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The effect of contrasting threat mitigation objectives on spatial conservation priorities

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ABSTRACT

The primary role of marine protected areas (MPAs) is marine conservation, however policy and practice around MPAs have not reflected this. The focus on cost-effectiveness by spatial conservation prioritization has led to a bias towards placing MPAs in areas that are least threatened. This study investigates how conservation priorities differ between two management strategies of either targeting or avoiding high threat areas for protection, using the case of the Sulu Sulawesi Seas in the Coral Triangle. For both strategies, the target of protecting 20% of habitat could not be achieved solely by protecting low threat areas. A high proportion of the region had large differences in conservation outcomes between the two strategies; majority of these areas were highly prioritized in the threat avoidance strategy but had low or zero importance in the threat selection strategy. Selecting for highly threatened areas required less habitat area to be protected to achieve the same conservation target and resulted in a more equitable distribution of priority sites per country and sub-region. This demonstrates the importance of deciding on the objectives of conservation and management policies up-front. The results suggest that, contrary to the common practice of avoiding threats in spatial planning, a threat selection strategy should be part of the management toolbox, particularly in transboundary planning for regions with high overall threat levels, where it may be important to achieve shared conservation targets equitably.

1. Introduction

Marine ecosystems face mounting pressures worldwide [1] and marine protected areas (MPAs) are a means to mitigate these threats to biodiversity by providing area-based protection [2]. MPA placement is often determined using marine conservation prioritization, which is a framework for objective-driven systematic planning [3]. Although MPAs are ultimately a tool to mitigate threats, the effects of opposing conservation objectives on the choice of conservation and management areas in relation to levels of threat remain largely unexplored.

Spatial conservation prioritization uses the conservation triage approach, where the aim is to maximize conservation returns at the least possible cost [4]. Opportunity cost is most commonly used, with foregone revenues typically represented by (1) uniform cost or area as a proxy for human use, (2) multiple socioeconomic costs, (3) fisheries profit per unit area, and (4) ecological impact of human activities [5]. Threats such as fishing pressure [5,6] were previously incorporated as a surrogate for opportunity costs and minimizing such opportunity costs minimizes impacts on resource users [5]. However, it leads to biases in setting up MPAs in remote areas or places that are unpromising for extractive activities [7]. As a result, the areas most exposed to threatening processes are often given the least protection [7,8].

There are two main ways of approaching threats in the context of conservation: target areas that are currently less threatened but may face increasing stresses in the future, or target threatened and often already degraded areas to increase their recovery or persistence probabilities. These can be seen as the “pre-emptive” and “fire-fighting” approaches respectively [9]. There is a strong bias towards threat-avoidance conservation strategies both in terrestrial [9,10] and marine realms [7,11]. Nine of the 10 largest MPAs in the world, which account for more than 53% of global MPA area, are largely established in remote and uninhabited places, making almost no difference to “business as usual" fishing activities [7]. Spatial planning's political pragmatism in minimizing costs to users thus risks shifting the primary objective away from biodiversity conservation [7,12].

Protection bias towards less threatened areas often results when habitats under high anthropogenic pressure are deemed to be of lower value for biodiversity and sustainable use than those

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less disturbed [6,13]. Highly threatened sites are not cost effective to protect and hence are often eliminated as candidate sites [4]. However, protection of threatened sites has ecological benefits, as habitats do not respond to threats in the same way. For example, while coral and seagrasses of the Great Barrier Reef are adversely affected by terrestrial pollutant runoff [14,15], mangrove forests are generally in good condition except where localized losses from coastal development occur [16]. In some instances, protecting areas under high threat might also allow some habitats to gain from the ecological services of adjacent protected habitats, such as water filtration from mangrove forests [17] and trophic exchange between habitats [18]. Moreover, for largely community-based MPAs, enforcement is stronger closer to inhabited coasts where poachers can be apprehended [19,20].

Protection of threatened sites also has within habitat benefits, both from direct prevention of coastal development and amelioration of other threats. Reducing fishing on coral reefs, for example, increases herbivory, which promotes coral recruitment and growth by limiting macroalgae growth [21]. This allows for faster coral reef recovery from other threats such as bleaching [22] and catastrophic flooding [23]. On the other hand, exploited and unexploited marine areas tend to be different community types [24], and there have been calls for the protection of marine wilderness areas which are generally more pristine [25].

