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Original Research Article

Integrated conservation planning for coral reefs: Designing conservation zones for multiple conservation objectives in spatial prioritisation

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ABSTRACT

Decision-makers focus on representing biodiversity pattern, maintaining connectivity, and strengthening resilience to global warming when designing marine protected area (MPA) systems, especially in coral reef ecosystems. The achievement of these broad conservation objectives will likely require large areas, and stretch limited funds for MPA implementation. We undertook a spatial prioritisation of Brazilian coral reefs that considered two types of conservation zones (i.e. no-take and multiple use areas) and integrated multiple conservation objectives into MPA planning, while assessing the potential impact of different sets of objectives on implementation costs. We devised objectives for biodiversity, connectivity, and resilience to global warming, determined the extent to which existing MPAs achieved them, and designed complementary zoning to achieve all objectives combined in expanded MPA systems. In doing so, we explored interactions between different sets of objectives, determined whether refinements to the existing spatial arrangement of MPAs were necessary, and tested the utility of existing MPAs by comparing their cost effectiveness with an MPA system designed from scratch. We found that MPAs in Brazil protect some aspects of coral reef biodiversity pattern (e.g. threatened fauna and ecosystem types) more effectively than connectivity or resilience to global warming. Expanding the existing MPA system was as cost-effective as designing one from scratch only when multiple objectives were considered and management costs were accounted for. Our approach provides a comprehensive assessment of the benefits of integrating multiple objectives in the initial stages of conservation planning, and yields insights for planners of MPAs tackling multiple objectives in other regions.

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1. Introduction

Marine protected areas (MPAs) are increasingly viewed as an important spatial management tool within a suite of policy alternatives to address rapid declines in coral reef biodiversity (Mumby and Steneck, 2008). Where properly implemented, MPAs have proven to be effective tools for reef conservation, with documented empirical evidence of their benefits (Mumby and Harborne, 2010; Harrison et al., 2012; Olds et al., 2013). However, uncertainty remains over strategies to optimise MPA spatial design for conserving biodiversity in the long term and maintaining wider ecosystem functions (McCook et al., 2010). There is also an increasing recognition that many MPAs are ineffective at addressing a diverse set of conservation objectives (Watson et al., 2014). Optimising the diverse roles expected from MPAs and their effective implementation is therefore a current central concern of conservation planning.

Quantitative conservation objectives (sometimes referred as targets in the conservation literature) are the foundation for conservation planning (Game et al., 2013), and their formulation is a key step in applying scientific insights to achieve desired MPA outcomes (Pressey et al., 2015). The formulation of objectives can accommodate representation of biodiversity patterns (e.g. ecosystem types), while also addressing ecological and threatening processes related to the long-term maintenance of biodiversity, such as larval connectivity and global warming (Pressey et al., 2007). Despite processes being increasingly incorporated into decision-making strategies in recent years (Magris et al., 2014), most marine planning exercises typically develop objectives that represent only static elements of biodiversity (e.g. Green et al., 2009; Tulloch et al., 2013). However, representation objectives for biodiversity alone are probably insufficient to guarantee biodiversity persistence if an MPA system is composed of widely spaced, separate MPAs in which the maintenance of viable populations is limited by lack of connectivity. Similarly, conservation objectives that do not account for projected sea-surface temperatures might not support coral reef species in adapting to rapid global warming. Clearly, improving MPA design for persistence, complementing the longstanding focus on biodiversity representation, is essential to ensure adequate protection of coral reef systems over the next century.

In this study, we seek to address two influences on biodiversity persistence, which are particularly important for fostering coral reef conservation, but not yet well developed or interpreted in conservation planning: connectivity related to larval dispersal and global warming. Several studies have proposed approaches to designing well connected MPA systems for coral reefs (e.g. McCook et al., 2009; Beger et al., 2010; Magris et al., 2015b) and to maintaining functioning of these ecosystems under global warming (e.g. Chollett et al., 2014; Makino et al., 2014; Magris et al., 2015a). However, an assessment of the synergies between potentially competing objectives requires an integrated approach that investigates whether there is spatial coincidence between areas required to protect them, and seeks to maximize this coincidence. Beyond addressing aspects of possibly conflicting objectives in conservation planning, another challenge is therefore to integrate multiple sets of objectives. This integration can result in extensive proposed MPA systems that are financially challenging to implement in a real-world context with limited conservation funding (McCarthy et al., 2012). However, MPA systems composed of a mix of management regimes (hereafter "MPA zones") could help the feasibility of integrated planning by reducing opportunity and management costs associated with no-take areas. Marine planning that accounts for variability in MPA zones to accommodate multiple sets of objectives could therefore provide planners and policy-makers with more flexibility, higher social acceptance, and a greater likelihood of implementation.

Here, we apply an MPA zoning approach to develop an integrated planning framework that links MPA design for different sets of conservation objectives to implementation costs. We address four main aims:

1. To enhance the process of framing conservation objectives for representing biodiversity pattern, maintaining connectivity, and strengthening resilience to global warming;
2. To assess the achievement of combined sets of conservation objectives by an existing system of MPAs with different zones, intended to protect Brazilian coral reefs;
3. To design an expanded MPA system that allocates multiple zones to achieve three sets of objectives simultaneously as a refinement of the existing MPAs, while also testing the extent to which planning for single sets of objectives incidentally achieves other sets not explicitly targeted;
4. To provide a method that assists planners to develop multi-objective MPA systems and demonstrate the value of developing integrated approaches from the outset of MPA planning.

We focus on coral reefs because they are ecosystems for which connectivity and resilience to global warming objectives can be defined in detail, and because of their heavy reliance on spatial management.

2. Methods

2.1. Conservation planning definitions

Conservation prioritisation involved several stages of analysis: assembling input data on biodiversity pattern, connectivity, and global warming; formulating the respective objectives; undertaking a gap analysis; and application of conservation planning software to develop scenarios. For these analyses, we resampled all features into 176 reef cells of 10 × 10 km that