Where do national and local conservation actions meet? Simulating the expansion of ad hoc and systematic approaches to conservation into the future in Fiji

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Abstract

The marginal benefits of systematic over ad hoc selection of protected areas are rarely measured, even though this information is crucial to investing limited conservation resources effectively. We developed a method to predict the marginal benefits of systematic over ad hoc approaches to conservation over time. We tested it in Fiji, where ambitious national conservation goals for inshore marine waters rely on community support to implement the required management. We used Maxent to develop a suitability layer for different forms of marine resource management based on predictors derived from interviews with key informants. This suitability layer, together with data on established marine protected areas (MPAs) and the software Marxan with Zones, informed simulations of the expansion of ad hoc and systematic conservation. With the same constraints on the additional extent of MPAs, the ad hoc approach achieved quantitative conservation objectives for half the ecosystems in our analysis, although all objectives were achieved or nearly achieved with the systematic approach. By defining the likely upper and lower bounds of plausible futures given different decisions about conservation investments, this work was designed to guide conservation strategies and actions in Fiji. This work is currently influencing the development of policies in Fiji to promote more strategic use of limited conservation resources.

Introduction

Ongoing biodiversity loss and limited resources for conservation require effective and cost-efficient conservation actions, defined as interventions undertaken to achieve conservation goals (e.g., marine protected area establishment). Most conservation actions have been ad hoc, lacking broader spatial context, and taking advantage of opportunities at the time, for example, willingness and capacity of resource owners and users to participate (e.g., Pressey *et al.* 2000). Here, we define ad hoc actions as conservation actions implemented without explicitly considering complementarity with existing actions or contribution to achievement of broader goals (e.g., species persistence). Ad hoc actions address local goals and respond to local constraints and opportunities, including support from communities. They can therefore be implemented effectively even where central governments lack capacity for coordination (e.g., Johannes 2002). Theoretically, ad hoc actions can coalesce into ecologically and socially functional networks that achieve broader, as well as local, conservation objectives. However, they can also waste limited resources by contributing marginally to regional-scale objectives (Pressey & Tully 1994).

An alternative to ad hoc actions is systematic conservation planning (hereafter "systematic planning"; Margules & Pressey 2000), characterized by explicit objectives and consideration of spatial context, through complementarity and connectivity, to guide selection of conservation areas and actions. Systematic planning involves three kinds of decisions. First, systematic conservation assessment (hereafter "systematic assessment") includes the social and technical activities that identify priority areas for conservation action. Second, implementation strategies determine how conservation actions are applied (Knight *et al.* 2006). Third, management and monitoring aim to maintain the values of conservation areas after actions have been applied (Pressey & Bottrill 2009). Intuitively, this more strategic approach should allocate conservation actions more efficiently to achieve objectives, and many millions of dollars have been invested in its application. However, most conservation plans focus only on identifying priority areas for conservation, and few have guided extensive on-ground implementation (Knight *et al.* 2006). The exceptions (e.g., Pressey *et al.* 2009; McCook *et al.* 2010) have been facilitated by atypical circumstances, such as lack of private tenure.

The marginal benefits of systematic over ad hoc approaches have rarely been measured and are likely to be context specific, and there is debate over the most effective blend of the two (e.g., Pressey & Bottrill 2008). Such comparisons, and better understanding of their respective strengths and limitations, are vitally important if we are to invest limited resources effectively. Predictions of the extent to which conservation objectives are better achieved through systematic over ad hoc approaches provide insight into the benefits of coordinating actions. This understanding can help practitioners decide whether systematic planning is worthwhile or what incentives could motivate individual actions toward better coordination.

For the purposes of this study, we chose to define systematic and ad hoc approaches as mutually exclusive. Our main reason was to understand the bounds on the decision space, i.e., the potential distribution of outcomes from conservation decisions, within which conservation planners are working. There are previous attempts, both in the literature and in practice, to integrate ad hoc and systematic approaches (e.g., Armada *et al.* 2009; Henson *et al.* 2009; Ban *et al.* 2009a; Pressey & Bottrill 2009; Game *et al.* 2011), but these are likely to produce results within the decision space that we define here. Ad hoc actions are being "scaled up" to better achieve fisheries and conservation objectives that require perspectives broader than individual local governance units (e.g., in Danajon Bank, in the Philippines; Armada *et al.* 2009). Concurrently, systematic assessments are being "scaled down" or adapted to address local objectives (e.g., community preferences; Ban *et al*. 2009), unforeseen constraints on conservation actions, and errors in data (Henson *et al.* 2009).

