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Executive Summary

Adaptive management of Marine Protected Areas (MPAs) is crucial towards balancing nature and human needs, as MPAs are one of the policy instruments available to help ensure the conservation and sustainable use of the marine ecosystems. The present deliverable provides a conceptual framework and respective guidelines to assist MPAs managers increase the effectiveness of strategic planning through evaluating alternative management planning options by considering trade-offs between conservation, social and economic objectives under a truly transparent and participatory process. The proposed generic framework comprises a standardized scalable approach which can be applied to a wide range of MPAs with the aim to integrate a variety of multiple criteria and adopt a comprehensive selection process for identifying preferred scenarios and improve ecosystem-based decision making.

1. Introduction

Marine protected areas (MPAs) are a cornerstone of marine conservation, and their level of protection varies from fully protected, where all extractive activities are prohibited, to partially protected, where some extractive activities are allowed but with varying restrictions (Giakoumi et al., 2017). In Mediterranean MPAs fully protected areas occupy only the 0.04% of the surface, while the level of management still remains weak with over the half of a sample group of MPAs, considered in the frame of a study conducted under the IUCN umbrella, still not having a management plan (MedPAN and UNEP-MAP-SPA/RAC, 2016). According to the latter study, management in many sites is not actually implemented and little is also known about the management measures in place and if they are effective at maintaining or restoring the biodiversity they aim to protect, underlining the need to evaluate MPA management plans to look into their effectiveness. Furthermore the presence of an effective management plan, high enforcement, stakeholder engagement and promotion of sustainable activities have been identified as essential attributes for both achieving conservation goals while allowing for socio-economic benefits generated by MPAs (Di Franco et al., 2016). Following the latter, MPA planning and management should be based on adaptation. An adaptive approach involves monitoring and evaluation of management effectiveness and in case of poor outcomes, exploring alternative ways to meet the MPA objectives through the development of suitable scenarios. The present document is dedicated to provide a description of processes on how to synthesize and compare alternative MPA management solutions and how to select the most appropriate solution in order to end up with a final management plan or a revised management plan when there is already a plan in place. Hence, those in charge of producing either a new plan or making revisions to an already established one, should follow a step by step approach that is translated into specific actions that are facilitated by a number of tools and processes that can be combined. In the following figure a widely accepted step-by-step approach developed by Ehler and Douvere (2009), which is proposed to be followed in Maritime Spatial Planning (MSP) applications fitting also to MPAs management concepts is presented.

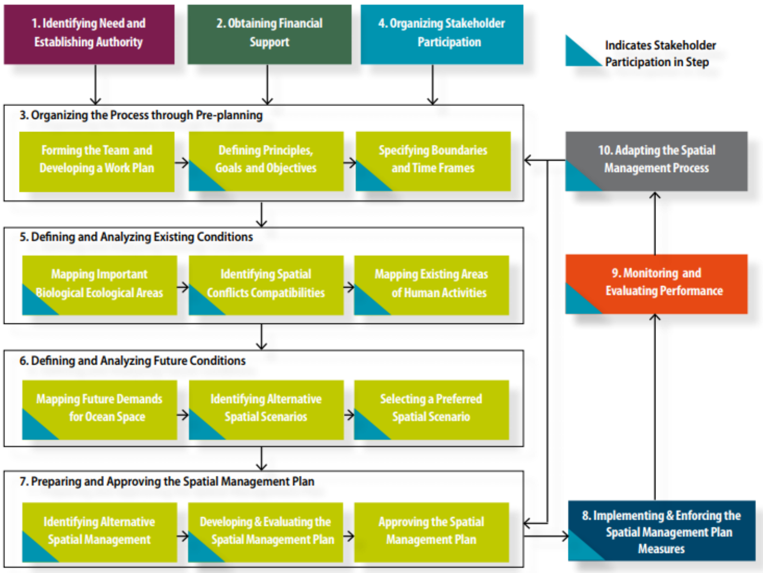

Figure 1. A Step-by-Step Approach to Marine Spatial Planning fitting also to MPAs management concepts (source: Ehler and Douvere, 2009)

Indeed, the process of setting up an MPA management plan belongs to the broader MSP planning process. It documents an explicit set of goals, outcomes, and activities that will be undertaken over a specified period of time and area, and articulates how the conservation strategy being used is designed to address the pressures that may constitute possible threats, considering also sustainable development approaches in line with the EU Blue Growth Strategy.

More precisely, an MPA management plan should be able to:

- Describe what already existing and potential future human activities that affect important natural areas and values will be managed and how.
- Provide a zoning plan with various levels of protection zones, various levels of sustainable development zones and when possible multi-use zones.
- Streamline policies, negotiations and licensing procedures that are essential for ensuring sustainability and balance of interests
- Provide a vision of what the MPA could or should look like in the near future.

Setting up an MPA management plan is a task that should be based on clear, straightforward steps that are linked to explicit actions and associated tools that facilitate those actions. It is a task undertaken mainly by the MPA planner/manager with input provided by related stakeholders when required.

Already existing guidelines describe in detail how MPA management plans could be developed and what they should contain (Salm and Clark, 2000; Kellerher, 1999), however, the document Ehler and Douvere, 2009, that refers to the broader process of MSP in which MPA planning is also included, provides a more structured and comprehensive process on how to set up a marine spatial plan and consists of a number of steps (see also Figure 1) which are adapted below to address MPA concepts and relevant issues:

Step1: Reasoning behind the need for an MPA and establishing the MPA

Step 2: Obtaining financial support by estimating the costs of MPA activities and identifying alternative means to obtain financing for those activities

Step 3: Organizing the process through pre-planning. Pre-planning should develop: a planning team, a work plan (including schedule), the boundaries and time-frame for planning, a set of principles (e.g. transparency, precautionary, polluter pays principles), a set of general goals, a set of clear and measurable objectives, an assessment of the risks of what might go wrong during the planning process and possible contingencies.

