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Social and ecological effectiveness of large marine protected areas

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ABSTRACT

Large marine protected areas are increasingly being established to meet global conservation targets and promote sustainable use of resources. Although the factors affecting the performance of small-scale marine protected areas are relatively well studied, there is no such body of knowledge for large marine protected areas. We conducted a global meta-analysis to systematically investigate social, ecological, and governance characteristics of successful large marine protected areas with respect to several social and ecological outcomes. We included all large (>10,000 km^2), implemented (>5 years of active management) marine protected areas that had sufficient data for analysis, for a total of twelve cases. We used the Social-Ecological Systems Meta-Analysis Database, and a consistent protocol for using secondary data and key informant interviews, to code proxies for fisheries, ecosystem health, and the wellbeing of user groups (mainly fishers). We tested four sets of hypotheses derived from the literature on small-scale marine protected areas and common-pool resources: (i) the attributes of species and ecosystems to be managed in the marine protected area, (ii) adherence to principles for designing small-scale marine protected areas, (iii) adherence to the design principles for common-pool resource management, and (iv) stakeholder participation. We found varying levels of support for these hypotheses. Improved fisheries were associated with older marine protected areas, and higher levels of enforcement. Declining fisheries were associated with several ecological and economic factors, including low productivity, high mobility, and high market value. High levels of participation were correlated with improvements in wellbeing and ecosystem health trends. Overall, this study constitutes an important first step in identifying factors affecting social wellbeing and ecological performance of large marine protected areas.

1. Introduction

Global concerns about declines in marine biodiversity (Cheung et al., 2009) have led to increasing commitments to establish marine protected areas (MPAs) (Convention on Biological Diversity, 2010). Marine protected areas – "a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Day et al., 2012) – have been used as a resource and biodiversity conservation tool for centuries (Johannes, 2002). Although most MPAs are relatively small in size (median size 3.3 km^2; Boonzaier and Pauly, 2016), recent years have seen an increase in the designation of very large MPAs (Boonzaier and Pauly, 2016).

Large MPAs (LMPAs, also referred to as large-scale MPAs), some of which exceed one million km^2, have become a high profile marine conservation strategy that have moved us closer to achieving international biodiversity targets (e.g., Aichi Target 11; Boonzaier and Pauly, 2016). LMPAs differ from small MPAs because

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they encompass more extensive areas, including biologically connected ecosystems, and a greater diversity of habitats, including pelagic and deep benthic areas (Wagner et al., 2013), as well as different human dimensions, that may include a greater number or diversity of human populations (Gruby et al., 2016). Thus, LMPAs have unique management requirements and challenges, including education and enforcement over vast areas, and management of dynamic seascapes (Maxwell et al., 2014). The primary objective of LMPAs is biodiversity conservation (Day et al., 2012), although this is often expanded to include other factors such as improvement or maintenance of fisheries and social wellbeing (Wilhelm et al., 2014). Diversity of objectives leads to LMPAs taking a variety of forms (e.g., no-take, multi-use, etc.) and thus encompassing complex social-ecological interactions, which means the evaluation of both social and ecological outcomes is important (Agrawal and Benson, 2011; Ferraro and Hanauer, 2015).

From the ecological perspective, LMPAs are considered critical because they encompass entire ecosystems, enable synergistic links to adjacent ecosystems (Toonen et al., 2011; Sheppard et al., 2012), and may be more resilient to large-scale disturbances (McLeod et al., 2009; Toonen et al., 2013). Furthermore, they are thought to provide benefits to wide-ranging species, such as seabirds and tunas (Maxwell and Morgan 2013; Young et al., 2015), and also have less negative social impacts through better accommodation of multiple uses (Balmford et al., 2004). However, it is important to note that some argue LMPAs are largely used as a vehicle for meeting global marine conservation targets (e.g., Aichi Target 11), and as such contribute more to achieving political goals rather than strengthening biodiversity conservation (Devillers et al., 2015). Nonetheless, the further increase in the number and total size of LMPAs (Boonzaier and Pauly, 2016; S1) will undoubtedly continue in the near future.

Given this reality, empirical investigations of LMPA effectiveness are urgently needed to validate the development and maintenance of such areas. More specifically, understanding the social, ecological, and governance mechanisms that contribute to a range of conservation outcomes – including improved ecosystem health, fisheries, and social wellbeing – would help improve management of existing LMPAs and inform the establishment of others (Gruby et al., 2016).