Of the four published studies that estimated the marginal benefits of systematic over ad hoc approaches, three were retrospective and one was predictive. The retrospective studies (Rebelo & Siegfried 1992; Pressey & Taffs 2001; Hansen *et al.* 2011) compared the observed, at least partly ad hoc, representation of ecosystems within protected areas to the potential representation had more systematic approaches been taken. The predictive study (Pressey & Tully 1994) projected potential representation of ecosystems from expansion of protected areas with both ad hoc and systematic approaches. Retrospective assessments provide lessons for the future, whereas the potential of predictive comparisons, which has barely been explored, is to construct alternative futures arising from different policy settings, thereby informing decision makers about the consequences of proceeding in alternative ways. Here, we develop a predictive comparison of ad hoc and systematic approaches that builds on the existing literature and previous applications in three ways. First, this is the first marine case study. Second, whereas Pressey and Tully's (1994) ad hoc scenario came from specific areas proposed for reservation by an agency, ours required the development of new methods, including modeling suitability for different types of community-based marine protected areas (MPAs), and emulating the expansion of ad hoc MPAs with a decision tree linked to spatial data. These innovations are likely to be broadly applicable to community-based conservation. Third, our study is closely associated with policy and practice through the Fiji National Protected Area Committee (S.D.J. is leading the marine working group of the Fiji Protected Area Committee), and we are engaging the Committee in a dialogue about strategies for achieving conservation goals. Together with our links to communities and the Fiji Locally Managed Marine Area (LMMA) network, this is a different type of engagement than the agency connections of Pressey and Tully (1994).

This article has two aims. The first is to predict the marginal benefits for representation of ecosystems of systematic over ad hoc approaches in the inshore marine waters of Fiji. We address three questions: (1) given current trends in ad hoc actions, will their expansion achieve national conservation objectives by 2020? (2) considering realistic constraints on conservation actions in Fiji, would systematic allocation of fishing closures achieve national conservation objectives by 2020? and (3) what is the difference in achievement of objectives between ad hoc and systematic approaches?

Our second aim is to inform policy initiatives in Fiji. Because the Fiji Government has currently devolved to communities most responsibility for achieving national conservation objectives through locally based actions, we want to investigate approaches to complement ad hoc expansion of fisheries closures to achieve conservation objectives by 2020. This work has full support from the

Fiji National Protected Area Committee. Simulation of expanding MPAs was a priority of the Fijian Department of Environment for 2011 and is seen as contributing to the Fiji National Biodiversity Strategy and Action Plan under the Inshore Fisheries thematic section. This work therefore has direct impact on policy and allocation of conservation resources.

Methods

Planning region and policy context

Our study region covered Fiji's inshore marine waters, extending across ~30,000 km^2 from the high water mark to the outer barrier reef, and divided into legally demarcated traditional fishing grounds (hereafter ″fishing grounds″). Fiji's national government has committed to protecting 30% of its inshore waters within MPAs by 2020 (Jupiter *et al.* 2010). Progress toward this commitment has mostly been through ad hoc implementation of community-based MPAs. These are implemented by, for, and with the local community (Western *et al.* 1994), and referred to as LMMAs. In Fiji, LMMAs, consisting of fishing closures and other forms of management surrounding them, cover whole traditional fishing grounds. The motivation for LMMAs has been the widespread perception of decline in marine resources (Veitayaki *et al.* 2003). The Fiji LMMA network of practitioners shares knowledge and experience and supports the national government's 30% commitment (Jupiter *et al.* 2010). Based on an initial verbal or written request, partner organizations within the Fiji LMMA network will support villages wanting to establish management within their traditional fishing grounds as time and resources permit.

LMMAs can have multiple, simultaneously operating forms of marine resource management (hereafter ″management″). Some closures prohibit resource extraction permanently. Others, termed conditional closures, are in two categories: those with controlled harvesting (harvesting allowed once per year or less often, as dictated by a management plan or community decision); and those with uncontrolled harvesting. Areas outside closures under ″other management″ are subject to bans on fishing gear, species bans, and seasonal prohibitions. After one or more closures are implemented within a fishing ground, other management is applied across the remainder of that fishing ground (Mills *et al.* 2011).

Data and conservation objectives

We used all available national-scale data on the spatial distribution of the following marine ecosystems: fringing reefs, nonfringing reefs, mangroves, intertidal and ″other benthic substrata.″ The latter included soft-bottomed lagoons and seagrass and was divided into four depth classes (0–5 m, 5–10 m, 10–20 m, 2030 m). Our ecosystem-specific conservation objectives were set by Fijian stakeholders during a workshop in 2010, based on the government's 30% goal (see Mills *et al.* 2011 for details). The objectives were 10% representation of other benthic substrata in all depth classes and 30% for all other ecosystems. The 10% objectives have been achieved with existing management, so we used the 30% objectives for the systematic scenario, below (Mills *et al.* 2011).

At the same workshop in 2010, participants estimated, for several focal species groups in each ecosystem, a range of relative per-unit-area contributions to objectives of each form of management (permanent closures, conditional controlled closures, conditional uncontrolled closures, and other management; for details see Mills *et al.* 2011). These assessments gave several values of relative effectiveness of each form of management for each ecosystem, depending on the focal species group being considered. For this study, we simplified these assessments because Marxan with Zones uses only one value of relative contribution for each form of management, regardless of ecosystem type. For each form of management, we used the most common minimum contribution to focal species groups across ecosystems. This approach erred on the side of conservative estimates of relative contributions.

