Marine Policy 53 (2015) 54–66

Contents lists available at ScienceDirect

Marine Policy

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

Adaptive management, international co-operation and planning for marine conservation hotspots in a changing climate

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ARTICLE INFO

Article history:
Received 3 July 2014
Received in revised form
18 November 2014
Accepted 18 November 2014
Available online 11 December 2014

Keywords:
Priority habitats
Climate change
Species distribution modelling
Marine spatial planning
Marine strategy framework directive
Marine Protected Area

ABSTRACT

The aim of this study is to predict changes in the distribution and extent of habitat forming species defined as "Priority Marine Habitats" (PMHs) in the North-East (NE) Atlantic under future scenarios of climate-induced environmental change. A Species Distribution Modelling method was used for each PMH to map the potential distribution of "most suitable" habitat. The area and percentage cover was calculated within each country's Exclusive Economic Zone for the baseline (2009) and the projected (2100) years. In addition, a conservation management score was calculated based on the number of PMHs that co-occur in assessment units. Overall, this study reveals the potential for movement and/or change in the extent of some PMHs across the NE Atlantic under an increased ocean temperature scenario (4 °C) by 2100. There are regional differences in the predicted changes and some countries will experience greater/different changes than others. The movement of biodiversity hotspots (where one or more PMHs occur in the same broad area) provides both opportunities and risks for conservation management that are discussed. Co-operation between neighbouring countries and marine regions will require substantial enhancement in order to provide a robust adaptive management strategy going forward.

1. Introduction

Information on the spatial distribution of species is essential for both protecting biodiversity and setting appropriate conservation priorities [1] within, for example a transboundary Marine Protected Area (MPA) network. The use of predictive Species Distribution Modelling (SDM) methods, such as Maxent [2,3] has become prominent within the scientific, policy, and public literature around the potential impacts of climate change [4]. Maxent models have been successful in addressing sensitivities to environmental change including those involving temperature [5,6]. There are, however, limitations with the use of SDMs [4] in that they should not be considered as a complete substitute to gathering primary scientific data [4]. When used in conjunction with data gathering, SDMs have the potential to highlight theoretical problems and/or help define and influence their theoretical landscape, accepting that the climate change predictions of one model over another can vary, [6]. However, despite model uncertainties at high resolution, climate related range shifts of 10s to 100s of km have already occurred [7] and are predicted to continue [8] and therefore the general implications for management are important.

The Intergovernmental Panel on Climate Change (IPCC) provides scenarios for climate change [9] with differing likelihoods, partly dependent on future carbon emissions. In a precautionary conservation management context it makes sense to consider a plausible but worst case IPCC scenario to emphasise conservation management and policy issues at regional and international scales.

Priority Marine Habitats (PMHs) are threatened and declining in the NE Atlantic and are subject to conservation management (see Section 2). Maxent has been used to predict contemporary PMH distributions in the deep sea [10] and the future UK distribution of the PMH, *Modiolus modiolus* beds [11] (Table 2).

The aim of this study is to predict climate-related changes in the distribution and extent of habitat-forming (biogenic) species that are PMHs in the NE Atlantic. Predicted changes were used to determine: (a) the extent of "conservation hotspots" (measured as PMHs co-occurring in the same broad areas) under baseline (2009) and a future scenario (increased ocean temperatures by 2100); (b) whether a movement of the PMHs may be seen between member state boundaries; (c) to understand to what extent

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http://dx.doi.org/10.1016/j.marpol.2014.11.017

modelled PMHs fall within the current MPA network and whether these MPAs accommodate a changing climate (e.g. will the MPAs still protect PMHs in the future?); and (d) what the implications of climate-related change will be for future marine conservation and management planning. This study is concerned with the high-level policy context for the PMHs created by habitat forming (biogenic) species and not small scale habitat prediction; nor habitat PMHs such as seamounts that will physically remain, irrespective of climate-induced environmental change.

2. European marine management strategies

Priority Marine Habitats (PMHs) are determined as "threatened and/or declining" under the OSPAR Convention (The Convention for the Protection of the Marine Environment of the NE Atlantic 1992) and are considered to be of greatest marine nature conservation importance within the NE Atlantic (latterly referred to as the OSPAR marine region). PMHs are used to prioritise marine biodiversity conservation and protection under Annex V of the OSPAR (Oslo-Paris) Convention 1992[1] [12].

