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Evaluating the influence of candidate terrestrial protected areas on coral reef condition in Fiji

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ABSTRACT

In any given region, there are multiple options for terrestrial protected area networks that achieve goals for conservation of terrestrial biodiversity and ecosystem values. When deciding on the location of terrestrial protected areas, planners typically focus only on terrestrial conservation goals, ignoring potential linked benefits to marine ecosystems. These benefits include maintenance of downstream water quality, as forest protection can prevent changes in amount and composition of river runoff that negatively impacts coral reefs. This study aims to determine the benefit of different terrestrial reserve networks to the condition of coral reefs adjacent to the main islands of Fiji to support the work of Fiji's Protected Area Committee in expanding the national protected area estate through integrated land–sea planning. Options for terrestrial protected area networks were designed using six approaches, where the primary objective of each approach was to either achieve terrestrial conservation goals (e.g., represent 40% of each vegetation type) or maximize benefits to coral reefs by minimizing potential for land-based runoff. When achieving terrestrial conservation goals was the primary objective, the potential benefits to coral reef condition were 7.7–10.4% greater than benefits from the existing network of protected areas. When benefiting reefs was the primary objective, benefits to coral reefs were 1.1–2.8 times greater per unit area than networks designed to only achieve terrestrial conservation goals, but 31–44% of the terrestrial conservation goals were not achieved. These results are already being used by Fiji's Protected Area Committee to modify the boundaries of existing priority places to deliver outcomes that better meet terrestrial conservation goals while offering greater benefits to coral reef condition through prevention of run-off.

1. Introduction

Protected areas are fundamental to any conservation plan as they are one of the most effective ways at mitigating threats to species and habitats. A common goal when deciding on the location of terrestrial protected areas is to adequately represent each type of habitat or vegetation community [1]. Rarely are terrestrial protected areas placed to benefit marine ecosystems [2].

Activities on the land can influence marine ecosystems through changes in land-based runoff. The impact of these activities can vary across space depending on their intensity, geology (e.g., soil type), and geography (e.g., steepness of landscape). As a result, the protection of different places on the land will have differential impacts on marine ecosystems. For example, a recent analysis in Fiji found that potential benefits to coral reef condition are highly variable, depending on where forest is protected [3]. Consideration of the impacts of terrestrial activities, including protected area establishment, is important for the protection of marine biodiversity. In some cases, marine conservation efforts have little conservation benefit unless the adjacent land is also managed for conservation [4,6].

To maximize biodiversity benefits, planning for both the land and sea should be integrated. However, integrated land–sea planning is the exception in most places as governance of marine and terrestrial areas are usually done separately [2,7]. In Fiji, however, a national Protected Area Committee (henceforth 'Committee') was established to make decisions about what and where to protect to achieve the Government's goal of protecting 30% of its inshore waters and 20% of its land by 2020 [8]. Although this does not guarantee integrated planning, the Committee is composed of government and non-government representatives from terrestrial and marine sectors and is interested in ways that they can make decisions with both the land and sea in mind.

Fiji's existing terrestrial protected areas have been established on an ad hoc basis without particular attention to biodiversity

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values [8]. Although there is consensus that the network needs to be significantly expanded, final decisions about the location of terrestrial protected areas in Fiji have not been made, despite extensive discussions about conservation goals and priority sites. The Committee has expressed interest in designing a network that achieves terrestrial targets while maximizing benefits to downstream marine ecosystems, but an evaluation of feasible terrestrial protected area networks has not been conducted to assess this goal (S. Jupiter, personal communication). Such an assessment is urgently needed to help inform decisions about the location of marine and terrestrial protected areas in Fiji.

Here, terrestrial protected area networks were designed using six different approaches and it was determined how much each network (Table 1), if implemented, would contribute towards maintaining coral reef condition and represent terrestrial vegetation communities. Systematic conservation planning was used to design four networks that achieve terrestrial conservation goals of Fiji's Committee (e.g., protect 40% of each vegetation type). The four networks differ in the extent to which they emphasize clustering of sites and the transaction cost of establishing a terrestrial reserve where multiple clans would be involved in land-use decisions. Using the same transaction cost, two terrestrial networks that protect 20% of the land that most cost-effectively benefits coral reef condition were designed. The two networks differ in the extent to which they consider the importance of achieving terrestrial conservation goals. The results of the networks were compared, in terms of reef condition and representation of terrestrial vegetation communities, to the following other conservation scenarios, assuming in all cases that vegetation outside the network would be cleared for other land uses: (1) no new protected areas are added to the existing terrestrial network; (2) proposed "high priority" areas for terrestrial conservation determined by the Fiji Committee in 2010 are added to the existing network. This analysis has provided guidance to Fiji's Committee as they determined the exact location of terrestrial protected areas, and will inform development of integrating land–sea planning more broadly in similar tropical island ecosystems.