We subdivided the planning region into planning units for assessment and comparison as potential future closures. These planning units were mostly grids, trimmed at closure boundaries, the coastline, boundaries of fishing grounds (so each unit was associated with only one fishing ground), and the outer bounds of the study region, with modal size of 0.5 km^2.

Suitability layer for closures

For both the ad hoc and systematic scenarios, we modeled the suitability of planning units outside existing closures for the establishment of new closures. First, we conducted 11 semi-structured interviews with key informants to identify factors that influence opportunities for, and constraints on, implementing closures in Fiji (for additional information see Appendix S1). From these, we identified spatial predictors of existing closures (Table 1). Our spatial predictors were: distance from another closure; proportion of inshore fishing ground (<3 km from the coast) within closures; distance from nearest road; distance from nearest village; presence of a provincial resource management support team; and ecosystem type (see Table 1 for rationale). With these predictors, we used Maxent (Phillips *et al.* 2006) to develop maps of suitability

Table 1 Factors identified during key informant interviews as important in determining the presence, size and location of closures in Fiji, and spatial predictors used in Maxent

Factors influencing presence, size, and location of closures, identified by interviewees	Spatial predictors used in Maxent model	Rationale provided by interviewees and/or scientific literature supporting use of spatial predictor
(1) Perceived benefits of being associated with an international conservation NGO	Data not available	Villagers are attracted to conservation projects by the direct benefits received from NGOs (e.g., employment opportunities) or indirect benefits of being associated with them (e.g., help with leveraging funds from other organizations, improvement of village status relative to surrounding villages; Foale 2001).
(2) Establishment of closures by adjacent villages	Distance from nearest other closure within any fishing ground[a]	After a village joins the LMMA network, the villagers present their work at provincial meetings (LMMA), initiating interest from other villages in the same province (USP 2007; WRI 2008). In other regions, such as the Philippines, communities also become interested in establishing MPAs after hearing from others about their potential benefits (Alcala & Russ 2006).
(3) Perception of resource decline	Data not available on a national scale	Villagers will manage their natural resources when they see them as threatened or in decline (Johannes 2002).
(4) Need for access to traditional fishing grounds	Proportion of inshore traditional fishing ground (<3 km from coast) within closures[a,b]	Villagers are unlikely to change their preferred fishing areas and abide with new resource regulations if they do not have suitable alternative fishing areas (Abernethy *et al.* 2007; Daw 2008). Because few villagers have access to motorboats, most people are restricted to fishing and collecting marine resources within approximately 3 km of their villages (Adams *et al.* 2011). In addition, the scope for fishers to change fishing locations in Fiji is restricted by the limits of traditional fishing grounds and use rights based on their lineages.
(5) Accessibility and visibility from village/ability to enforce and monitor resource regulations	Distance from nearest road[b]	The spatial mobility of fishers is limited by transport and fuel costs (Begossi 2001). Fishing grounds closer to roads are more accessible.
	Distance from nearest village[b]	Enforcement of regulations is highly reliant on vigilance by members of the village. Managed areas must be visible from villages to allow effective enforcement (Aswani & Hamilton 2004; Leisher *et al.* 2007).
	Presence of a provincial resource management support team[a]	One of the responsibilities of the provincial resource management support teams is to integrate rules from LMMAs into provincial legislation (WRI 2008). When regulations are so integrated, they can be legally enforced (Tawake 2007).
(6) Ecosystem health, productivity, and type	Ecosystem type[c]	Villagers choose to protect either: (1) the most productive (e.g., coral reefs) and healthy ecosystems to get the maximum benefit from management; or (2) degraded ecosystems to promote recovery. Information on ecosystem health and productivity was not available. However, ecosystem type could be a useful surrogate because some are more productive than others (e.g., mangroves and reefs are more productive than other benthic substrata, Mumby *et al.* 2004; Manson *et al.* 2005).

[a]Map created with data provided by the Fiji Locally Managed Marine Area network.
[b]Map created with data provided by the Fijian National Government.
[c]Map from Mills *et al.* (2011).

for new closures within fishing grounds (for detailed information see Appendix S2). We used Maxent because it is robust to the limitations of presence-only data that indicate where features of interest have been observed but not where they have been looked for and not observed (Phillips *et al.* 2006). We interpreted data on the distribution of closures as presence-only because we did not know which areas outside existing closures might have been considered by villagers for closures but found to be unsuitable.