Step 4: Organizing stakeholder participation (i.e. a plan indicating who, when and how to involve stakeholders throughout the MPA planning process)

Step 5: Defining and analyzing existing conditions. In this step the following are required/produced: maps of important biological and ecological areas and maps of current human activities (and pressures) and an assessment of possible conflicts and compatibilities between existing human uses and the environment.

Step 6: Defining and analyzing future conditions. In this step the following are developed and examined: a baseline scenario illustrating how the MPA will look if present conditions continue (i.e. according to Step 5) alternative spatial sea use scenarios and finally a preferred scenario required by Step 7

Step 7: Preparing and approving the spatial management plan. This step includes identification and evaluation of alterative management measures, identification of criteria for selecting alternative management measures, the production of a comprehensive management plan (including a zoning plan if needed).

Step 8: Implementing and enforcing the MPA management plan. During this step the MPA management plan is converted into actual operating programs. Also, compliance with and enforcement of the requirements of the management plan are taking place.

Step 9: Monitoring and evaluating performance. In this step the achievement of management goals and objectives is examined with the use of performance indicators.

Step 10: Adapting the MPA management process. Using input from previous steps i.e. knowledge on what has been accomplished by implementing the MPA management plan and what are the new needs in the framework of the current environmental, social and economic context, proposals for improvement of the MPA management should be done in this step.

As the present document is focusing on developing a conceptual framework for producing new or revising existing MPA management plans, the most essential steps to be described are steps 3, 4, 5, 6 and 7, covering issues related to a) identification of goals and objectives, b) identification and engagement of stakeholders, c) assessment of current conditions, d) assessment of future conditions and e) production and acceptance of the plan will be contemplated. Indeed, a successful MPA design primarily depends on clearly stated goals, balancing multiple objectives through appropriate trade-offs (PISCO, 2016). Furthermore as engaging diverse stakeholders in MPA planning processes is vital for their successful establishment and management (PISCO, 2016), special focus needs to be exerted on step 4; the organization of the participatory process aims to explore the socio-economic consequences of management alternatives and minimize the potential impacts, guiding the development of the scenarios to respond to stakeholder concerns. Then the planning activity will be based on defining and analyzing existing conditions, but also looking into trends for the future by providing a set of spatial sea use scenarios (i.e. a business as usual baseline scenario in case there is an existing plan, and alternative ones that project adaptations to the use of marine space according to the outcomes of steps 5 and 6 and taking into account the MPA goals and objectives with the aim to provide recommendations for possible improvements in the existing plan. Evidently, in cases where no plan exists alternative plans will be only provided. The above will lead to the selection of the preferred spatial use scenario that will depend on a set of criteria according to the priority given by the MPA manager and the stakeholders to the categories of objectives (ecological, economic or social); ideally the preferred scenario should ensure full protection of the MPA conservation objectives, guiding its truly sustainable socio-economic development. The latter corresponds to deciding upon a number of management measures translated to a zoning plan. It is obvious that after the implementation of the MPA plan there should be an explicit timeframe for monitoring and evaluating its effectiveness in order to provide recommendations for revisions or adaptations of the plan. (steps 8, 9, 10) which however are not in the scope of this report.

Hence, the present document will provide a detailed description of steps 3, 4, 5, 6 and 7, explaining the actions required by each one. Then a catalogue of tools and processes that can be used to facilitate these actions will be also made available. Lessons learned from already existing studies (MedPAN and UNEP-MAP-SPA/RAC, 2016) as well as key points raised in the Consensus Statement on MPAs related to their Characteristics, Governance, and Sustainable Financing (Gabrie et al., 2012) have been also considered while drafting the present document.

2. A structured process for developing alternative MPA spatial planning options

2.1 Identifying a set of general goals and corresponding clear and measurable objectives

Protected areas are “clearly defined geographical spaces, recognized, dedicated and managed, through legal or other effective means, to achieve long-term conservation of nature with associated ecosystem services and cultural values” (Leung et al., 2015). MPAs are established for a wide range of purposes, including protecting marine species and habitats, conserving marine biodiversity, restoring fisheries stocks, managing tourism activities, and minimizing conflicts among diverse resource users. There is now a large consensus on the fact that MPAs can be effectively managed only when the managers have a clear understanding of the overall goals and of what exactly is needed to reach those goals. To achieve the goals, specific and measurable objectives need to be defined in terms of what outputs and outcomes are being sought. Goals and objectives are in fact different from one another: goals refer to the general intentions (i.e. the environmental restoration of degraded ecosystems) are qualitative (or non-numeric) and cannot be measured, while objectives are tangible and concrete actions defined within a limited time period and are measurable. In order to make objectives ‘measurable’, they need to be defined on the basis of quantitative targets. Targets, in turn, could be related to the protection of key values present in the MPA (i.e. important species, habitats or ecosystems) or to the major sectors of activities involved with the MPA management (e.g. tourism, education). Goals and Objectives are site-specific and should be defined based on a full understanding of the ecological and socio-economic values of the MPA through a participatory process, to balance needs and desires of the different stakeholders involved with the management of the MPA but also having stakes there.

2.2. Organizing stakeholder participation: identification and engagement

Planning for and addressing possible short-term losses from MPA establishment is critical to achieve long-term benefits, gain support from users, and increase compliance; many strategies have been developed for involving public and private sectors (i.e. stakeholders) which can also help to reduce the short-term losses of MPAs (PISCO, 2016). Indeed, the term MPA stakeholder refers to anyone who has an interest in or who is affected by the establishment of a protected area (National Research Council, 2001). For instance, MPA stakeholders may include (but are not limited to) fishermen, divers, general public, resource managers, scientists, volunteers, teachers, tour guides and representatives of a suite of economic sectors such as oil/energy companies, aquaculture farms. Taking into account that social factors are the primary determinants of the success of MPAs (Mascia, 2003), stakeholder participation in the production of a sustainable management plan is essential. Indeed, management failures are frequent in Mediterranean MPAs where a top-down approach is usually followed in both the planning and implementation phases and stakeholders are not involved, while there are certain successful examples that take up adaptive co-management strategies based on the collaboration between local authorities, end-users (e.g. fishers) and scientists (Pipitone et al., 2014), which can serve as baselines of good practice. Along a similar vein successful stakeholder involvement requires defining (Ehler and Douvere, 2009):

a) who should be involved,
b) when should they be involved,
c) how should they be involved.

