

Candidate/potential sites/ areas	Offshore locations that fulfil some fundamental technical, socio-economic and environmental requirements for the development of a wind farm, but certainly require more in-depth assessment for its proper implementation
Coastal Zone Management	Management of coastal areas (and adjacent shorelands) in order to balance environmental, economic, and human activities through sustainable solutions
Decommissioning	The process of dismantling an (offshore) wind farm from an area
Environmental Impact Assessment study	A process of assessing the potential (both positive and negative) environmental impacts of a proposed offshore wind energy project in the (local) community and eco-system
EWEA	European Wind Energy Association
Factor rating table	A table with the assigned weighting of each quantifiable technical factor (parameter) involved in the analysis of the Smart Wind Chart
Floating wind turbines	Offshore wind turbines attached to the seabed by mooring lines in deep waters
GDP	Gross Domestic Product
GIS	Geographic Information System: a platform where geographical data can be stored, integrated, analysed, modified and displayed
GES	Good Environmental Status
In situ wind data	Wind measurements at an offshore location performed by a meteorological mast (usually installed on an existing offshore structure) or an on-site buoy
IPCC	Intergovernmental Panel on Climate Change
Initial conditions	Specification of the reference values of the variables that are necessary for the atmospheric model setup at a particular time
Lidar	Light Detection and Ranging: an instrument based on laser beams used for wind measurements at various heights above sea level
MPA(s)	Marine Protected Area(s)
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Planning: process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that usually have been specified through a political process (UNESCO, 2009)
NIMBY	Not In My BackYard
NIS	Non-Indigenous Species

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