Ad hoc scenario

The simulation of ad hoc closures emulated the approach of the Fiji LMMA network to encouraging management. We based the simulation on Fiji LMMA reports (e.g., LMMA 2003), discussion with LMMA members, and the suitability models from Maxent (see Appendix S3 for details). We included existing closures in every simulation as starting points for expansion. Each simulated future closure was assigned a closure status (permanent, controlled, or uncontrolled) using decision rules derived from the current distribution of closures and Maxent predictions. Because there was a stochastic element in the simulation model (Appendix S3), we ran 100 repeat simulations, each for 10 annual time steps (2011–2020), to produce 100 maps of potential future closures. The simulations placed approximately 90 km^2 in closures each year. This reflected the average annual addition when expansion of LMMAs peaked from 2002–2004, allowing us to simulate the maximum potential achievements of ad hoc actions. After closures had been allocated to fishing grounds, all other planning units within fishing grounds containing closures were classified as ″other management,″, reflecting practices by the Fiji LMMA network (Mills *et al.* 2011).

Systematic scenario

We used Marxan with Zones for a systematic assessment that identified closure configurations to achieve conservation objectives. Because part of the software's selection method is stochastic, we ran the selection process 100 times. We minimized impacts of closures on villages by preferentially selecting planning units most suitable (from Maxent) for each closure type, with more suitable planning units having lower cost. Marxan with Zones selected planning units for different forms of management (zones) based on their relative costs and contributions to conservation objectives (Watts *et al.* 2009). We included existing closures in all configurations and counted their contributions to objectives. Planning units outside existing closures could be assigned to one of three zones: permanent, controlled, or no management. Uncontrolled closures were not considered in this scenario because accrued benefits can be rapidly reversed during intensive harvests (Foale & Manele 2004), whereas uncontrolled closures were considered in the ad hoc scenario because they are implemented by villages. We made objectives proportional across fishing grounds so, for example, 30% of the mangroves within each had to be represented. We adjusted the relative costs of the forms of management so that selected permanent and controlled closures were in the same ratio (1:4) as existing ones, reflecting existing preferences for the different types of closures. We ran the analyses to maximize achievement of objectives within the constraint of adding an average of 90 km^2 of closures per year, the same as in the ad hoc scenario. Selected closures were attributed to individual years between 2011 and 2020, assuming that closures with highest suitability would be added first. After closures had been allocated to fishing grounds, to match the ad hoc scenario, all other planning units within fishing grounds containing closures were classified as ″other management.″

Comparing ad hoc and systematic scenarios

After the different forms of management were allocated to fishing grounds in the ad hoc and systematic scenarios, we averaged the percentage achievement of each ecosystem's objective across the 100 simulations (ad hoc) or 100 repeat runs (systematic) for each annual time step over the 10 years. We also averaged yearly achievement of objectives across the 100 replicates and across all ecosystems to give a single parameter for comparing ad hoc and systematic scenarios over time.

Results

The four Maxent models, predicting suitability for the different types of closures and all closures combined, produced good fits to the existing data (cross-validated AUC at least 0.98). The most important predictors were: distance from nearest road (correlated with distance from nearest village and distance from nearest closure); proportion of inshore fishing ground already closed; and presence of a provincial resource management support team (Figure 1).

Simulations showed that neither the ad hoc nor systematic scenario achieved all conservation objectives by 2020, although the systematic approach was more successful (Figure 2). In the ad hoc scenario, fringing and nonfringing reefs, mangroves and intertidal ecosystems missed their objectives by at least 12–17%, whereas objectives for ecosystems of other benthic substrata were