Regarding who should be considered for involvement in the management plan production, these should include groups or organizations that:

• are or will be affected by the management of the MPA;
• are dependent on the resources of the management area;
• have or make legal claims or obligations over areas or resources within the management area;
• conduct activities that impact on areas or resources of the management area;
• have special seasonal or geographic interests in the management area; and
• have a special interest in the management of the area (such as environmental NGOs and cultural advocacy groups).

Once the group of stakeholders has been identified, ideally, an MPA management body consisting of a core group of their representatives along with the MPA manager, should be established following the relevant institutional and legal processes foreseen in each country where the MPA is located. In case a management body is established its obligations will be officially stated, however, even in cases such an establishment cannot be pursued the involvement of stakeholders is a prerequisite.

Indeed, the different stakeholder groups, with varying levels of interest and entitlement, can take part in different steps of the MPA management plan making process as indicated in Figure 1. In the frame of their involvement stakeholders can also provide spatial data and information on a wide range of expectations, opportunities and conflicts that take place in the management area. Generally, the greater the participation in the process of setting goals and objectives, the greater the stakeholder acceptance and compliance is likely to be. Regarding how stakeholders can be involved, in the case there is not an officially appointed management body, there are many different ways, ranging from ‘communication’ with no real participation, by simply getting informed by the planning authority about its intentions, then by getting consulted for their opinions with no binding commitment that these opinions will be considered. Then there is a dialogue in the form of a ‘horizontal’ interaction among stakeholders who are positioned as equals, then a common position among a group of stakeholders is developed and presented or defended before the planning authority and the ultimate way of stakeholder involvement is 'negotiation' where decision-making power is shared among stakeholders. However, what type/category of stakeholders, in what stage of the plan making process and what kind of involvement they may have, largely depend on the political or legal requirements for participation that are already established in the region.

2.3 Definition and analysis of existing conditions

The definition of the existing conditions is an essential step for the development of an operational management plan. The status should be defined on the best available evidence, using both qualitative and quantitative data to support assessments (Cook and Hockings, 2011; Hockings et al., 2009) and it should be intended here as the pre-existent status before or after the establishment of the MPA, before enforcing management actions.

In order to compile the inventory of the initial conditions, spatial information is needed concerning (1) mapping biodiversity with a focus on those areas of known ecological importance for particular species or biological communities, (2) mapping of ecosystem goods and services provided by the ecosystem under study, (3) the presence of oceanographic or other physical environmental features (e.g. bathymetry, currents, sediments) which may be important for specific habitats or important ecological processes, (e.g. upwelling areas), and (4) the distribution of human activities within the area.

Data need to be collected from many sources including: direct field measurement, scientific literature, expert scientific opinion or advice, institutional information sources and local knowledge (Ehler and Douvere, 2009). Most spatial planning efforts rely heavily on the first three sources of data, although local knowledge is increasingly recognized as a valuable source of information for spatial planning. Later on in the process, if important knowledge gaps are identified, field measurements can be conducted to fill the gaps. It is also worthwhile to observe that the type of information may be different depending on the context, e.g. whilst qualitative data might be most appropriate for some aspects of management (e.g., measuring stakeholder engagement), other aspects (e.g., measuring ecological status) need quantitative data sourced from monitoring and research (Hockings et al., 2009).

Long-term quantitative monitoring can provide data that reveal both the effectiveness of protection and the temporal dynamics of species/habitats/ecosystems. These two aspects are in fact needed to interpret environmental conditions, to disentangle the natural variability of the systems from the variability imposed by the effects of protection (Hereu et al., 2012), and to decide when to adapt management plans to a new condition (Addison et al., 2015). Details about monitoring designs and protocols can be found in the Deliverable *3.3.1 on Monitoring protocols.*

Data need to be organized to produce an inventory of knowledge which should be the most comprehensive as possible (ecological data and human uses). The methodology used to produce the inventory should be replicable and information should be kept updated on a regular basis. The database development represents a crucial product of the planning effort and it will be central for the definition of the decision support framework. Geospatial databases have strongly developed in the recent years. The Relational Database Management System of the geodatabase data model allows users to explicitly link tabular data and targets, goals, geography with the spatial data representing them in one repository. Spatially-explicit dedicated databases would also enable to integrate the existing scientific knowledge including monitoring data and metadata, or any other element useful for the spatial analysis (see *Deliverable 3.2.1* for further details about geodatabases).

As an example, in the MPAs included in the project, different levels of information are available as far as habitat mapping; in Torre Guaceto there is detailed spatial information on the distribution of habitats within the borders of the MPA, while in the other two sites as existing information is more limited, attempts were made to retain the best possible ecological description in the final maps (Figs 2-4) using ancillary data sets that were reviewed for quality assurance before being incorporated into the project's geodatabase.

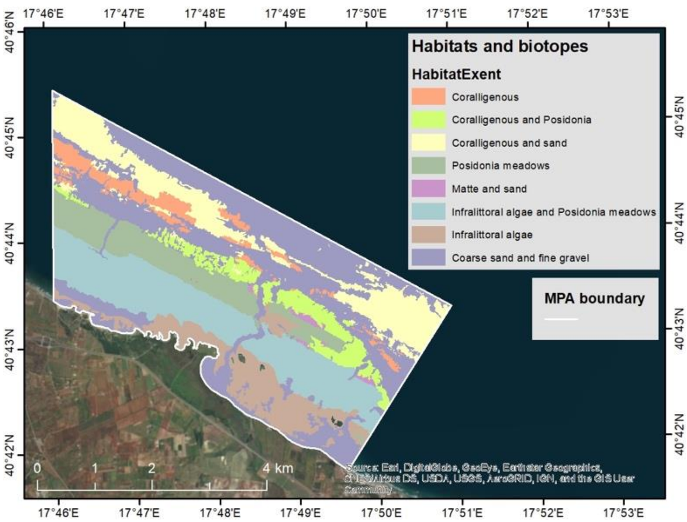

Figure 2. Habitat mapping in Torre Guaceto (Italy)

