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On the ecological relevance of landscape mapping and its application in the spatial planning of very large marine protected areas

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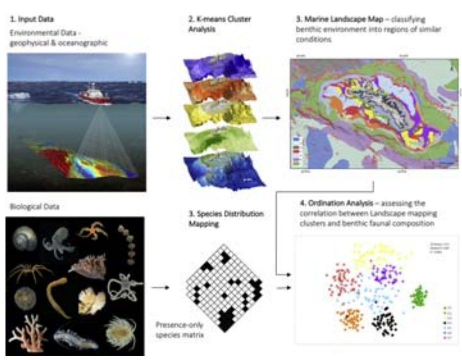
HIGHLIGHTS

- Broad-scale landscape maps correlate with sub-Antarctic benthic faunal composition.
- Landscape maps effective in ensuring representative protection in MPA design.
- Analysis highlights challenges associated with analysing large historical datasets.
- Functional trait analysis effective in an environment dominated by rare species.

GRAPHICAL ABSTRACT



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ABSTRACT

In recent years very large marine protected areas (VLMPAs) have become the dominant form of spatial protection in the marine environment. Whilst seen as a holistic and geopolitically achievable approach to conservation, there is currently a mismatch between the size of VLMPAs, and the data available to underpin their establishment and inform on their management. Habitat mapping has increasingly been adopted as a means of addressing paucity in biological data, through use of environmental proxies to estimate species and community distribution. Small-scale studies have demonstrated environmental-biological links in marine systems. Such links, however, are rarely demonstrated across larger spatial scales in the benthic environment. As such, the utility of habitat mapping as an effective approach to the ecosystem-based management of VLMPAs remains, thus far, largely undetermined.

The aim of this study was to assess the ecological relevance of broadscale landscape mapping. Specifically we test the relationship between broad-scale marine landscapes and the structure of their benthic faunal communities. We focussed our work at the sub-Antarctic island of South Georgia, site of one of the largest MPAs in the world. We demonstrate a statistically significant relationship between environmentally derived landscape mapping clusters, and the composition of presence-only species data from the region. To demonstrate this relationship required specific re-sampling of historical species occurrence data to balance biological rarity, biological cosmopolitism, range-restricted sampling and fine-scale heterogeneity between sampling stations. The relationship reveals a distinct biological signature in the faunal composition of individual landscapes, attributing ecological relevance to South Georgia's environmentally derived marine landscape map. We argue therefore, that landscape mapping represents an effective framework for ensuring representative protection of habitats in management

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plans. Such scientific underpinning of marine spatial planning is critical in balancing the needs of multiple stakeholders whilst maximising conservation payoff.

1. Introduction

Currently, there is a disconnect between a global trend towards the establishment of very large-scale marine protected areas (VLMPAs), and the data available to underpin their establishment and inform on their zonation. Biological sampling, especially in isolated locations, is logistically difficult, time consuming and prohibitively expensive to conduct over large spatial scales. As such, large-scale spatial protection inevitably equates to paucity in biological sampling at a scale relevant to management (Lecours et al., 2015; McHenry et al., 2017). Nonetheless, within international frameworks such as the Convention of Biological Diversity (CBD) (Secretariat of the CBD, 2010), over the past decade VLMPAs (here defined as reserves > 100,000 km^2 in area) have increasingly been adopted as a holistic and geopolitically achievable approach to conservation of the marine environment. Through initiatives such as the Big Ocean Network (Wilhelm et al., 2011), the proportion of the World's oceans afforded protection has increased to 3.27% (Boonzaier and Pauly, 2016). This increase has overwhelmingly been met by VLMPAs (Fig. 1). Taking the UK as an example, 22% of its territorial waters are afforded some form of marine protection. Excluding VLMPAs from this analysis, however, reduces that figure to <1% (Shugart-Schmidt et al., 2015). Recent estimates suggest that the wide-scale adoption of VLMPAs globally has expedited international compliance with the CBD's Aichi target of 10% protection, by thirty years, bringing it forward from 2055 to 2025 (Toonen et al., 2013).