The Sulu-Sulawesi Marine Ecoregion or SSME [26] constitutes the first priority seascape under the Coral Triangle Regional Plan of Action [27]. The ecoregion lies in the heart of the global center of tropical marine diversity [28], providing food and livelihood to about 40 million people [27]. However, it is also among the most highly threatened areas of the Coral Triangle [29]. Previous conservation planning work for the SSME adapted the key biodiversity areas (KBA) approach to identify priority conservation areas (PCAs) [30]; threats were only considered after the PCAs were identified based on biological factors [31,32]. Selected areas of SSME also underwent scoring analysis for MPA network development based on ecological criteria [33]. Specific numerical representation targets were not explicitly included.

This study aims to inform policy-makers and managers who face the challenge of needing to choose viable conservation strategies by considering multiple threats, both mitigable and non-mitigable, in the context of spatial conservation planning of the Sulu Sulawesi Seas. Within the limitations of readily accessible data, the study evaluated whether conservation targets could be achieved with Win–win areas, i.e. areas consistently prioritized regardless of threat strategy, or if planners face a trade-off where the two threat strategies prioritized vastly different areas.

2. Methods

2.1. Study region

The Sulu-Sulawesi Marine Ecoregion spans three countries: Philippines, Indonesia and Malaysia. The study area extends the SSME boundaries to include land for the consideration of mangrove forests, and the western Palawan reefs (Fig. S1). The study area was further split into six sub-regions, following The Nature Conservancy's functional seascapes of the Coral Triangle. These were delineated based on geographic integrity, connectivity, environmental factors, and shared ecological distinctiveness [34]. The study area covers 77,458 km^2 and was divided into a planning unit layer of 1 km^2 grid squares.

2.2. Datasets

The main conservation features considered were broad habitat types as surrogates for associated biodiversity. These were derived from remote sensing and included shallow and deep coral, mangroves, seaweed/seagrass, sand bottom, rocky reef and mud bottom [35]. The shallow coral reef habitat was amended with UNEP-WCMC global coral reef data [36] and supplemented seagrass data with survey information from gray and published literature [33,37–48] by creating circular patches of 100 m radius to each survey point.

The location and extent of existing MPAs was obtained from the Coral Triangle Atlas (http://ctatlas.reefbase.org, April 2013), and amended from community-based MPA data from the Philippines [49,50]. Two proposed terrestrial nature reserves overlapping with mangrove forests were also included, with the data obtained from the World Database on Protected Areas [51].

Multiple threats were represented using spatial data from the Reefs at Risk analysis on the Coral Triangle [29]. The local threats used for this study included coastal development, marine pollution, watershed pollution and overfishing and destructive fishing [29]. Integrated threats reflected the cumulative impact of these four threats by four categories following the Reefs at Risk methodology [52]: (1) low, if all single threats were low; (2) medium, if one or two single threats were medium of a single threat was high; (3) high, if there were at least three medium single threats, or medium for one threat and high for another threat, or high for two threats; (4) very high, if at least three threats were medium or higher, and high for at least one threat.

2.3. Current status

Of the six functional sub-regions, the north-east Borneo sub-region and the Palawan-Sulu Sea-north Borneo sub-region, cover more than 80% of all the habitat areas in the study area (Fig. S2) and had the largest percentage area of strictly protected habitat (Fig. S3b) and highest protection equality (Fig. S3a). The latter reflects the evenness of protection across habitat types and was calculated by reversing the Gini coefficient [53]. These two sub-regions were also the least threatened (Fig. S3d). Very high and high levels of threats impacted mud bottom, mangrove and seaweed/seagrass the most (Fig. S3e). None of the habitats attained the conservation target of 20% (Fig. S3c).

With the exception of Central Philippines and Mindanao sub-regions, protection bias was evident with a higher proportion of strictly protected habitats in areas of low threat (Fig. S3f). The same was found across habitat types (Fig. S3g), with the exception of mangroves and mud bottoms, which had the same proportion of strictly protected habitat area in all threat levels as was found throughout the study area (Fig. S3e).

2.4. Spatial planning analysis

Conservation priorities were identified using the conservation decision support tool Marxan [54]. Marxan provides multiple solutions to the objective function representing conservation goals, whilst minimizing the cost of a conservation action [55]. Overfishing is the largest threat in the study site and the biggest opportunity cost will likely be borne by fishers. To avoid using fishing as both threat and cost, threat from fishing estimated from coastal human population and distance to large populations or market centers as per Reefs at Risk data, was incorporated in the integrated threat data whilst opportunity costs of lost fisheries revenue was represented by habitat area. This study aims to include 20% of each habitat whilst minimizing this cost. This 20% target was set following the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) MPA indicator jointly decided by the six countries of the Coral Triangle [56]. To ensure that conservation priorities were spatially represented throughout our study site, a target to represent 10% of each sub-region was set.