5.7.4. Mapping marine and coastal ecosystem services

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Introduction

The marine environment, from the coasts to the open ocean, is closely tied to human well-being; from small-scale artisanal fisheries providing local communities with food, to large-scale regulating benefits like protecting coasts from erosion and regulating global climate. Intense human intervention in these areas, for example, through maritime transport, fishing and aquaculture, oil extraction, tourism and coastal land use, alter these ecosystems, hence impacting human well-being. Several treaties and policy instruments have been enacted from the local to global level to regulate human influence on the marine realm and to sustain these ecosystems (for example, the UN Convention of the Law of the Sea, the UN High Seas Treaty). In addition, the EU Marine Strategy Framework Directive and that on Maritime Spatial Planning require an ecosystem-based approach to the management of human activities.

Mapping of ES can help decision-makers define critical areas for intervention and aids regulation of activities. Although mapping methodologies are rapidly advancing for the terrestrial and inland water ecosystems, marine and coastal ecosystem service (MCES) mapping is still limited.

This chapter gives an overview of MCES mapping principles. We present below the major ES provided by marine and coastal habitats, the particularities and differences of MCES mapping compared to the terrestrial realm and its major requirements and limitations.

ES provided by marine and coastal habitat types

Each marine or coastal habitat type can generate different ecological functions which can then generate ES for the benefit of human beings. In Table 1, we list the major marine and coastal habitats and the MCES they provide according to what has been documented in the literature. The missing links between habitats and ES highlight the areas with the largest knowledge gaps, but not the lack of a link. It is worth mentioning here that very few of these ES have been actually mapped.

Mapping marine and coastal ecosystem services

To map ES provided by marine and coastal ecosystems similarly to the terrestrial ecosystems, one has to understand the process of ES provision, from the ecosystem components, functions and processes to the actual ES. For each component of the ES provision chain, data need to be acquired and quantification methods applied

Table 1. Major marine and coastal habitat types and their links with ES as documented in the literature. The (✓) symbol represents the relationships between habitat types and ES that have been assessed and documented in the literature. The (?) is there to represent the lack of sufficient knowledge to assess and hence quantify and map this relationship.

	Provisioning			Regulating and maintenance							Cultural		
	Food provision	Water storage / provision	Biotic materials/Biofuels	Water purification	Air quality regulation*	Coastal protection	Climate regulation	Ocean nourishment	Life cycle maintenance	Biological regulation*	Recreation Tourism	Symbolic/Aesthetic values	Cognitive effects
Beach and dunes	✓	✓	✓	✓	✓	✓	✓	✓	✓	?	✓	✓	✓
Coastal wetland	✓	✓	✓	✓	?	✓	✓	✓	✓	?	✓	✓	✓
Estuary		✓	✓	✓	?	✓	✓	?	✓	?	✓		✓
Mangrove	✓	?	✓	✓	?	✓	✓	✓	✓	?	✓	✓	✓
Coral Reef	✓	?	✓	✓	?	✓	?	✓	✓	?	✓	✓	✓
Maerl bed*	?	?	?	?	?	?	?	?	✓	?	?	?	?
Oyster reef	✓	?	?	✓	?	✓	?	✓	✓	?	?	?	?
Macroalgal bed	✓	?	?	?	?	✓	✓	?	✓	?	?	✓	?
Seagrass meadow	✓	?	?	✓	?	✓	✓	✓	✓	?	✓	?	?
Unconsolidated sediments	✓	?	?	✓	?	?	✓	✓	✓	?	?	?	?
Open ocean/ pelagic	✓	✓	✓	✓	✓	?	✓	✓	✓	?	✓	✓	✓

* These habitats and ES are still very poorly analysed.

throughout. This information can be used to spatially represent the ES distribution. In Figure 1 we illustrate the process of generating a map of MCES with a hypothetical example.

In the oceans and coastal seas, many ecosystem functions occur within the water column which adds a third spatial dimension to the system. These functions change with depth, water temperature, solar irradiance, salinity and other factors and are extremely variable in space and time. This makes it difficult to capture this information in two-dimensional maps.