Advocates of VLMPAs highlight the holistic, entire-ecosystem level protection they offer (Sheppard et al., 2012), maintaining connectivity to adjacent ecosystems (Toonen et al., 2011), ensuring protection of ecosystem services (Toonen et al., 2013) and greater resilience to environmental change in the marine environment (Micheli et al., 2012; Roberts et al., 2017; Toonen et al., 2013). They are seen as better able to protect mobile habitats such as upwelling zones (Toonen et al., 2013), and as particularly beneficial to highly mobile species, mega fauna and species which are migratory or transitory through regions (Fox et al., 2012; Lester et al., 2009; Maxwell and Morgan, 2013). Furthermore, VLMPAs are demonstrably more cost-effective than multiple smaller reserves (McCrea-Strub et al., 2011), offering policy makers and advocates such as NGOs, the high-profile benefits of safeguarding large areas of pristine environment in a politically expedient manner. The protection of 10% of the world's oceans, and notably the majority use of VLMPAs, as an effective target by which to measure the success of global marine conservation is however open for debate (see Agardy et al., 2016; Leenhardt et al., 2013; Jones and De Santo, 2016; Wilhelm et al., 2014). A key criticism is that the target-driven nature of VLMPA protection prioritises quantity over the representativeness of the habitats it protects or the effectiveness of that protection (Leenhardt et al., 2013; Jones and De Santo, 2016).

Representative protection of marine realms is a key requirement of CBD Aichi goals (Secretariat of the CBD, 2010). Consequently, protection of a representative range of habitats is often central to MPA design, notably when an MPA is designed in a multi-use or zoned way, such as with the inclusion of demersal fisheries in certain areas at South Georgia and South Sandwich Islands MPA (Rogers et al., 2015). Many MPAs, however don't assess the physical habitat types within their protective sphere. Those that do, often don't take the next step of establishing a link between these environmental classifications and the biological communities which inhabit them (often the key attribute of the environment the MPA serves to protect). A key reason for this is often paucity in regional biological datasets at a scale relevant to management (Lecours et al., 2015; McHenry et al., 2017).

Increasingly VLMPA placement has demonstrated strong bias towards very remote overseas territories (Devillers et al., 2015), most notably waters within national jurisdictions of the USA, UK and France. Such regions typically exhibit minimal stakeholder activity and/or local populations with limited powers of recourse, resulting in fast implementation of marine protection. As these more easily implemented MPAs are fulfilled however, future designations will have to target less remote - more populated regions of the world. Such regions are more likely to be in more contentious national waters, and thus subject to ongoing commercial exploitation. As such, future designations will become progressively more challenging, and so too our ability to fulfil the Aichi targets. Already this has led to the development of more politically complex VLMPAs that transcend national jurisdictions (BALANCE, 2008; Notarbartolo di Sciara et al., 2008; PAME, 2015), transnational cooperative frameworks (Jeftic et al., 2011), and high-seas MPAs in areas beyond national jurisdictions (ABNJs), such as South Orkney Islands (2009), Charlie-Gibbs (2010) and Ross Sea (2016). It may also lead to proposals for future MPAs undergoing increased negotiation and compromise in order to finalise such potentially politically-complex protection. In such cases there would be an increased likelihood of spatial and

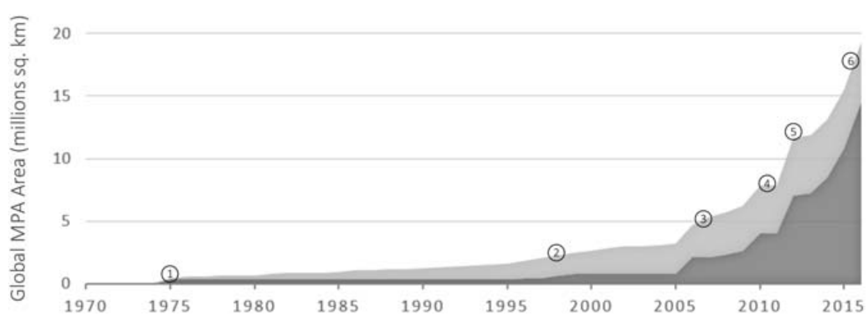

Fig. 1. Change in global MPA coverage between 1970 and 2016. Total MPA coverage is symbolised in light grey, with the proportion of that coverage attributed to large-scale MPAs (> 100,000 km^2) symbolised in dark grey. Data adapted from MPAtlas online portal (http://www.mpatlas.org/; date of access: 25/05/2017) and includes all IUCN levels of protection (Categories Ia to VI), but excludes taxa-specific exclusion zones (e.g. shark sanctuaries). Analysis includes formal commitments for recent MPAs. Circled numbers indicate the establishment of key large-scale MPAs: 1. Great Barrier Reef marine park (Australia); 2. Galapagos Marine Reserve (Ecuador); 3. Papahānaumokuākea Marine National Monuments Park (USA); 4. Chagos (UK) and Charlie Gibbs North High Seas MPA (International); 5. South Georgia & South Sandwich Islands (UK) and Coral Sea (Australia); 6. Pitcairn Islands (UK), Ascension Island (UK), Palau National Marine Sanctuary (Palau), Naza-Desventuradas (Chile), Ross Sea (International) and the extension on Papahānaumokuākea Marine National Monuments Park (USA). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)