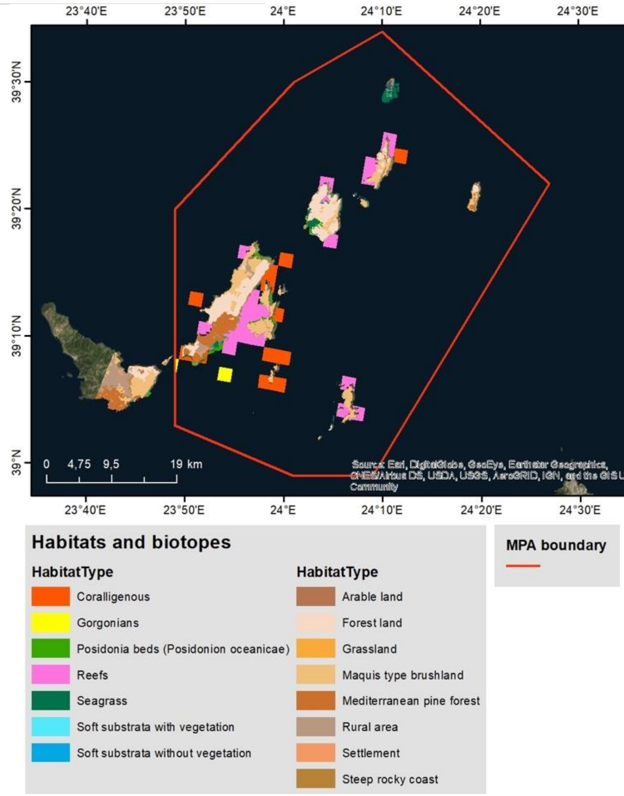

Figure 3. Habitat mapping in Sporades (Greece)

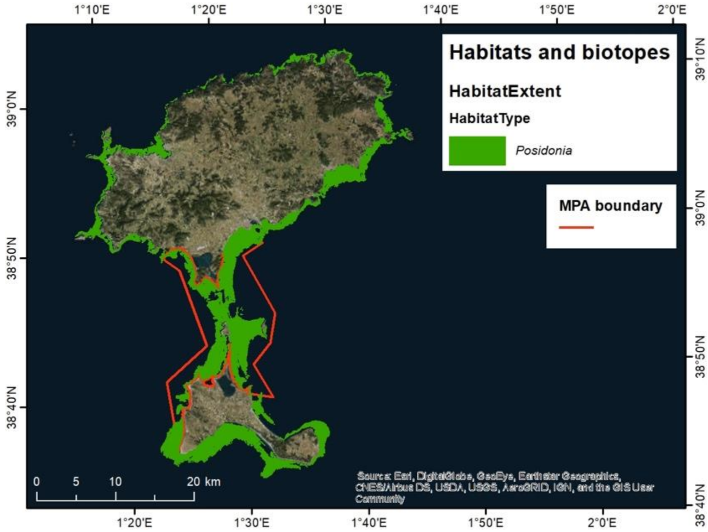

Figure 4. Habitat mapping in Baleares (Spain)

In summary the status of an MPA can be defined by compiling:

- An inventory of biodiversity and maps of critical species/habitats in the MPA;
- An inventory of maps with identified valuated ecosystems goods and services
- An inventory and maps of current human activities and pressures in the MPA;
- An assessment of the effects between pressures and the status of critical species/habitats in the MPA and of conflicts and compatibilities among existing human uses;

- Distribution of critical species/habitats in the MPA;

The knowledge about the distribution of the different biological/ecological features (i.e. key species presence, habitat diversity) together with the assessment of their status is of crucial importance for the planning process.

Knowing which areas are most important to conserve and which areas are compatible with multiple human uses is crucial when setting up the management plan (Ehler and Douvere, 2009). MSFDs descriptors (Directive 2008/56/EC and it's following modifications) should also be considered. Habitat mapping is a fundamental requirement in providing inventories of habitat types and their occurrence as the identification of habitat diversity hot spots. Maps allow changes in habitat cover to be detected, boundary demarcation of multiple-use zoning schemes (Fraschetti, 2012) to be drawn, and may support informed choices about how to manage the MPA in relation to the pressures deriving from human use of the marine area. Accordingly, existing scientific knowledge about the biological/ecological resources should be included in the geodatabase. Knowledge gaps should be identified, to prioritize actions, so that gaps should be filled by specific surveys.

- Distribution of human activities in the MPA

In this case, the inventory should provide elements to answer to the following questions:

- What are the main pressures affecting the marine area, and is there any specific threat for the ecosystems present in the MPA?
- What are the main driving forces likely to shape marine development in the near future?
- Is there any specific economic and social factor that need to be considered?
- Is there any sector that depends on a certain type of marine area?

Georeferenced data are needed to understand the spatial extent of the pressures. Moreover, number and frequency of multiple human activities should be assessed at multiple spatial scales (e.g. MPA scale or regional scale). Such data can be derived both from dedicated geoportals (i.e. AMAre Geoportal) or through other existing open access databases (e.g. regional geoportals associated to planning documents, national statistics catalogues etc.). Data in some cases might need to be integrated with some modeling to backtrack potential controllable sources of the pollution/alteration.