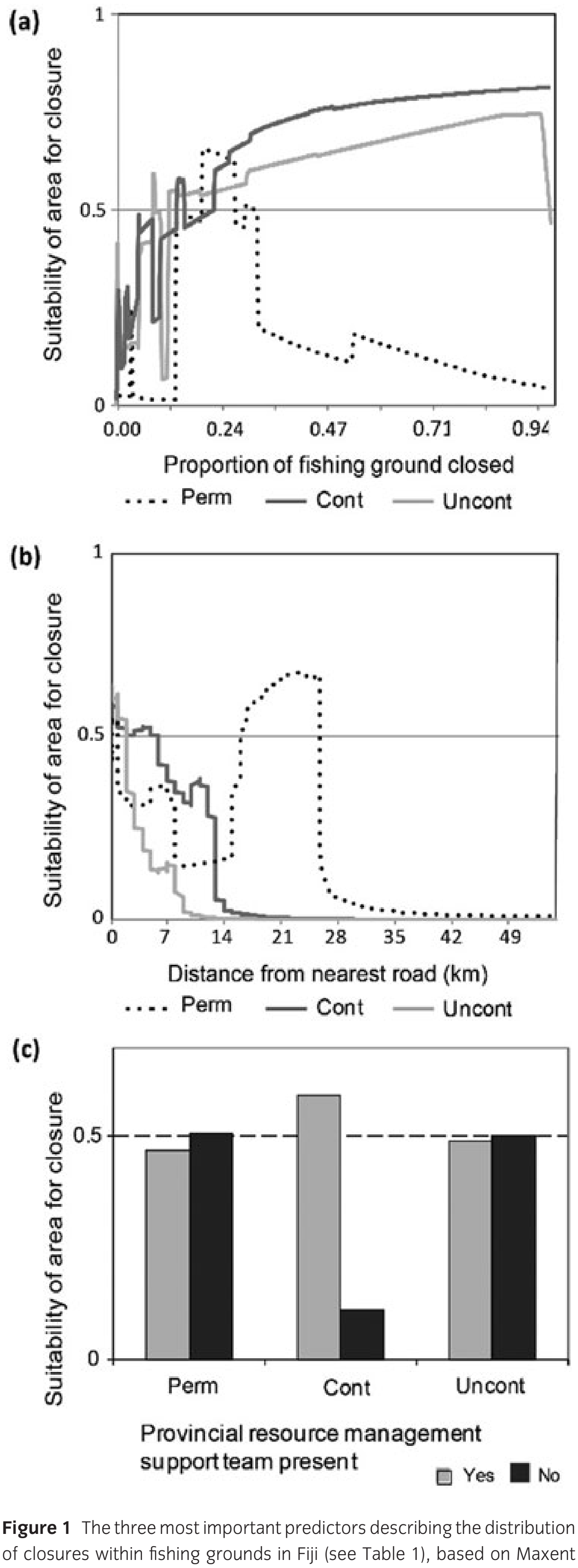

Figure 1 The three most important predictors describing the distribution of closures within fishing grounds in Fiji (see Table 1), based on Maxent models. The response curves show how the suitability of areas within

exceeded (Figures 2a and c), having been achieved before the simulations began. In the systematic scenario, nonfringing reefs and mangroves missed their objectives by 2–5%, but all other objectives were exceeded (Figures 2b and d). In the systematic scenario, high selection frequencies were concentrated on targeted ecosystems (Figure 3). Selection frequencies in the ad hoc scenario were unaffected by ecosystem type and were consequently lower and more evenly spread across fishing grounds (Figure 3), indicating higher flexibility in the choice of planning units, but also lower efficiency in achieving objectives within the constraint of 90 km^2 of closures per year. Ad hoc closures were confined to a small set (31% on average) of fishing grounds because of their higher suitability nationally. Systematically selected closures were spread across most (95% on average) of the fishing grounds.

The overall achievement of objectives by the ad hoc and systematic scenarios, averaged across 100 selection processes and across all ecosystems, was similar for the first 4 years (Figure 2e). After 2013, achievement of objectives by the systematic scenario increased much more quickly.

Discussion

Our study aimed to inform decision makers about potential future outcomes of different approaches to locating conservation actions. In this way, we hope to encourage strategic thinking about local conservation investments. For Fiji, our study is embedded in the policy process surrounding the expansion of MPAs. For other regions, our study could be adapted easily, recognizing the need for context-specific models of suitability and simulation rules for ad hoc decisions about conservation management.

Figure 1 (continued) fishing grounds for each type of closure was related to each predictor. These curves did not incorporate interactions between the predictors. (a) Suitability for closures in relation to the proportion of inshore fishing ground already closed. The effect of this predictor was greatest for permanent closures (contributing to 73% of the model). (b) Suitability for closures in relation to distance from nearest road. This predictor was significantly correlated with both distance from nearest village and distance from nearest closure. Attribution related to the three predictors has been combined, so single predictors should not be interpreted in isolation. The effect of distance from nearest road was greatest for uncontrolled closures (contributing to 67% of the model) and controlled closures (contributing to 34% of the model). (c) Suitability for closures in relation to the presence of a provincial resource management support team. The effect was greatest for controlled closures (contributing to 28% of the model). The effects on other closure types were negligible. Perm = permanent closures; Cont = conditional controlled closures; Uncont = conditional uncontrolled closures.

