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Integrating distribution models and habitat classification maps into marine protected area planning

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A B S T R A C T

Effective conservation planning requires biotic data across an entire region. In data-poor ecosystems conservation planning is informed by using environmental surrogates (*e.g.* temperature) predominantly in two ways: to develop habitat classification schemes (1) or develop species distribution models (2). We test the utility of both approaches for conservation planning of marine ecosystems, and rank environmental surrogates, such as depth and distance from shore, according to their power to predict the distribution and abundance of biotic species. Specifically, we compared a habitat classification scheme; based on coarse levels of habitat types derived from depth and distance from shore; against species distribution models, which predict fish abundance and prevalence as a function of environmental surrogates (depth, distance from shore, latitude, reef area, zoning, and several metrics of habitat structural complexity). We consistently set conservation target levels to 21% of each conservation feature, following global standards and a sensitivity analyses. Thus when running scenarios to protect fish species we aimed to protect at least 21% of each species, and when running scenarios of habitat classes, we aimed to protect at least 21% of each habitat class. We found that when aiming to protect 21% of the chosen conservation targets, distribution models protected 21% of the predicted abundance/occurrence of all modelled species and functional groups, but did not protect most habitats. Contrastingly, using a habitat classification scheme protected 21% of all habitat types and 34% of all species and functional groups, but required protecting three times more area. Thus, using only distribution models as targets in data-poor ecosystems could be a risky conservation planning strategy. Ultimately the best conservation outcomes were achieved by incorporating local knowledge to synthesize the conservation outcomes of both scenarios.

1. Introduction

Systematic conservation planning approaches, such as Marxan (Watts and Possingham, 2013), have been used extensively as a decision support tool for spatial planning over the past 30 years to improve conservation benefits and outcomes (see full explanation of systematic conservation approaches in Margules and Pressey, 2000; Pressey and Cowling, 2001) and inform adaptive management (McCook et al., 2010; Levin et al., 2013). Modern conservation planning uses systematic approaches to increase the probability of achieving conservation objectives; which improve integration of biotic, social and environmental data (Groves and Game, 2016), especially compared to *ad-hoc* or even "expert" selection approaches (Cowling et al., 2003; Stewart et al., 2003; Leslie, 2005). Spatial systematic conservation planning approaches objectively select areas most likely to maximise representation of conservation features (*e.g.* biodiversity), avoiding biases where datasets and areas are large (Margules and Pressey, 2000; Ferrier, 2002; Sarker et al., 2006). Additionally, systematic conservation planning can

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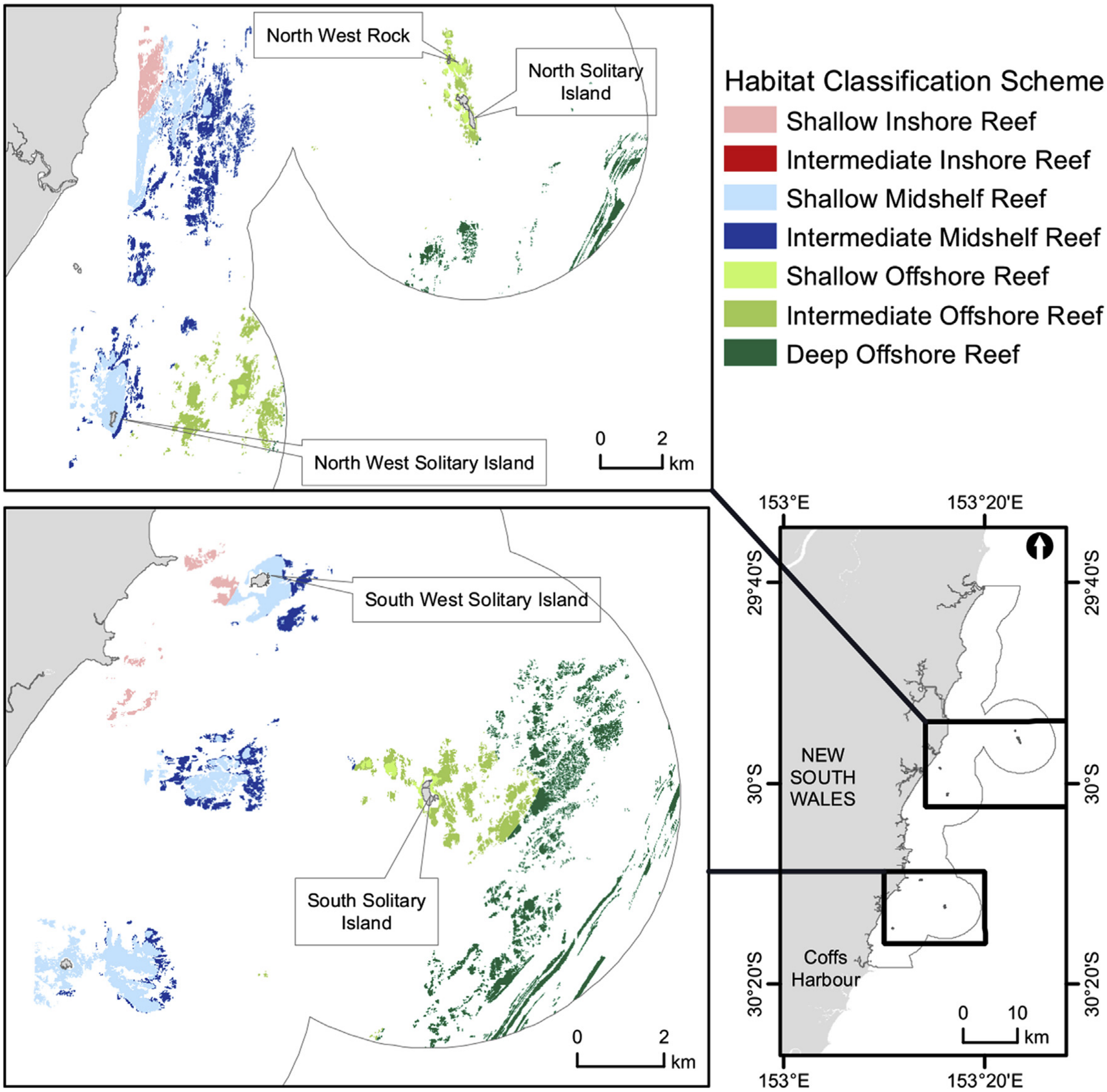