- Assessment of the relationship between human pressures and ecosystem status

Finding the balance between the conservation of the marine environment and the sustainable use of natural marine resources is the key factor in the management of a MPA. So, understanding the relationships between multiple human pressures and the status of ecosystems is crucial to develop management plans (Giakoumi et al., 2015b; Halpern et al., 2008a; 2008b; Coll et al., 2012; Katsanevakis et al.,2017; Korpinen and Andersen, 2017; Micheli et al., 2013;). Yet, understanding the relationships between multiple human activities and the status of ecosystems is difficult for two main reasons: (1) multiple pressures may interact in complex non-additive manners (Shears and Ross, 2010) and (2) information on the cumulative effect of multiple stressor on ecosystem are still lacking (Halpern et al., 2008; Fraschetti et al., 2009; Coll et al., 2012; Micheli et al., 2013; Stock & Micheli, 2016; Bevilacqua et al., 2018; Stelzenmuller et al., 2018). Several Cumulative Effect Assessments (CEAs, Jones, 2016) have been published in the recent years in order to evaluate the combined effects of human activities and natural processes on the environment (see Stelzenmuller et al., 2018), however a standardized procedure is still missing and there are gaps in the uncertainties assessment (Jones et al. 2018). Disentangling complex interactions among multiple pressures (e.g. non-additive behaviors) can be challenging in the real world, where pressures are multiple and very often spatially correlated. Congruence of cumulative impact scores is still a central question in such assessments, since the power to discriminate among expected levels of impact can change substantially depending on data resolution, thresholds of impact scores and weights assigned to anthropogenic drivers (Stock & Micheli, 2016). As recently discussed by Korpinen and Andersen (2016) in a global review, in most works the effects of different pressures in order to calculate cumulative impact scores were weighted based on expert judgement (e.g. Halpern et al., 2007). However, the understanding of potential effects of human pressures on different ecosystems is far from being exhaustive, thus limiting the possibility of comparisons between empirical evidence and expert opinion (Micheli et al., 2013; Teck et al., 2010). In addition, despite several studies used global weights in regional assessments (e.g. Micheli et al., 2013, Afferback et al., 2017), others have stressed the importance to calibrate assessments to the specific region of interest (e.g. Guarnieri et al.,2016; Korpinen et al., 2012; Knights et al., 2014).

In spite of such difficulties, surrogates (e.g. presence/absence of relevant human activities or weighted distance from these activities) have been successfully used to mapping potential risks of human impact (Eastwood et al., 2007; Petrosillo et al., 2010; Stelzenmuller et al., 2010; Mensa et al., 2011). If the spatial distribution of both marine habitats and human pressures is available, then risk maps can be produced, thereby helping identify the most efficient management solution, i.e. the one capable to minimize the risk of impact (see also Halpern et al., 2009; Stelzenmuller et al., 2010; 2018; Coll et.al. 2012; Micheli et al. 2013; Selzenmuller et al., 2010, 2014, 2018; Tulloch et al., 2015; Wu et al. 2016).

These approaches have the invaluable advantage that spatial plans can be implemented when data on ecosystem status are missing or scarce, e.g. over large scales allowing a synoptic view of the territory to be managed (Bianchi, 2008). The main drawback of such approaches, however, is that multiple pressures are generally assumed arbitrarily to play additively (Halpern et al., 2009). Without using data on ecosystem status, in fact, expert- or literature-based techniques can hardly detect and understand the complex interactions that may exist among pressures (e.g. synergisms or antagonisms). In addition, these interactions are spatially variable and site-specific, so it is difficult, if not impossible, to extrapolate as general rules over vast spatial scales (Crain et al., 2008). However, more than analyzing compatibilities and conflicts between activities uses and functions, consideration should be given to the already impacted ecosystems, the prospective new human uses and their likely impacts (Fernandes & Alves, 2016).

Field data about human pressures and their intensities can be used to identify areas where ecosystem health status and cumulative impact levels meet the objective or where it is mismatched. Indeed, a crucial element in the planning process is the quantification of the cumulative pressure affecting the MPA and contiguous areas (e.g. human activities producing noise, aquaculture, fishing effort and catches; civil and industrial effluent discharges, diffuse pollution due anthropogenic pollutants – i.e. nutrients, pesticides, plastic etc.). Priority should be given to the pressures included within the MSFD's descriptors. The resulting information can be used to evaluate different management alternatives (i.e. expected or planned variations in human pressures distribution and intensities) to make strategic decisions and monitor progress towards management objectives.

2.4. Defining and analyzing future conditions

The planning activity should not be limited to defining and analyzing only existing conditions, but it should also explore spatial sea use scenarios that project the future use of marine space based on a set of assumptions/objectives about the future. The baseline information on existing conditions within the MPA derived from the previous step coupled with the conservation goals and objectives and the stakeholders' expectations on sustainable development activities within the MPA will constitute the core for developing the MPA spatial planning options appearing below.

2.4.1 Trend scenario

The trend scenario (i.e. business as usual) considers how the MPA will perform if present conditions continue without new management interventions (baseline scenario); it is based on the projection of the future spatial and temporal trend evolution of existing human uses and shows what is likely to happen if no actions are taken in the management of the area. So the scenario considers the evolution of the present pattern of pressures and the potential resulting impacts (e.g. if the tourism pressure is increasing, also tourism impacts may increase). For developing the trend scenario, the historical trends about human uses (i.e. shipping, tourism) should be considered. Moreover, it is important to determine the time frame for the forecasting and apply it consistently for all forecasts. New demands for sea space, their spatial and temporal requirements within the management area and within the selected time frame should be integrated in the scenario.

2.4.2 Scenarios of alternative spatial sea use

The alternative scenarios illustrate how the MPA will perform when human activities are redistributed. New MPA goals and objectives in these scenarios may cover various aspects: ecological (e.g. conservation of the biodiversity), economic (e.g. economic return obtained from the use of the marine resources) and social aspects (e.g. establishment of recreation and tourism as well as cultural opportunities).
These scenarios should be generated based on the assessed or presumed (e.g. based on a precautionary principle) causal relationship between pressures and the quality status of the ecological values, and by evaluating the spatial relationship between areas that need special protection because of their ecological value and the changes in the distribution of human uses. The scenarios will primarily indicate:

• Areas for special protection;
• Areas for a sustainable development;
• Spatial relationships between different areas.

The set of alternative spatial use scenarios could be developed based on the priority given to the list of MPA goals and objectives. Each of the alternatives should be investigated in terms of how changes of human uses, and particularly their distribution both in space and time, may change the environmental impact, or affect the provision and quality of key ecosystem services provided.