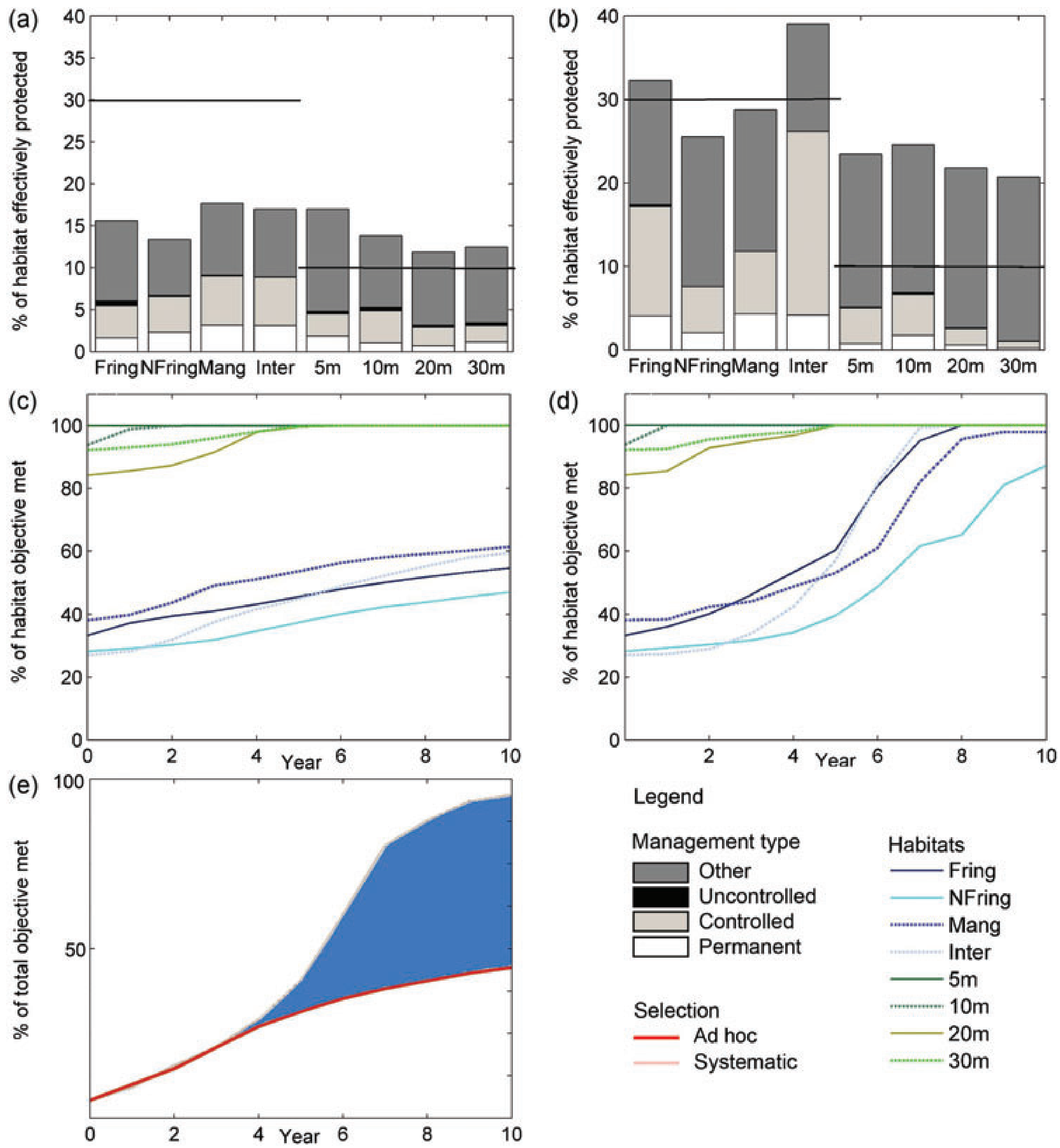

Figure 2 Achievement of objectives by the ad hoc and systematic scenarios. (a) Representation of ecosystems by 2020 in the ad hoc scenario. Horizontal lines indicate conservation objectives. (b) Representation of ecosystems by 2020 in the systematic scenario. Horizontal lines indicate conservation objectives. In all parts of this figure, the percentages of ecosystems effectively protected considered the relative per-unit-area contribution of each management type: 100% contribution by permanent closures; 70% contribution by controlled conditional closures; 10% contribution by uncontrolled conditional closures; and 20% contribution by other management. The effectiveness of different forms of management in protecting each ecosystem was based on Mills *et al.* (2011). (c) For the ad hoc scenario, the increase in representation of each ecosystem over the ten years to 2020, averaged across 100 simulations. (d) For the systematic scenario, the increase in representation of each ecosystem over the 10 years to 2020, averaged across 100 runs. (e) Achievement of objectives over the 10 years to 2020 in the ad hoc and systematic scenarios, averaged across 100 selection processes and across all ecosystems. The area shaded in blue bounds the potential achievement of objectives. Intermediate achievements are likely with scaling down of the systematic design, perhaps compromising achievement of some objectives, and with scaling up ad hoc actions by coordination between villages and fishing grounds. Fring = fringing reef; NFring = nonfringing reef; Mang = mangroves; Inter = intertidal; 5 m = other benthic substrata, 0–5 m depth; 10 m = other benthic substrata, 5–10 m depth; 20 m = other benthic substrata, 10–20 m depth; 30 m = other benthic substrata, 20–30 m depth.

