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Ocean zoning for conservation, fisheries and marine renewable energy: Assessing trade-offs and co-location opportunities

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ABSTRACT

Oceans, particularly coastal areas, are getting busier and within this increasingly human-dominated seascape, marine biodiversity continues to decline. Attempts to maintain and restore marine biodiversity are becoming more spatial, principally through the designation of marine protected areas (MPAs). MPAs compete for space with other uses, and the emergence of new industries, such as marine renewable energy generation, will increase competition for space. Decision makers require guidance on how to zone the ocean to conserve biodiversity, mitigate conflict and accommodate multiple uses. Here we used empirical data and freely available planning software to identified priority areas for multiple ocean zones, which incorporate goals for biodiversity conservation, two types of renewable energy, and three types of fishing. We developed an approached to evaluate trade-offs between industries and we investigated the impacts of co-locating some fishing activities within renewable energy sites. We observed non-linear trade-offs between industries. We also found that different subsectors within those industries experienced very different trade-off curves. Incorporating co-location resulted in significant reductions in cost to the fishing industry, including fisheries that were not co-located. Co-location also altered the optimal location of renewable energy zones with planning solutions. Our findings have broad implications for ocean zoning and marine spatial planning. In particular, they highlight the need to include industry subsectors when assessing trade-offs and they stress the importance of considering co-location opportunities from the outset. Our research reinforces the need for multi-industry ocean-zoning and demonstrates how it can be undertaken within the framework of strategic conservation planning.

1. Introduction

Unsustainable use of the marine environment has led to rapid declines in biodiversity (Airoldi and Beck, 2007; Sala and Knowlton, 2006; Worm et al., 2006). Efforts to restore and maintain marine biodiversity are focused increasingly on spatial approaches; over the past two decades there has been a surge of mandates for the establishment of marine protected areas (MPAs) and MPA designation rates have increased rapidly (Pita et al., 2011). MPAs are designated for a variety of reasons, including biodiversity conservation (Agardy, 1999; Jones, 1995) and fisheries management (DEFRA, 2005; Gell and Roberts, 2003; Halpern et al., 2010). There are many types of MPAs and the level of protection varies, from highly protected marine reserves to areas where all activities are accommodated at managed levels. Fishing is the most common activity restricted or excluded from MPAs, creating conflict between the conservation and fishing communities. Consequently, most MPA planning processes seek to minimize this conflict (e.g. Gleason et al. (2010), Yates and Schoeman (2014)). However, as oceans get busier and new industries emerge, both conservation and fisheries will face growing competition for space, and marine planners will have to deal with a wider range of spatial conflicts.

Ocean zoning, a component of marine spatial planning, has been proposed to accommodate multiple conflicting and compatible uses of the ocean (Crowder et al., 2006). Ocean zoning is the process

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of dividing a marine region into zones and within those zones, regulating uses to achieve specific purposes (Courtney and Wiggin, 2002). General frameworks and guides for ocean zoning exist, and are typically part of broader marine spatial planning guidelines (Agardy, 2010; Day, 2002; Ehler and Dourvere, 2009; Foley et al., 2010; Halpern et al., 2008). As part of these, spatial analyses must be conducted to identify priority areas for the multiple zones – but how? A range of spatial prioritization approaches has been suggested; however, these approaches are of limited focus or cannot optimize benefits for a range of activities. For example, zoning approaches based on multi-criterion analysis (Bruce and Eliot, 2006; Portman, 2007; Villa et al., 2002) or trade-off analyses have been demonstrated (White et al. 2012), but ignore important principles of protected-area design (Margules and Pressey, 2000; Wilson et al., 2009). Other approaches, based on systematic conservation planning, have been applied but are focused on a narrow suite of human priorities, namely conservation and fishing (Grantham et al., 2013; Klein et al., 2010). In reality, countries need to allocate zones for a broader suite of activities.

The rapid expansion of the marine renewable energy industry, driven by nations' commitments to reducing greenhouse gas emissions, has been a catalyst for the progression of ocean zoning and marine spatial planning (Douvere and Ehler, 2009; Firestone and Kempton, 2007). The marine renewable energy industry expansion is likely not only to continue, but to accelerate. In the UK, for example, offshore wind energy capacity increased by 37% between 2010 and 2011, to 1.8 GW, and is expected to increase to 18 GW by 2020 (Hooper and Austen, 2014). Nations require systematic and transparent approaches to help make decisions about the locations of future offshore energy developments, as well as other emerging ocean uses, whilst balancing competing uses, including conservation and fishing.