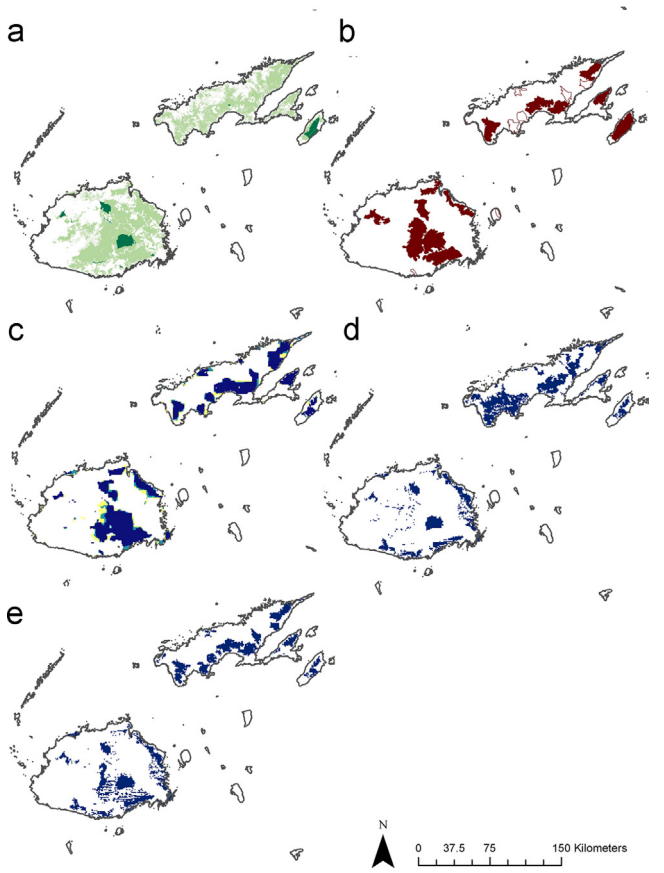

Fig. 1. Current and candidate terrestrial protected areas in Fiji: (a) distribution of vegetation (light green) and current protected areas (dark green); (b) Protected Area Committee priority places (solid red) and Olson et al. [10] priority forests (solid red and hollow red); (c) selection frequency of protected areas designed with Marxan to meet vegetation targets (Clan cost, clumped; dark blue selected $>75\%$, light blue selected 25–75%; yellow selected $<25\%$); (d) 'Benefit coral reef' scenario: protected areas designed to maximize benefit coral reefs and protect 20% of land; (e) 'Benefit coral reef and vegetation' scenario: protected areas designed to maximize benefit to coral reefs only in areas that contribute towards achieving vegetation targets and protect 20% of land.

2. Material and methods

2.1. Policy context

Less than 3% of Fiji's land is protected, covering 5.8% of remaining forests (Protected Area Committee, unpublished data). The Fijian government has set a goal of increasing the protected area estate to 20% of the land by 2020. Analyses to identify priorities for conservation of terrestrial resources have been conducted at the national scale. Olson et al. [10] proposed a network of 40 priority forests for conservation (henceforth 'priority forests') that cover 23% of Fiji's total land area and 58% of Fiji's remaining native forest (Fig. 1). The priority forests were selected based on area requirements for some native species, habitat and species representation goals, ecological processes, as well as practical considerations associated with conservation in Fiji. In 2010, a working group of Fiji's Committee used a scoring system to rank the Olson et al. [10] priority forests, and selected 13 as high priority sites for conservation (henceforth 'Protected Area Committee priority places'; Protected Area Committee, unpublished report) (Fig. 1). Although the approach used by the Committee is not consistent with spatial conservation prioritization principles and approaches accepted widely by the international conservation community [9], the ranking system was done specifically to give weighting to factors not easily incorporated into conservation planning software, such as feasibility of implementation and local knowledge of current financing levels at priority forest sites (Table S1). Given that exact boundaries of new terrestrial protected areas have not been formally defined and distributed throughout Government ministries, there is an opportunity to use systematic conservation planning approaches to adapt the Committee's priority places to a network that better achieves terrestrial conservation goals and benefits marine ecosystems.

2.2. Designing terrestrial protected areas with Marxan

There are many ecological and socioeconomic goals of terrestrial protected areas in Fiji. Two ecological goals are consistently discussed across the various conservation efforts, including (1) comprehensive representation of Fiji's major vegetation types; and (2) protection of endemic, threatened and culturally important species [8,10,11]. Systematic conservation planning principles were used to design networks of protected areas consistent with these goals. The study region is limited to Fiji's three largest islands, Viti Levu, Vanua Levu, and Taveuni, because habitat data are not available for the smaller, outlying islands. The study region was divided into 1 km^2 planning units, each of which could be selected for protection, unless currently protected.

To address the goal of comprehensively representing Fiji's major vegetation types, spatial data that represents the distribution of vegetation types in Fiji were used (Fiji Department of Forestry [12]). The vegetation types include cloud/montane forest,