2.4.3 Selection of the preferred scenario

The selection of the preferred spatial use scenario will depend on a set of criteria. The preferred scenario will depend on the priority given to the categories of objectives (ecological, economic or social) selected for the MPA. Ideally, the alternative that will produce results in the most effective (i.e. leading toward results), efficient (i.e. producing expected results at the least cost), and equitable way (i.e. costs and benefits for achieving results are distributed equitably) should be the preferred one.

2.5. Preparation and approval of the MPA action (management) plan

Ideally, the preferred scenario should guide the ecological, social, and economic development of the MPA and will provide the basis for selecting management measures in the spatial management plan and consequently propose a suitable zoning, where different sea uses are categorized into zones, each having its own set of standards and requirements. In other words, it should identify when, where, and how goals and objectives will be met under the preferred scenario by the drafting of an action plan (i.e. the zoning plan) that will be prepared by the MPA managers. The action plan will include conservation measures, according to the individual priorities and resources of the MPAs and should identify ecologically meaningful targets for the percent of a bioregion to be protected by a specific date, while addressing issues responding to socio-economic concerns. A fundamental component of a MPA management measure involves the basic question: How can human activities be induced to do what is necessary to produce the desired mix of goods and services from the MPA? The reply to this question implies the need for efficiency as well as conflict minimization or even resolution between already existing and future uses of the area that may be impacted by the decided management measures. The selection of the management measures should be made following an agreement with the stakeholders involved and can be facilitated by tools and processes analyzed in a later section of this document. It is obvious that aside from conservation targeted measures, capacity-building ones are also important for ensuring stakeholder compliance during the implementation phase. Finally, the plan should include provisions on monitoring, evaluation and adaptive management to ensure management practices are achieving goals and objectives.

3. Selecting tools and processes to facilitate each planning step

A number of tools and processes exists that can visualize and evaluate MPA management plan alternatives (including zoning and management measures alternatives) and facilitate the selection of the best alternative. However, not every tool or process requires the same data input or is appropriate for all tasks involved in the production of a management plan (visualization, evaluation and selection).

In the Table 1 (see the Annex) a list of tools and methods is presented along a brief description, applications so far, level of technical skill required and steps of to address. Such tolls have been selected based on their ability to incorporate ecosystem services valuation, trade-off analysis and alternative scenarios comparison (COS, 2011; Seaplan, 2016; Stamoulis and Delevaux, 2015).

3.1 Tools and processes for generation and evaluation of management plan alternatives

Generation and evaluation of management alternatives is part of a (spatial) decision making process and it requires:

- mapping of human uses, biodiversity and ecosystem services
- (Monetary) Evaluation of the provision of multiple ecosystem services and biodiversity for any given pattern of sea use and/or management measure across a marine area in order to Illustrate synergies and trade-offs among ecosystem services and biodiversity conservation
- Defining of efficiency frontiers that show the maximum possible combinations of human uses, ecosystem services provision and biodiversity conservation in a specific area or zone.

By balancing ecosystem services and biodiversity, managers can locate areas that, if managed correctly, can provide high levels of both. By comparing outcomes across different management alternatives, conservationists and managers can gain insight into which alternatives may be most desirable (Polasky et al., 2011).

Compatibility matrixes for an initial assessment of conflicts and compatibilities

Ehler and Douvere (2009) suggest a matrix method for identifying compatibilities and conflicts among existing human activities or between human pressures and environmental receptors.

Mapping and digitizing human uses, biodiversity and ecosystem services

Compiling spatial data into a Geographic Information System (GIS) database is the most effective way to store, analyse and map relevant information such as present and future human uses, areas with various levels of biodiversity and ecosystem services and the change in their provision under different management measures. There are also participatory GIS approaches whereby stakeholders identify and map important resources or potential MPA sites on hardcopy maps, which are then digitized into GIS format (Laffoley, 2008).

To map marine ES, it is required to understand the process of ES provision, from the ecosystem components, functions and processes to the actual ES. As depicted in Fig.2, For each component of the ES provision chain, data need to be acquired and quantification methods applied throughout. This information can be used to spatially represent the ES distribution. In an example of whale watching tourism as an ES provided by whales, species and habitat distribution models are used to describe the basic ES components. Then models are used to describe the ecosystem functions. The outputs of all these models are then combined along with socio- economic variables (e.g. whale watchers and/or revenues from whale watching) in order to generate a final map of the benefit or value from whale-watching tourism (Drakou et al., 2017).

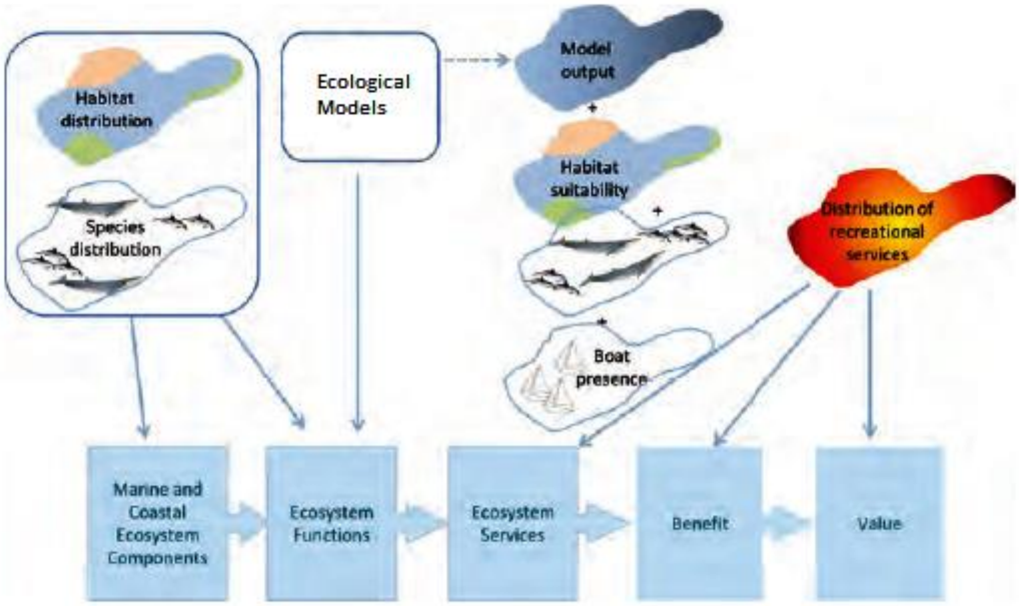

Figure 2. Depiction of how data and ecological models contribute to the different components of a basic ecosystem service generation framework (ES cascade at the bottom of the figure) in order to generate ecosystem services maps (adapted by Drakou et al., 2017).