Here, we build upon previous zoning approaches focused on zoning for conservation and fishing (Grantham et al., 2013; Klein et al., 2010) to also include zones for wind and tidal energy. We develop an ocean zoning approach to optimize space allocation for conservation, fishing, and offshore marine renewable energy generation, and apply it to Northern Ireland, a country that is expanding its existing MPA network and developing its renewable marine energy generation infrastructure. We identify multiple zoning configurations and evaluate the trade-offs between conservation, fishing, and renewable energy. We also evaluated the impact of co-locating fishing using static gear (pot fishing) and renewable energy on both the cost and spatial configuration of zones. Our zoning approach and trade-off analysis will help make decisions about ocean zoning more systematic, transparent, and repeatable, and can be used to identify cost effective priorities for any number of ocean uses (e.g. aquaculture, mining) around the world.

2. Materials and methods

2.1. Study area and policy context

Our study area was Northern Ireland's territorial waters, up to 12 nautical miles offshore, covering an area roughly 4600 km^2. Within these waters, the three main fisheries are *Nephrops* (trawl), scallops (dredge) and pot fishing (creels, mainly for lobsters and crabs). There are currently no offshore wind farms in place or under development, and there is one experimental tidal energy turbine, in Strangford Lough. There are six existing MPAs (see Supplementary Fig. S1), designated, among other classifications, as Special Areas of Conservation under European Legislation (EC, 2007).

Northern Ireland marine management is governed by a complex hierarchy of legislation and policy, including: International conventions, European directives, National UK legislation, and local Northern Ireland specific legislation (Yates et al., 2013). Recent legislative and policy developments have placed an increased emphasis on MPAs and spatial management, and the Northern Ireland is committed to expanding the existing network of MPAs to develop a more coherent, representative network (Yates et al., 2013). The main driver for expanding the existing MPA network is the need to conserve biodiversity. However, there is also a growing desire, both top-down, from national policy makers, and bottom-up, from local fishers, for the use of MPAs as a tool for fisheries management (Yates, 2014; DEFRA, 2005). The newly passed Northern Ireland Marine Act has provided the Assembly with the necessary powers to both expand the existing MPA network and to develop a comprehensive Marine Spatial Plan (The Northern Ireland Assembly, 2013a).

In addition to the increased demand for space for MPAs, there is also the emerging demand for space for marine renewable energy generation. The UK is committed to reducing its carbon emissions (DTI, 2007), and under the governments Renewables Obligation at least 9.7% of Northern Ireland's electricity must be generated through renewable sources (The Northern Ireland Assembly, 2009, 2013b). This percentage is anticipated to rise steeply each year until the UK Government's target, 20% by 2020, is met. In Northern Ireland much of the focus is on developing tidal energy and offshore wind farms. A series of potential development areas have already been identified (Supplementary materials S1) by the Northern Ireland Department of Enterprise, Trade and Investment in their regional locational guidance (DETI, 2011).

2.2. Data

2.2.1. Biodiversity features

We targeted a total of 60 biodiversity conservation features for inclusion into MPAs under all scenarios. These consisted of 45 habitats, two foundation species, two spawning areas, five nursery grounds, and six depth zones (Supplementary materials S2). Data were provided by the Northern Ireland Department of the Environment (DOE) and the UK Joint Nature Conservation Committee (JNCC). Along with all other data in this study, biodiversity data were managed within the Geographical Information System (GIS) ArcGIS 10.0.

2.2.2. Fishing

We used fisheries data derived from Spatial Access Priority Mapping (SAPM) interviews with 103 Northern Irish fishers, all of whom were vessel skippers and/or owners. Interviews were conducted in 2012 (Yates and Schoeman, 2013). Respondents mapped their priority area(s) directly into the GIS, identified which fishery each area was for and assigned relative importance to each area, such that total importance value for each respondent was 100. Respondents also provided details about their vessel, including the total number of crew. The Spatial Access Priority (SAP km^{-2}) of each area was then calculated as follows:

$$SAP_x = \frac{C_x \times I_x}{A_x} \quad (1)$$

where x is a given area mapped by a respondent. C is the number of crew on that respondent's vessel, I is the importance value assigned by the respondent for that area, and A is number of square kilometres the area covered.

Individual SAPs were multiplied by a weighting to account for differences in the proportion of respondents obtained from the various sections of the fishing community and then summed generate maps that represent the whole fleet (Equation (2)).