Our aim is to assess the social and ecological performance of LMPAs through the lens of four thematic hypotheses, based on their origin in the literature: 1) Ecological and economic attributes of the species or ecosystem; 2) Attributes of the MPA; 3) Institutional design principles; and 4) Participation (S2). We evaluated factors from these thematic hypotheses against three outcomes: trends in ecosystem health, fisheries, and social wellbeing. Our study is the first to empirically examine multiple outcomes in LMPAs, and provides insights that can help guide management of current and future LMPAs.

1.1. Hypotheses framing

Given the paucity of data and information on LMPAs in the literature, we approached framing hypotheses based upon a review of recent findings regarding the management of marine resources (Claudet et al., 2010; Cinner et al., 2013), the design and management of small-scale MPAs (Edgar et al., 2014), and the management of common-pool resource at large spatial scales (Fleischman et al., 2014; Cox et al., 2016). Whereas the first two sets of hypotheses – ecological and economic attributes of species or ecosystems, and attributes of the MPA – are salient because of similarities in the biophysical context (i.e., marine environments); institutional design principles were included as hypotheses because of similarities in the spatial scale of analysis (i.e. large, >10,000 km^2). Finally, a fourth set of hypotheses investigates multiple measures of participation because of its particular importance for helping groups to achieve long-term sustainable governance that balances conservation with livelihoods (Persha et al., 2011; Bennett and Dearden, 2014).

Thematic hypothesis I: Ecological and economic attributes of the species or ecosystem. Recent studies highlight the importance of the ecological and economic attributes of species and ecosystems being managed: systems or species that are more productive, resilient, less mobile, sheltered from major markets, and have lower market value are more likely to exhibit positive responses to protection (Claudet et al., 2010; Collette et al., 2011a). Therefore, we hypothesized that if the species and ecosystems within LMPAs have high productivity, high ecological resilience and low mobility, in addition to a lower market value, and greater distance to market, they would be more likely to be correlated to improved ecosystem health and fisheries trends.

Thematic hypothesis II: Attributes of the MPA. A recent study found that certain attributes of MPAs have a disproportional effect on ecological outcomes. In a review of 87 MPAs worldwide, Edgar et al. (2014) found that MPAs that include no-take areas, are well-enforced, old (>10 years), large (>100 km^2), and isolated are more likely to be ecologically effective (i.e. as measured through higher fish biomass). In addition, a growing body of research and guidance on MPA design argues that MPAs or MPA networks that are explicitly designed to be comprehensive, adequate, and representative are more likely to be ecologically effective (Margules and Pressey, 2000). We hypothesized that MPAs that are older, have a larger spatial extent, larger proportion of no-take areas, more isolation, high levels of compliance and enforcement, in addition to explicit inclusion of MPA design criteria (comprehensive, adequate, representative) in MPA selection and zoning will be more likely to have improved trends in fisheries and ecosystem health.

Thematic hypothesis III: Institutional design principles. The literature on common pool resources provides insights on several institutional factors collectively known as the "institutional design principles" (Ostrom 1990; Cox et al., 2010) that could affect the performance of MPAs. This literature suggests that the persistence of governance arrangements – and hence resource sustainability – is more likely in the presence of one or more of a number of facilitating conditions, including: clearly defined boundaries of the resource (e.g., the MPA, and resources within it) and the actors eligible to extract resources therein; the fit between rules and the attributes of the problems they are meant to address; monitoring of users and ecological conditions; sanctioning of rule-breakers; conflict resolution mechanisms; and coordination among jurisdictions for larger systems (Ostrom 1990; Cox et al., 2010). We hypothesized that presence of the institutional design principles would lead to improved fisheries, ecosystem health, and social wellbeing.

Thematic hypothesis IV: Participation. Stakeholder participation is widely considered essential for effective management of natural resources (Ostrom, 1990; McCay and Jentoft, 1996; Berkes, 2009). Although participation of stakeholders in rule-making is considered one of the institutional design principles outlined in the previous thematic hypothesis, it has multiple aspects not explored in the design principles that are potentially relevant for LMPAs. In the context of MPAs and fisheries, direct and active involvement of fishers in the decision making process often enhances their willingness to negotiate agreements and