Trade off analysis to define (Pareto) efficient solutions

Generation, comparison and selection of optimal and widely acceptable management alternatives require evaluation and visualization of trade-offs among human activities, various ecosystem services and biodiversity conservation. For instance, management measures over the use of a marine area may enhance one or a few services or use areas, at the expense of others. Hence, it is important to determine how supply of ecosystem services generated by marine habitats may vary in response to different anthropogenic activities (for example types of seabed use).

Multi-criteria decision making (MCDM)

Management plan alternatives can be evaluated by a number of people (managers, decision makers, stakeholders, interest groups), who are often characterized by unique preferences with respect to the relative importance of criteria on the basis of which the alternatives are evaluated. Multi-criteria decision making (MCDM) is appropriately described as a non-monetary approach for comparing stakeholder preferences and analyzing trade-offs (Maguire, 2014), among multiple, often competing, objectives, while adding clarity and facilitating quantification throughout a decision-making process.

Main elements of (spatial) MCDM are a) the evaluation criteria, b) the alternatives, c) the decision-maker preferences and c) the set of assumptions, specifying the ways in which alternatives and criteria can be evaluated. Criteria may be biological (biodiversity representation, shape, size, dispersion, connectivity, alignment, etc.) and sociopolitical (cost, cultural value, educational value, etc.).

These elements can be combined using multicriteria decision rules that provide the basis for ordering the decision alternatives and for choosing the most preferred alternative.

Decision rules have been categorized into multiattribute (MADM) and multiobjective approaches (MODM) (Malczewski, 1999).

In MADM approaches attributes serve as both decision variables and decision criteria. For instance, in spatial /GIS-based decision making the decision variables can be assigned to the spatial objects (alternatives) that are stored in a GIS database. For example, each pixel in the raster data layer can be considered as an alternative, and the decision variables (attributes) can be assigned to the rasters. Consequently, standard GIS operations and cartographic modeling are sufficient to implement most multiattribute decision rules. Additive decision rules are the best known and most widely used MADM methods (especially in spatial/GIS-based decision making) i.e.: the simple additive weighting method, value/utility function approaches, and the analytic hierarchy process.

Unlike MADM, in MODM approaches a distinction is made between decision criteria and decision variables. The MODM decision rules define the set of alternatives in terms of causal relationships and constraints. This implies that the alternatives are not given explicitly. They have to be generated implicitly within a multiobjective procedure. Therefore, in spatial /GIS-based decision making it is usually impossible to implement the MODM methods within a GIS using the cartographic modeling approach. It typically requires a combination of mathematical programming software and the GIS capabilities. Distinctive approaches that are frequently applied to (spatial) MODM problems are: value/utility function methods, goal programming, interactive programming, compromise programming, and data envelopment analysis.

MADM and MODM decision rules can be further subdivided according to the nature of the data and information available (deterministic, probabilistic, and fuzzy logic transformations) as well as according to the number of decision makers (interest groups) involved in the decision-making process (single decision maker or group of decision makers).

(Spatial) Decision support tools

Decision support tools constitute a class of interactive computer-based information systems that support decision-making activities (Yates et al., 2015) They integrate and synthesize data in order to visualize and assess trade-offs between different management strategies and identify areas of synergy and conflict (White et al., 2012) and they compare alternative scenarios to identify potential optimal alternative solutions (Collie et al., 2013). These alternatives may be generated based on ecosystem service values, trade-offs between ecological, social, and economic systems, or optimizing the degree to which the planning objectives are met (COS, 2011).

The Coastal-Marine Ecosystem-Based Management Tools Network has catalogued such tools that are capable of addressing trade-offs, in an online database (ebmtools.org) (Carr, 2011) such as the Cumulative Impacts Model, the InVEST, the Multipurpose Marine Cadastre, the Open OceanMap, MarineMap, Marxan with Zones, MIMES and NatureServe Vista. Additionally to these tools the Center for Ocean Solutions (COS, 2011) considers also Aries, Atlantis and Coastal Resilience. SeaPlan, 2016 has created an inventory of tools focusing on assigning, analyzing, and comparing the value of marine ecosystem services. It includes again ARIES, Atlantis, InVEST, Marxan, MIMES and Vista, complemented by BVMtool, the Coastal Capital Valuation Tool, Envision, InVitro, Madrona, RIOS, SERVES, SolVES and Zonation.

For instance, MARXAN identifies “optimal” reserve designs based on explicit trade-offs that have been used in many locations as part of the planning process (Airame et al., 2003; Leslie, 2005; Green et al., 2007). These DST such as MARXAN have limitations as the solutions identified are very dependent on the data and assumptions included as inputs, they generally do not explicitly address dynamic processes such as network connectivity, and results may not mesh with local knowledge or more complex socioeconomic considerations (Laffoley and Kilarski, 2008). However, there are present efforts to make this tool less static (Beger et al., 2010).

3.2 Tools and processes for selecting the best alternative management option

Although, trade-off analyses (and the related decision aiding tools and processes) are able to calculate optimal solutions (known as Pareto-optimal solutions) for various management measures, the challenge is how to select that single solution that will be acceptable by all interested parties i.e. a solution that can ensure not only efficiency, but also fairness, equity and sustainability, that can consider both spatial and interpersonal synergies and that can maximize the net aggregate benefit produced by the selected management measures as well as the individual net benefit produced by each sector and/or objective involved. Most popular methodologies for facilitating such selection are described below.