The maintenance of PMHs will also contribute to the achievement of 'Good Environmental Status' (GES) under the European Union's (EU) Marine Strategy Framework Directive[2] (MSFD; 2008/56/EC; the environmental pillar of the Integrated European Maritime Policy [12]). Appropriate area-based management strategies, including an ecologically coherent network of well managed Marine Protected Areas (MPAs) by 2016 [13] are being considered under the MSFD with these and other habitats in mind [14]. The OSPAR Commission is the main platform through which coordination of the MSFD implementation will occur. This includes the development of regionally coordinated tools for the implementation of integrated management of human activities and ecosystems, such as Marine Spatial Planning [15], integrated coastal zone management (ICZM) and cumulative impact assessment.

Along with the adoption of the MSFD in 2008 came the introduction of a European wide integrated approach to marine environmental protection [16]. During the past decade there has been a dramatic rise in the number and size of MPAs being designated as a result of international environmental protection targets [17] and it could be argued that Europe has been the most active in establishing regional management strategies [18]. While nations are understandably concerned with their own marine environment first and foremost, some consideration of the potential future movement, expansion and contraction of habitat types and species of conservation importance (as a result of changing climatic conditions) between different Exclusive Economic Zones (EEZs) is necessary. However, implementing a network of MPAs in Europe, and all the factors that need consideration within that (including climate change), is likely to be challenging because marine conservation governance approaches are often developed at both a European and national level [19].

Integrated marine environmental protection is challenged by a number of factors. There are substantial knowledge gaps regarding the condition of the seas and the effects of anthropogenic pressures. There is also a lack of coordination between community and international measures (including the coordination between neighbouring states), and it is widely acknowledged that conservation measures are often restricted in scope, therefore granting limited environmental protection [20,21].

Collaborative management is a commonly published concept that is employed by governments and local communities to manage and protect natural resources in partnership at a national level [22,23]. In contrast, literature regarding how neighbouring nations, within Europe or globally, will manage adjoining marine areas now or in the future, particularly for those habitats and species requiring protection, is sparse. The European Commission (EC) argues that a regional approach (European within this context) to a marine environmental protection regulatory system is required given that marine ecosystems are transboundary and cannot be adequately governed, managed and protected by separate and fragmented national jurisdictions [20]. It has been acknowledged that through the implementation of the MSFD, enhanced cooperation between neighbouring states may develop [24] and that integration of a cross-sectoral policy under this Directive will strengthen marine protection [16]. It is also noted that, despite this, different approaches to marine management are being implemented by the different nations within Europe [21,24]. Some of the issues of transboundary Marine Spatial Planning (MSP) are being considered between England and Scotland through the MSP encompassing the Solway Firth [25], and between Finland and Sweden in the Bothnian Sea [26]. There are a number of challenges associated with transboundary planning, including: legal and policy frameworks, stakeholder interactions, methods of approach, agreed goals and targets and complications associated with devolved/federal nations (e.g. UK and the United States) [27,28].

The difference in marine management strategies being applied within Europe leads to a number of key questions, notably: Will these management strategies be complementary? How will PMHs that straddle Exclusive Economic Zones (EEZ: Art. 56, UN Convention on Law of the Sea) be managed? What happens if climate change leads to the movement of a PMH into an EEZ where it is currently not protected?

In 2006, the OSPAR contracting parties submitted a summary of the distribution of PMHs, within the OSPAR marine region (Table 1). The data are being continuously updated with the most recent submission in 2012. The 2012 dataset (used here) incorporates new discoveries and excludes previously erroneous submissions. The OSPAR Commission's 2012 status report [13] states that MPA networks may be designed to be resilient to a changing climate. A lack of data and shortcomings in the understanding of the potential impacts of climate change on the distribution of PMHs and their management has however, led to a requirement for the development of predictive management tools. Consideration therefore needs to be given to the potential extent of PMHs under current and future climate conditions between neighbouring countries and within the present MPA network.

3. Methods

3.1. Priority Marine Habitat occurrence datamarine habitat occurrence data

OSPAR PMHs records were extracted from the OSPAR priority habitats dataset [29]. The geographical coverage of some of the environmental data layers was limited; therefore a number of records were excluded because they did not coincide with one or more of the environmental layers. Sample sizes for each PMH are shown in Table 2. The environmental layers were chosen based on their expected relevance to benthic PMHs and if they were freely and publicly available (to demonstrate cost effectiveness and ready application).

[1] The OSPAR Convention entered into force in 1998 with the aim of providing a comprehensive and simplified approach to addressing all sources of pollution which might affect the maritime area (within the North-East Atlantic), as well as matters relating to the protection of the marine environment, including the conservation of biological diversity and sustainable use of its components.

[2] The MSFD will fulfil international commitments undertaken at the World Summit on Sustainable Development; and under the Convention on Biological Diversity and the OSPAR Convention.