MCES maps are delivered by:

Analysis of primary data, for example, high resolution remote sensing of the coastal and pelagic zone, field sampling and socio-economic surveys. It can be very accurate, but it is also time and resource consuming.

Habitat maps can be used to translate seabed habitat maps into capacity to deliver ES based on scoring factors. This method can be feasible and quick if the seabed habitat maps of the study area are already available. However, the scoring system can be subjective and the results reflect only the services provided by benthic habitats.

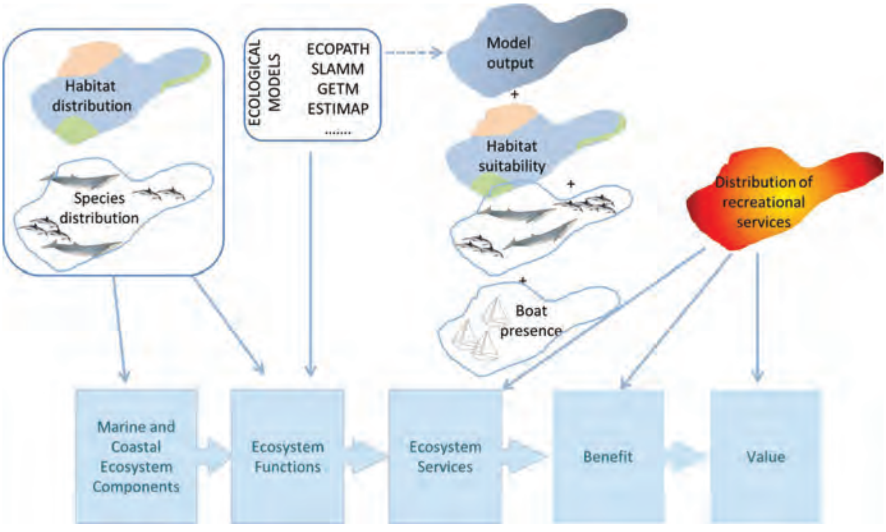

Figure 1. The figure depicts the way data and ecological models contribute to the different components of a basic ecosystem service generation framework (ES cascade at the bottom of the figure) in order to generate ES maps. In an example of whale watching tourism as an ES provided by whales, species 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 parameters (in the example we refer to the number of whale watchers, but it could also be revenues from whale watching) in order to generate a final map of the benefit or value from whale-watching tourism. The arrows show the flow of information within the elements of the ES cascade.

Modelling

Models such as those below can be used:

a. *Ecosystem models* optimally integrated with socio-economic data, or bio-economic models. They can be relatively accurate with quantifiable uncertainty and capture three-dimensional (3D) processes across spatial scales. Still they require a lot of data, time and expertise. Model outputs may not be usable as such; composites or proxies often need to be generated for MCES mapping.
b. Already available MCES *mapping tools* (see the following section).

Most MCES maps depict the ES capacity and very few address the actual flow of, or the demand (Chapter 5.1) for MCES. The analysis of all these ES aspects is essential, especially for MCES whose use is often distant from the source of ES provision (e.g. the nutritional value of globally consumed tuna or climate regulation by mangroves in South-East Asia).

Required data for MCES mapping

The possibility of creating MCES maps is often limited due to scarcity of spatial data. For proper ES mapping, data should ideally be available for:

- Habitats' spatial distribution (or their model-derived proxies);
- ecological state of the habitats;
- water quality affecting ES provision (e.g. eutrophication or amount of harmful substances);
- species distribution of dominant, habitat forming and keystone species that either provide or support ES;
- biomass of fish and other seafood;
- human activities affecting the production of ES or those which could be used as indicators for ES use (e.g. fishing activity, tourism etc.).

Collecting such data is laborious and expensive, mostly because of the methodological challenges. Some examples are given in the following text.

Data on benthic habitats need to be collected with echo-sounding methods and tedious geological analysis of the sonar data. Species data need to be collected with a suite of methods that vary in spatial coverage and taxonomic accuracy. Data on sea bottom substrate and larger species can be collected with underwater cameras, while information on smaller species can be derived with underwater surveys (e.g. through scuba diving) and benthic sampling. Species identification often requires microscopic analysis.