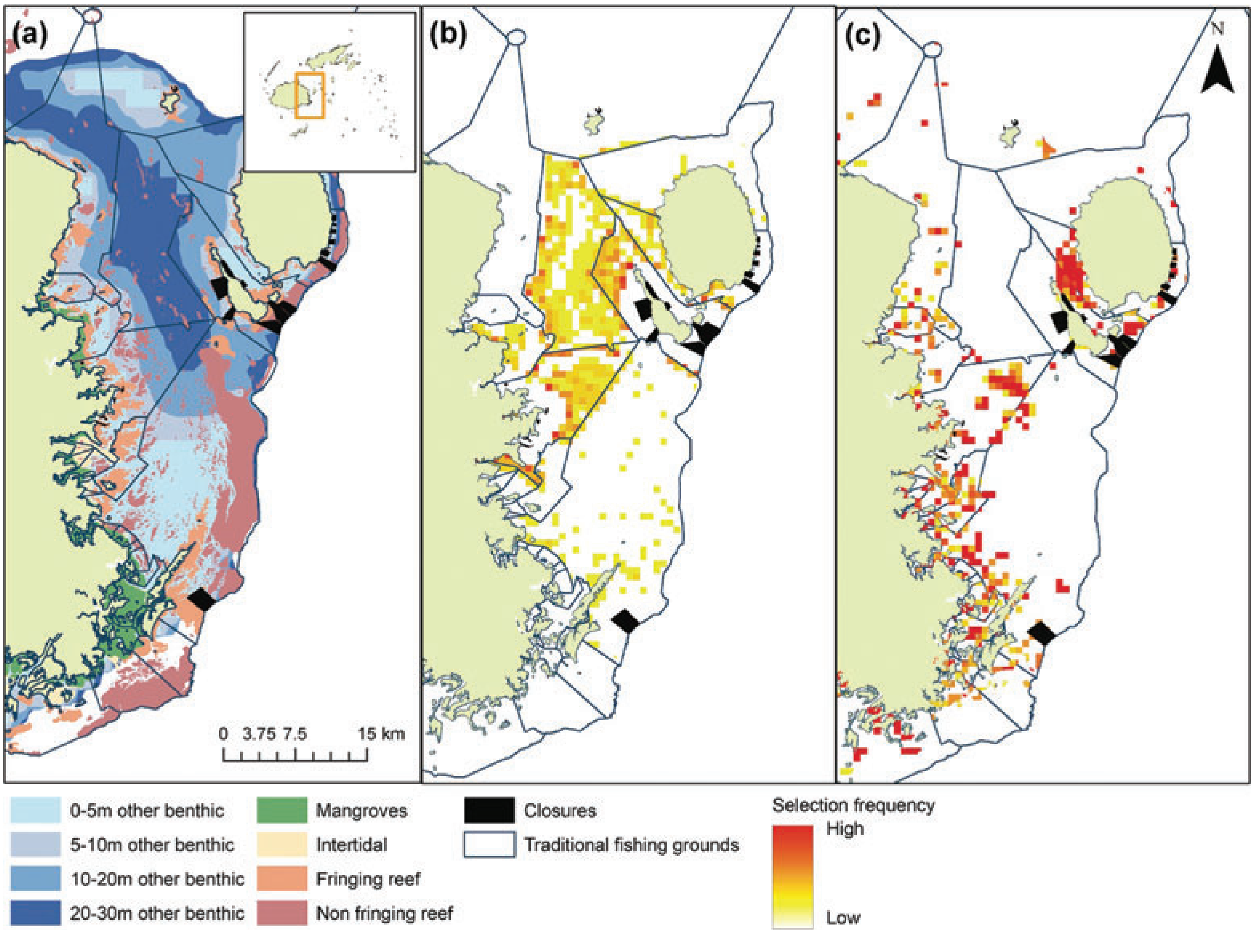

Figure 3 Ecosystems and selection frequencies of areas in fishing grounds on the east coast of Viti Levu. Inset shows Fiji, with the main figure focused on inshore waters in portions of Tailevu, Lomaiviti, and Rewa Provinces. (a) The eight ecosystem types with spatial information nationally. (b) Selection frequencies of areas for the ad hoc scenario, measured across 100 simulations. (c) Selection frequencies of areas for the systematic scenario, measured across 100 runs. Areas selected more frequently across the different scenarios are shown in warmer colours. In (c), areas with high selection frequencies are those with few spatial options to achieve conservation objectives.

Our simulations defined the likely upper and lower bounds of plausible futures given different decisions about the extent of coordination of conservation investments. We found that, in Fiji, a systematic approach, if it could be implemented, would lead to better achievement of national conservation objectives than an ad hoc approach. This was not surprising given that the systematic approach is specifically designed to achieve these objectives. Better results from systematic selection are also likely in other contexts where priority for quantitative objectives and opportunity for ad hoc decisions are poorly related, or where ecological values are negatively correlated with social values (e.g., Raymond & Brown 2011; Bryan *et al.* 2011).

Realistically, though, not all areas selected by the systematic approach will be available for conservation, and the systematic approach is likely to be more costly. We minimized this cost by restricting the size of closures and the percentage of each traditional fishing ground they could cover. In addition, our cost layer (the inverse of the suitability layer) led to preferential selection of more suitable areas in the systematic scenario. However, areas classified as ″unsuitable″ were still available for selection and some were included in the systematic MPA network. As with any systematic plan, scaling down will require adjustments of design to accommodate availability of areas and errors in data, probably losing of some of the theoretical marginal benefit of our systematic assessment (Figure 2e).

