Ocean & Coastal Management xxx (2017) 1–14

Contents lists available at ScienceDirect

Ocean & Coastal Management

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

An assessment of the efficiency and ecological representativity of existing marine reserve networks in Wales, UK

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A R T I C L E I N F O

Article history:
Received 4 January 2017
Received in revised form
24 April 2017
Accepted 29 April 2017
Available online xxx

Keywords:
Marine management
Marine protected areas
Marxan
Opportunity costs

A B S T R A C T

Marine Protected Areas (MPA) are one of the several means of protecting ocean biodiversity and are fundamental to the Aichi Biodiversity Target 11 of 2010. However, many existing reserves are inefficient in meeting current conservation goals and are questioned regarding their habitat representivity. This paper assesses the efficiency of existing Welsh reserves in meeting conservation goals, including implications of changing objectives. Marxan conservation planning software was used to determine 20 broad-scale habitat types found in territorial seas, using data obtained from the European Environment Agency's Level 3 Predicted EUNIS Habitats GIS dataset. Results demonstrated that the current Welsh MPA network, even at the lowest conservation targets (≤10%), fails to suitably represent more than two-thirds of the broad-scale habitats found in its coastal waters. Subsequently, a range of alternative reserve design scenarios was developed to reduce inefficiency opportunity costs. Analysis indicated that an increase of less than 5% in total reserve area, plus a retention of 75% of the current network area, would create a new network to meet or exceed all stated conservation goals. Therefore, existing reserves can be incorporated into an efficient, ecologically representative network that reduces international conservation opportunity costs.

1. Introduction

Protected areas are "clearly defined geographical spaces, recognised, 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., 2015:2). The deliberations about the best design and management of protected areas in the marine environment developed in the 1970s and 1980s with the SLOSS debate (Single large or several small) and in the 1990s with the discussions over networks and systematic, integrated planning (Lieberknecht et al., 2014). The community deliberated over integrated principles of designation and management which included: adequacy, viability, connectivity, replication, representivity and discussions around ecological coherence (OSPAR, 2006; Johnson et al., 2014) and this proliferation in interest led to an associated growth in research activity (Halpern, 2008).

Oceans make up 70% or 361 million km^2 of the planet's surface area and 95% of habitable space by volume, yet this environment is poorly understood (Kunzig, 2000), with only 0.0001% of the area scientifically studied (Benn et al., 2010). Also, research revealed that the marine environment was severely degrading and had limited protection and there was a necessity for a representative network of protection (CBD, 2004; CBD, 2008). Between 1990 and 2014 global protected areas increased from 13.4 million to 32 million km^2. This growth means that 8.4% of marine areas and 3.4% of the world's oceans are now protected to some degree (Wood et al., 2008; IUCN, UNEP-WCMC, 2014; Juffe-Bignoli et al., 2014). Within the marine environment, the principal tool of this protection is the 5000 Marine Protected Areas (MPAs). However, only half form part of a coherent network and less than 10% (300,000 km^2) are marine reserves with high levels of protection (Protect Planet Ocean, 2016) and 0.08% are designated no-take zones (Wood et al., 2008). Although there is considerable debate about the form of protected areas, the trend of sustained consciousness reflects the growing political, social and economic status of the natural world (IUCN-WCPA, 2008) and this in turn fuels debate about goals, forms, and efficiency (Lieberknecht et al., 2014). Hence, the expansion of MPAs and their political status has been substantial: for example, within the USA, the National Oceanic and Atmospheric Administration (NOAA) and the National Marine Protected Areas Centre have kept

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http://dx.doi.org/10.1016/j.ocecoaman.2017.04.016
0964-5691/

an MPA inventory since 2001, and the country now has more than 1700 MPAs (Brock, 2015). Furthermore, the establishment of large MPAs, especially around overseas territories, means some countries have already achieved their international targets before 2020 (Devillers et al., 2015) which shows the amplified political importance of our seas.

Nevertheless, biodiversity has continued to deteriorate, and the ability of protected areas to stabilise biological importance varies temporally and spatially (Henson et al., 2017). A corollary to abating the effects of this paradox between continued biodiversity loss and continued growth in global protected areas is the establishment of ecologically coherent and representative protected areas with transparent monitoring systems (Jones and Carpenter, 2009; Barber et al., 2012) and efficient targeted expansion (MacKinnon et al., 2015). Furthermore, there is a need to manage the MPAs coherently, effectively and for their designation to consider representivity more clearly than measure success on growth to the area of protection (Batista and Cabral, 2016). The importance of MPAs for achieving marine conservation goals is clearly recognised (Wood et al., 2008), especially about the importance of connectivity (O'Leary et al., 2012) and the need for sound scientific data to inform management (House, and Phillips, 2012; Kirkman, 2013). The Aichi Biodiversity Target 11 states the necessity for a 10% protection of global marine/coastal environments by 2020. Furthermore, it stipulates the importance of qualitative measures and design principles such as ecological representation, equitability, connectivity, and ecosystem services, (CBD, 2004, 2011; Juffe-Bignoli et al., 2014; Hill et al., 2016). However, the principal goal of Target 11 is ecological, yet other uses are inherently of interest and are often the focus of MPA research and publications (Table 1). For example, the role of eco-tourism (Tundi, 1993; Leung et al., 2015), distribution of stakeholder benefits (Hill et al., 2016), the importance of fishery management in achieving conservation goals (McClanahan et al., 2006) and how MPAs can facilitate the marine environments resilience to climate change (Green et al., 2014). This paper focuses on how protected areas can achieve the principle of ecological representivity within confines of efficient selection and management of marine environments. In the UK these were translated to Representativeness, Replication, Viability, Precautionary design, Permanence, Connectivity, Resilience, Size and Shape (Defra, 2009).