Some proxies for ES can be created for more cost-effective methods. The new satellite instruments provide high resolution data (e.g. WorldView3 images have a resolution of 30 cm) that can be used to create proxies for some ES, like habitats essential for fish production. Semi-automatic *in situ* mapping devices, such as robot gliders, have been developed for collecting sea bottom data instead of cruises on research vessels. Such methods can complement, but never entirely replace, the traditional methods.

Spatial data on certain human activities can easily be derived from public databases, but in most cases data are scarce. Proxies need to be calculated although these create uncertainties in the mapping.

MCES mapping tools

Different online tools, models and methodological frameworks allow practitioners to assess and map different components of the MCES generation chain (Figure 1). Amongst the most popular and well-established ones, are the models from the InVEST[1] toolkit that use ecological production functions to assess the supply and demand of MCES. These can assess wave energy, coastal protection, marine fish aquaculture, marine aesthetic quality, fisheries and recreation and marine habitat provision. ARIES[2] has also been applied for MCES assessment to generate maps mostly in coastal areas, using artificial intelligence networks and expert opinion. In most of these models, data availability and quality are the major issues that make their application difficult.

Several initiatives focus on publishing spatially explicit information regarding or potentially supporting MCES mapping. The SeaAroundUs[3] project has released a map server showing time series of the spatial distribution of fisheries around the globe. The EU has recently released a new tool for mapping fishing activities (MFA)[4] for the European seas which is based on AIS (Automatic Identification System) data acquired by fishing vessels. AquaMaps[5] also provide maps of marine species distribution globally. The Baltic Sea data and map service[6], by the Helsinki Commission, provides spatial data on biodiversity and human activities on sea. The Ocean Health Index Project[7] provides a global map of ES provided by the sea and how sustainably the countries are using them.

Challenges of MCES mapping

There is a high level knowledge pool on the functioning of the marine ecosystems and high expertise on ES mapping methods. Yet these two only recently started converging in an interdisciplinary manner. Hence the number of MCES assessments that actually provide maps is still very limited. Challenges to MCES mapping include:

1 http://www.naturalcapitalproject.org/invest/

2 http://ariesonline.org/

3 http://www.seaaroundus.org/data/#/spatial-catch

4 https://bluehub.jrc.ec.europa.eu/mspPublic/

5 http://www.aquamaps.org/search.php

6 http://maps.helcom.fi/website/mapservice/index.html

7 http://www.oceanhealthindex.org

- The dynamic three-dimensional (3D) nature of the marine environment, especially in the pelagic zone, makes it difficult to produce two-dimensional maps. Averaging over time and space is necessary and hence the level of spatial accuracy is low.
- Information on the distribution of habitat is scarce or entirely lacking making it difficult to map MCES based on these habitats.
- As the ecological functions and processes behind many ES, such as biological regulation, are not known or not easily quantified, their mapping is difficult.
- Cultural ES, such as recreation, aesthetic information or inspiration, are based on human experiences which may be very variable. Linkage of such experiences to a specific habitat is difficult.
- Data on ES demand or use is sensitive thus hard to obtain for some ES with high commercial value (e.g. food provision from fisheries).
- Uncertainty in data and maps is too high to be useful in a policy context, therefore having often a negative feedback effect on momentum to create these maps.

Future recommendations

Given the limited number of MCES maps, there is a need to:

- Adapt the current ES methodologies and frameworks that have been developed based on terrestrial ecosystems to the specificities of the marine environment.
- Improve the quality and spatial resolution of data and improve data availability; advance initiatives such as the European Marine Knowledge 2020; and feed data into harmonised databases like the EMODNET[8] data portal.
- Adopt a holistic view of the ES provision chain focusing on the intermediate steps (from the ES to the benefit). In particular, the valuation of regulating services and the ecological processes supporting provisioning and cultural services should be reinforced.
- Communicate the uncertainties in MCES maps. Explain how much of the spatial detail shown on maps is reliable. Recommend for which purpose the maps can – and cannot – be used.

Further reading

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[8] http://www.emodnet-biology.eu/

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