To date, conservation plans that have been effectively scaled down and implemented have relied on strong government leadership and incorporated fine-resolution

Table 2 Examples of previous studies of opportunity for conservation actions. These studies identified characteristics of private landholders or communities and related these to willingness to engage in different types of resource management

Examples of social characteristics related to opportunity	References
Social values assigned to natural areas (e.g., recreation and tourism value, intrinsic value, value for provision of fresh water)	Raymond *et al.* 2009; Bryan *et al.* 2011
Knowledge of landholders about biodiversity conservation and sustainable land use	Knight *et al.* 2010
Ability of land managers to adapt to environmental change (based on poverty rates, variance in resident income, and per capita state budget)	Sexton *et al.* 2010

information through extensive stakeholder engagement (e.g., McCook *et al.* 2010). Given limited government resources in Fiji (Lane 2008), much of the planning for marine management is outsourced through the Fiji LMMA network, which encourages ad hoc actions, and is now moving to coordinate these (WRI 2008). In this context, scaling up ad hoc actions will probably be more effective in Fiji than scaling down a national systematic plan, because scaling up would require only adjustment of the existing approach rather than a transformative approach.

By predicting future gaps in habitat protection from ad hoc decisions, our simulations point the way to identifying approaches to coordination that could make community-based MPAs more strategic and effective. Given the ad hoc approach will protect all other benthic habitats (across the four depth categories), new incentives should be directed at protecting mangroves, coral reefs, and intertidal habitats, without sacrificing local autonomy. Such incentives could include both financial and/or non-monetary benefits (e.g., payment for ecosystem service schemes, payment of school fees, national public recognition) in exchange for protecting larger or more specific areas. Greater incentives are likely to be needed, given that national coordinating bodies (FLMMA, Protected Area Committee) increasingly recognize that local communities are unlikely to bear the cost burden of contributing to national objectives. The Fiji Government and FLMMA partners have already indicated a willingness (to S.D.J.) to consider the results of our models to help strategically target future investment in community-based marine management actions.

Development of incentives also needs to be coupled with legislative reform and increased local awareness of MPA design principles to truly improve management and coordination of the Fiji LMMA network. With respect to legislative reform, strengthening local control over management, with support from higher level government, is recommended. For example, the Fisheries Act is currently undergoing a revision to an Inshore Fisheries Decree. Members of FLMMA have been vocal during consultations on this draft legislation to retain a clause that would legally recognized community-based management plans for inshore waters, provided they are aligned with other legislation. Power sharing between groups operating at different scales is often identified as key to effective resource governance (e.g., Dietz *et al.* 2003). With respect to boosting participatory comanagement processes, Fiji LMMA partners should focus on engaging communities to learn about the ways that design criteria used in systematic conservation planning (such as habitat representation and connectivity) can contribute to local objectives, and how local objectives can be explicitly incorporated into planning. This requires not just clear articulation of management objectives by communities but also the development of trust and effective cross-scale communication to facilitate shared learning (Armitage *et al.* 2008).

We illustrated the feasibility of modeling the suitability of areas for different kinds of closures as a proxy for likelihood of implementation or conservation opportunity. Data on opportunities inform managers about where to work and what tools to use (Knight *et al.* 2010), and opportunities for applying different forms of management will depend on the social and political context. Previous studies of opportunity have collected and mapped data on characteristics of private landholders or communities and related these data to willingness to engage in resource management (e.g., see Table 2). Ideally, opportunity would be predicted at a local scale with existing information, such as census data. However, the suitability of census data to predict opportunity is contested (e.g., Guerrero *et al.* 2010; Curtis *et al.* 2005). Instead of using census data on the human and social characteristics likely to influence opportunity for conservation, we used Maxent to model suitability for closures based on the spatial relationships between existing closures and spatial predictors, assuming that suitability was correlated with opportunity. Models such as this, covering multiple forms of management, could inform spatial prioritizations across local or larger extents in other regions.

Although this study provides a broad perspective on conservation opportunity in Fiji, numerous interconnected social, economic and political factors will also influence whether villages will undertake conservation (Ostrom 2007). These factors operate locally and are seldom depicted spatially. Our suitability models, though supported by the resource management literature for the Pacific, are therefore only a starting point for discussion with communities about the potential enhancement of conservation achievements by coordinated local actions. Other factors that will influence the spatial distribution of opportunity include policies, markets, characteristics of resource users, incentives, cultural values, and governance (Berkes 2007; Ostrom 2007). Incorporating insights into these factors will be critical to guiding initiatives to scale up local conservation actions.

We have concentrated this study on representation objectives but, in reality, planning processes involve multiple social and ecological objectives that vary between local and wider contexts. A more complete understanding of the benefits of systematic over ad hoc approaches will come from considering multiple objectives, the trade-offs between them given constraints on conservation resources, and the respective likelihoods of implementing management designed systematically or applied ad hoc.

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Supporting Information

Additional supporting Information may be found in the online version of this article:

Appendix S1. Background information on key informants.

Table S1. Key informant details.

Appendix S2. Maxent methods.

Appendix S3. Simulation of ad hoc expansion of community-based MPAs.

Figure S1. Flow diagram of simulation steps.

Figure S2. Types of closures in relation to distance from nearest road.

Table S2. The estimated percentage contributions of each predictor to the Maxent models for permanent, controlled, and uncontrolled closures and all closures combined.

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