1.1. Representivity and management

In recognition of the need to conserve biological diversity and productivity of the oceans in the face of increasing anthropogenic pressures, and in response to lessons from terrestrial protected areas, a more outcome-driven and monitoring-based approach is needed (Barber et al., 2012). MPAs have become recognised as one of a suite of tools required to meet these challenges (Beech et al., 2008; Hansen et al., 2011; Evans et al., 2015). Nonetheless, protected areas are often still not assessed for their Protected Area Management Effectiveness or the quality of governance decisions (Juffe-Bignoli et al., 2014; MacKinnon et al., 2015). Additionally, their designation and management can be based on a spectrum from ecological to socio-economic values (Ruiz-Frau et al., 2015). Also, there is a need to base management on stakeholder engagement and scientific data (McClanahan et al., 2006; Pasnin et al., 2016) in a coherent and accepted form.

A primary consideration when establishing an ecologically coherent MPA network is to include a representative selection of all habitats and species found within a given area (Margules and Pressey, 2000; Botsford et al., 2003; Pomeroy et al., 2004; Roberts et al., 2008; Fuller et al., 2010; Redmond and House, 2011; Evans et al., 2015). Recent research also emphasises the need to identify stressors within the area concerned (Mach et al., 2017; Henson et al., 2017). However, studies have shown that many reserves are often defined on an uncoordinated basis, and are therefore unlikely to include a representative selection of the range of species and habitats found in the wider environment (Kerr, 1997; Lunney et al., 1997; Margules and Pressey, 2000; Chape et al., 2005; Fuller et al., 2010; Evans et al., 2015). These shortcomings can be expressed in terms of the efficiency of reserve networks, with more inefficient reserves representing an opportunity cost, which in this case can be represented by the economic and social benefits foregone as a result of protecting a given area of habitat (Adams et al., 2010). Stewart et al. (2003) concluded that existing reserves could involve a significant opportunity cost and additional research shows the corollary between successful MPA management and financial strategies e.g. in Brazilian MPAs (Araújo and Bernard, 2016). Selection systems, management benchmarks and governance strategies are therefore necessary if MPAs are to achieve their goals efficiently (O'Leary et al., 2012; Stolton et al., 2013). Hence, it is imperative to move from a defined to a designed MPA designation.

1.2. Opportunity costs and systematic conservation planning (SCP)

Historically, MPAs have been established “rather haphazardly” (Halpern and Warner, 2003: 1871) and were often designated on simplicity of implementation rather than need (Devillers et al., 2015). They tended to be near military installations, critical infrastructure (such as undersea cables and oil rigs), dramatic natural features, or have been established for fisheries management and scientific research (Ballantine and Gordon, 1979; Oldfield et al., 2004). Ecological principles played a minor (or sometimes non-existent) role in the establishment of marine reserves and the majority were based on political (Roberts et al., 2003) or economic considerations (Margules and Pressey, 2000). Hence, they were in areas where the opportunity costs of conservation were limited (Cowling and Pressey, 2003).

The first quantitative global ecological based targets for MPAs were established in 2003 and yet 95% of the world's MPAs in 2006 were already in existence (Wood et al., 2008). Hence, a significant proportion of the world's first generation marine reserves were selected without considering many of the principles of reserve design and in particular SCP tools (Table 2). Since these first generation reserves, a structured, systematic approach to conservation planning has become a standard framework that should be employed to implement coherent MPA networks.

SCP was introduced to the field of marine conservation by Margules and Pressey (2000) who identified that early

Table 1
Qualitative characteristics of Aichi Target 11 (Adapted from Hill et al., 2016).

Qualitative Measures	Characteristics
Representivity	Ecological processes Identification of areas biodiversity and community status
Equity	Local social demographic Local policy framework Engagement with local populations Engagement with and between stakeholders
Connectivity	MPA networks and corridors for gene flow Local and traditional ecological knowledge and management
Ecosystem services	Food security Fisheries Tourism Aesthetics Cultural value systems Resilience to impacts of climate change

Please cite this article in press as: House, C., et al., An assessment of the efficiency and ecological representativity of existing marine reserve networks in Wales, UK, Ocean & Coastal Management (2017), http://dx.doi.org/10.1016/j.ocecoaman.2017.04.016