Cooperative game theoretic allocation

Management plan selection criteria described already are well captured by Cooperative game theoretic (CGT) allocation rules that could be ideally integrated in already existing tools and processes in order to address all MPA management plan making steps as described in the conceptual framework. CGT allocation rules are decision making rules that are used to select the best alternative outcome of a bargaining game where multiple players and/or objectives are involved and interact with each other in order to reach an agreement over various management options. A bargaining game resembles tradeoff analysis process and the alternative outcomes are no other than the set of efficient solutions (on the Pareto frontier) that result from trade-off analyses or bargaining between players and/or objectives. When applying CGT allocation, the solutions on the Pareto frontier, should first be restricted to the Core of the game which is a set of solutions that ensure that the stakeholders involved get at least what they would get without the management plan. The CGT allocation rule calculates the single solution from the core that is fulfils the selection criteria described above. From those CGT allocation rules, the most popular are the Nash bargaining solution (NBS) (Nash, 1950, Nash 1953) and Kalai-Smorodinsky solution (KSS) (Kalai and Smorodinsky, 1975) concepts for two players games and the transferable utility (TU) and non-transferable utility (NTU) Shapley value (Shapley, 1953) and the TU and the NTU Nucleolus for games with more than two players (Schmeidler, 1969). One more advantage of these four allocation rules is that they do not require sophisticated calculations and in some cases only some basic linear programming.

Incentives/ Compensation

There might a need for incentives to make management measures acceptable, implementable and effective. Incentives are the positive and negative means to induce action to implement management measures. There are two types of incentives: (1) economic incentives; and (2) non-economic incentives. Such incentives are monetary or ecological compensatory actions or measures used often in order to resolve conflicts occurring due to environmental externalities or due to relocation of uses due to protection measures.

4. Concluding remarks

Setting up an MPA management plan is a task that should be based on clear, straightforward steps that are linked to explicit actions and associated tools that facilitate those actions. Most fundamental steps include: setting goals and measurable objectives, organizing stakeholder participation, defining and analyzing existing conditions, defining and analyzing future conditions, developing spatial planning options and selecting the most suitable one to be used for preparing the spatial management plan. The present framework gives a description of these steps along with their interlinkages and a sample of tools and processes that facilitate them. Such tools and processes are scenario development and comparison, decision making processes that use visualization of compatibilities and conflicts between human uses, biodiversity and ecosystem services trade-off analysis, multi-criteria evaluation, and finally allocation rules for mutually acceptable, sustainable management options. The proposed framework is applicable in any stand-alone MPA or a network of MPAs, and can guide effective decision making actions by integrating both the ecological and human dimensions in their planning and management.

Annex

The Table 1 below includes a list of tools and processes that have been selected based on their ability to incorporate ecosystem services valuation, trade-off analysis and alternative scenarios comparison (COS,2011; Seaplan, 2016; Stamoulis and Delevaux, 2015).

Table 1. Tools and processes that facilitate the visualisation, evaluation and selection of alternative management measures.

Methods and tools	Brief Description	Applications so far	Level of technical skill required	Steps of to address
Compatibility matrixes	Matrix that identifies levels of compatibilities and conflicts between human uses and the marine environment	See West Coast Aquatic, 2013; Maes et al. 2005; Thompson et al. 2008	Low	Assessing current conditions and future conditions
Trade off analysis	How supply of ecosystem services generated by marine habitats may vary in response to different anthropogenic activities (for example types of seabed use).	See Brown et al., 2001, White et al. 2012, Lester et al., 2012	Moderate	Assessing current and future conditions
(Spatial) Multi-criteria decision making	Evaluation of alternative courses of actions by a number of people (managers, decision makers, stakeholders, interest groups), with respect to the relative importance of criteria.	See Francour, P., et al., 2001; Wood, L.J. and Dragicevic, S., 2007; Portman, M.E., 2007; Villa, F., Tunesi, L. and Agardy, T., 2002.	Moderate	Assessing current and future conditions
ARIES	ARtificial Intelligence for Ecosystem Services (ARIES) is an open-source modeling platform for mapping potential provision of ecosystem services and valuation through ecological process and ad hoc probabilistic Bayesian models.	See Wendland et al. 2010	High	Assessing current and future conditions
Atlantis	Atlantis is a deterministic whole-ecosystem model, with sub-models for biophysical ecological processes, exploitation, sampling/assessment, and rules/management actions to fully cover adaptive management cycle.	See Kaplan et al. 2012	High	Assessing current and future conditions
Envision	Envision is an open-source GIS-based tool for scenario-based integrated planning assessments. The platform integrates a variety of spatially explicit models of landscape change processes and production for alternative futures analyses.	See http://envision.bioe.orst.edu/caseStudies.aspx	High	Assessing current and future conditions

InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) is a suite of open-source spatially-explicit software models that use maps and other information to value ecosystem services in resulting biophysical or economic terms. It also depicts gains and losses in ecological and economic benefits under alternative, spatially-explicit management scenarios.	See McKenzie, E., 2014; Ruckelshaus et al., 2013	High	Assessing current and future conditions
MarineMap	A web-based application that allows users to visualize geographic data, design perspective MPAs, analyze those MPAs, and share their designs with other stakeholders participating in the Initiative process	See Merrifield et al 2013; Cravens, A.E., 2016; (California MLPA Initiative).	Moderate	Assessing current and future conditions
Marxan	Marxan is a conservation planning software that provides decision support in new reserve design, reserve performance, and developing multiple-use zoning plans for natural resource allocation management.	See Airame et al. 2003; Leslie 2005; Green et al. 2007 and Yates et al., 2015.	High	Assessing current and future conditions
MIMES	Multi-scale Integrated Models of Ecosystem Services	See Altman et al., 2012	High	Assessing current and future conditions
Cooperative game theory	Fair, equitable, transparent process for allocating divisible goods and services among often conflicting interested parties or objectives	See Kyriazi et al. (2015) and Kyriazi et al. (2017)	Moderate	Producing the plan (Selecting final solutions)
Compensatory measures	Calculation of fair ecological or monetary compensation in order to facilitate coexistence of often conflicting activities and conservation	See Kyriazi et al. (2015)	Moderate	Producing the plan (Selecting final solutions)

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