Fig. 1. Map of the study area with the Habitat Classification Scheme (HCS) highlighted in colour. The grey line denotes the marine park boundary. Islands were clipped-out for the Marxan analyses. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

be used to maximise conservation benefits whist reducing socio-economic opportunity costs, such as restricting areas from fisheries (Klein et al. 2008a,b).

Although lagging behind terrestrial conservation efforts, systematic conservation planning approaches have increasingly been used in planning Marine Protected Areas (MPAs) over the past 15 years (Leslie et al., 2003; Fernandes et al., 2005; Cook and Auster, 2006; Klein et al., 2015). However, there are strong constraints (*e.g.* restricted time underwater, difficulty for remote sensing methods to penetrate the water surface, depth limits in SCUBA diving restrict most studies to shallow reefs)associated with obtaining biological information at scales suitable for undertaking systematic planning in the marine environment (Stevens and Connolly, 2004). Systematic planning is most effective when data are available across the entire planning area, which often does not exist in marine ecosystems (Ban, 2009; Elith and Leathwick, 2009). This can constrain effective systematic conservation planning due to missing data within the majority of the planning area. For instance, where there are few spatial data points, an algorithm will select those planning units where data is available, potentially misrepresenting planning units without data. Where biotic data are sparsely available their spatial distributions can be inferred by establishing their relationship with environmental data (Stevens and Connolly, 2004; Johnston et al., 2015). This includes the use of habitat classification schemes where environmental surrogates, such as temperature or depth, represent biotic patterns (Sarker et al., 2005; Moore et al., 2011) and modelling approaches that enable spatial predictions of individual species distributions based on their relationships with environmental variables (Guisan et al., 2013).

The differential effort required to develop robust classification schemes and distribution models has led to many studies comparing these approaches for systematic conservation planning. In terrestrial ecosystems, distribution models can improve conservation planning outcomes compared to classification schemes (Guisan et al., 2013). Yet, developing robust distribution models that are adequate for conservation planning requires statistical expertise that may not always be accessible to managers (Elith and Graham, 2009). Designing classification schemes that represent biotic distributions is more feasible because certain environmental surrogates, such as depth, are strongly related to biotic communities (Malcolm et al., 2011). Evidence supporting the use of distribution models in marine conservation planning is lacking (Ballantine and Langlois, 2008; Klein et al., 2015) and classification schemes have been more readily applied (Barrett et al., 2003; Jordan et al., 2005; Malcolm et al., 2011). Consequently, there are limited guidelines for integrating the results of multiple conservation scenarios