Marine Policy 98 (2018) 1–10

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Human activities and resultant pressures on key European marine habitats: An analysis of mapped resources

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ARTICLE INFO

Keywords:
Mapping
Ecosystem restoration
Marine spatial planning
Conservation

ABSTRACT

Human activities exert a wide range of pressures on marine ecosystems, often resulting in the loss of species and degradation of habitats. If effective policies and management practices to restore past damage and reduce future impacts to the marine environment are to be developed, knowledge of the extent, duration and severity of activities and pressures is essential, yet often lacking. As part of the EU H2020 project "Marine Ecosystem Restoration in Changing European Seas", this study uses an exhaustive review of published records, web resources, and grey literature to comprehensively assess the degree to which human activities and pressures are mapped within European seas. The results highlight a number of limitations and gaps, including: (a) limited geographic coverage at both the regional and sub-regional level; (b) insufficient spatial resolution and accuracy in recorded data for the planning of conservation and restoration actions; (c) a lack of access to the background data and metadata upon which maps are based, thus limiting the potential for synthesis of multiple data sources. Based on the findings, several recommendations for future marine research initiatives arise, most importantly the need for coordinated, geographically extended baseline assessments of the distribution and intensity of human activities and pressures, complying with high-level standardization regarding methodological approaches and the treatment of produced data.

1. Introduction

Human activities such as fisheries, agriculture, transport, tourism, mining and energy generation exert multiple pressures on the marine environment which contribute to ongoing habitat degradation and loss (e.g. [1,45]). In turn, such changes reduce the capacity of marine ecosystems to deliver valuable ecosystem services and increase their sensitivity to future impacts such as those associated with climate change [63]. In addition, they hamper progress towards global, regional and national efforts to conserve, restore and sustainably use the marine environment, such as UN Sustainable Development Goals, the EU Marine Strategy Framework Directive (MSFD) and Marine Biodiversity Strategy, the Maritime Spatial Planning Directive (MSPD) and the EU Blue Growth agenda [13].

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https://doi.org/10.1016/j.marpol.2018.08.038
Received 13 April 2018; Received in revised form 16 August 2018; Accepted 30 August 2018

The degree to which human activities impact the marine environment is a function of: (i) the pressures associated with an activity, e.g. the *activity* of trawling may exert the *pressure* of abrasion on the seabed, (ii) the sensitivity of a specific habitat to the above pressures, and (iii) the intensity and duration of the pressures and the spatial and temporal footprint over which they occur. Spatial maps of activities and their associated pressures are therefore essential to monitor, mitigate and reduce their impact, for example through marine spatial planning [3]. Specifically, spatial information can be used to highlight where action is needed to remove or reduce stressors [71]; forms the basis of species and habitat vulnerability assessments [48] and aids the design and spatial arrangement of marine protected areas [29].

Whilst global assessments of human impacts on marine ecosystems, such as those undertaken by Halpern et al. [33], outline broad scale patterns, the degree to which they accurately represent the magnitude and spatial distribution of human activities and pressures at regional, national and local levels depends upon the representativeness and accuracy of the underlying data. Within Europe, significant effort has been expended documenting, categorising and mapping human activities and their associated impacts [14,44,53], for example, through the MSFD [19,50] and outputs from multiple EU projects and academic research. Despite significant progress, data gaps persist, along with a poor understanding of the temporal and spatial dimensions of activities and pressures [16,44,46]. Nevertheless, whilst such limitations and biases are known to exist, the extent of these gaps and the degree to which they are spatially or temporally biased remains unclear. With this in mind, the aim of this paper is to produce, for the first time, an inventory of available spatial information relating to human activities and pressures within European regional seas in order to identify limitations and gaps in knowledge and drive future research efforts and data collection where it is most needed.

2. Methodology

2.1. Activities and pressures of interest

Activities and pressures were defined as follows: *activity* - a human action or endeavour that has the potential to create pressures on the marine environment, e.g. aquaculture or tourism [67]; *pressure* - the mechanism through which an activity has an actual (or potential) impact on the ecosystem [66]. Following Elliott [23] pressures are divided into two types: *endogenous*, i.e. those emanating from within the system and both their causes and consequences can be managed (e.g. abrasion on the seabed caused by trawling activities) and *exogenous*, i.e. those emanating from outside the system and only their consequences can be managed locally (e.g. a change in seabed morphology from tectonic events).

In total thirteen activities, as well as twenty-six endogenous and seven exogenous pressures were considered (Table 1), based on those defined in the MSFD and Smith et al. [68]; definitions and examples for those are provided in Table S1-Supplemetary Material.

2.2. Sourcing and inventorying information

A systematic search of resources was conducted to identify spatial information relating to activities and pressures within European regional seas (see below for a full list and relevant definitions). A standard web search was performed, supplemented with queries in two research databases (ISI Web of Science and Scopus) in order to ensure full coverage of the published evidence. Searches were targeted using keywords and keyword combinations relating to mapping of the activities and pressures considered within the area of interest (a full list of keywords used is provided in Table S2-Supplemetary Material). The first 100 results of each search, ranked by relevance, were examined for extraction of relevant information. Specific web resources of international organizations, commissions and agencies active on marine conservation (EEA, IUCN, UNEP-MAP-RAC/SPA, HELCOM, OSPAR, FAO, OCEANA, MarLIN) and European projects registered in the European Marine Spatial Planning platform (e.g. MEDTRENDS, CoCoNet, MESMA, PERSEUS, ADRIPLAN, THAL-CHOR, BALANCE) were also queried for all available material (including downloadable reports). The results of the above search were complemented by input from the MERCES consortium experts who were asked to use their expertise and regional knowledge to fill data gaps where possible. Searches extend to all records available as of the end of 2016.

For each resource identified, the following information was collected and inventoried:

1. Presence of the specific activities and pressures considered (see above for categorization).
2. The region and sub-region of spatial coverage; this includes:

- The MSFD region of the study: Baltic Sea; North-East Atlantic; Mediterranean Sea; Black Sea or Other (such as Norwegian waters, or seafloor banks in the international waters of North-East Atlantic).
- The sub-region: North-East Atlantic (Greater North Sea, including the Kattegat, and the English Channel; Celtic Seas; Bay of Biscay and the Iberian Coast), Macaronesian biogeographic region (Azores; Madeira and Canary Islands), the Mediterranean Sea (Western Mediterranean; Central Mediterranean; Adriatic; Ionian and the Aegean-Levantine Sea).

3. Particular habitat type(s) examined (see below for categorization), if applying; lacking specific indication regarding habitat, the source was characterised as 'broad-scale'.
4. The following specific features of the data presented in the maps were queried: (a) are they qualitative (i.e. presence/absence) or quantitative? (b) are they based on single or cumulative pressures? (c) are they derived from empirical studies (i.e. surveys, observations) or from modelling? (d) if modelled data, are projections contemporary, hindcast or forecast? (e) if modelled data, is uncertainty considered or not?
5. The type of information provided: map image; map viewer (interactive image on-line); GIS georeferenced file.
6. The source of information: on-line resource/website; scientific paper; report; conference proceedings; expert/unpublished.

2.3. Habitats over which activities and pressures take place

Fifteen habitats or keystone species of high ecological importance, conservation interest and/or those which are known to be particularly sensitive to human activities (e.g. EU Habitat Directive 92/43/EEC, OSPAR List of Threatened and/or Declining Species and Habitats [56], OSPAR 2008, SPA/BD Protocol Annex II list [76], as well as [63,69]) were considered, as outlined below:

Sublittoral soft-bottom:

- Seagrass beds (*Posidonia*, *Zostera*, other seagrasses)
- Other

Sublittoral hard-bottom:

- Maërl beds
- Coralligenous formations
- Gorgonian forests and sponge beds
- Macroalgal forests/beds (*Cystoseira* or other canopy-forming algae)
- Other

Deep-sea (> 200 m depth):

- Coral gardens
- Sponge aggregations