Conservation Biology

Conservation Practice and Policy

Incorporating Effectiveness of Community-Based Management in a National Marine Gap Analysis for Fiji

MORENA MILLS,*§ STACY D. JUPITER,† ROBERT L. PRESSEY,* NATALIE C. BAN,* AND JAMES COMLEY‡

*Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, QLD 4811, Australia
†Wildlife Conservation Society, Suva, Fiji Islands, email sjupiter@wcs.org
‡Institute of Applied Science, University of the South Pacific, Suva, Fiji Islands

Abstract: *Every action in a conservation plan has a different level of effect and consequently contributes differentially to conservation. We examined how several community-based, marine, management actions differed in their contribution to national-level conservation goals in Fiji. We held a workshop with experts on local fauna and flora and local marine management actions to translate conservation goals developed by the national government into ecosystem-specific quantitative objectives and to estimate the relative effectiveness of Fiji's community-based management actions in achieving these objectives. The national conservation objectives were to effectively manage 30% of the nation's fringing reefs, nonfringing reefs, mangroves, and intertidal ecosystems (30% objective) and 10% of other benthic ecosystems (10% objective). The experts evaluated the contribution of the various management actions toward national objectives. Scores ranged from 0 (ineffective) to 1 (maximum effectiveness) and included the following management actions: permanent closures (i.e., all extractive use of resources prohibited indefinitely) (score of 1); conditional closures harvested once per year or less as dictated by a management plan (0.50–0.95); conditional closures harvested without predetermined frequency or duration (0.10–0.85); other management actions, such as regulations on gear and species harvested (0.15–0.50). Through 3 gap analyses, we assessed whether the conservation objectives in Fiji had been achieved. Each analysis was based on a different assumption: (1) all parts of locally managed marine areas (including closures and other management) conserve species and ecosystems effectively; (2) closures conserve species and ecosystems, whereas areas outside closures, open to varying levels of resource extraction, do not; and (3) actions that allow different levels of resource extraction vary in their ability to conserve species and ecosystems. Under assumption 1, Fiji's national conservation objectives were exceeded in all marine ecosystems; under assumption 2, none of Fiji's conservation objectives were met; and under assumption 3, on the basis of the scores assigned by experts, Fiji achieved the 10% but not the 30% objectives for ecosystems. Understanding the relative contribution of management actions to achieving conservation objectives is critical in the assessment of conservation achievements at the national level, where multiple management actions will be needed to achieve national conservation objectives.*

Keywords: closures, conservation action, conservation-area design, effectiveness, marine protected areas, resource management

Incorporación de la Efectividad del Manejo Basado en Comunidades en un Análisis de Vacíos Nacional Marino en Fiji

§ *Address for correspondence: email morena.mills@my.jcu.edu.au*
Paper submitted October 31, 2010; revised manuscript accepted April 14, 2011.

DOI: 10.1111/j.1523.1739.2011.01749.x

Resumen: *Cada acción en un plan de conservación tiene un diferente nivel de efecto y, en consecuencia, contribuye diferencialmente a la conservación. Examinamos la manera en que varias acciones de manejo basadas en comunidades difirieron en su contribución a las metas de conservación a nivel nacional en Fiji. Realizamos un taller con expertos en fauna y flora local y en acciones de manejo marino para traducir las metas de conservación desarrolladas por el gobierno nacional en objetivos cuantitativos específicos para cada ecosistema y para estimar la efectividad relativa de las acciones de manejo basadas en comunidades para alcanzar estos objetivos. Los objetivos de conservación nacionales eran manejar efectivamente 30% de los arrecifes, manglares y ecosistemas intermareas (objetivo 30%) y 10% de otros ecosistemas bénticos (objetivo 10%). Los expertos evaluaron la contribución de las acciones de manejo en relación con los objetivos nacionales. Los valores variaron de 0 (inefectivo) a 1 (efectividad máxima) e incluyeron las siguientes acciones manejo: cierres permanentes (i.e., prohibición indefinida de todos los usos extractivos de recursos) (valor de 1); cierres condicionados cosechados una vez por año o menos según lo establecido por un plan de manejo (0.50-0.95); cierres condicionados cosechados sin frecuencia o duración predeterminados (0.10–0.85); otras acciones de manejo, como regulaciones de equipo y especies cosechadas (0.15–0.50). Mediante 3 análisis de vacíos, evaluamos si se alcanzaron los objetivos de conservación en Fiji. Cada análisis se basó en un supuesto diferente: (1) todas las zonas de áreas marinas manejadas localmente (incluyendo cierres y otras acciones) conservan especies y ecosistemas efectivamente; (2) los cierres conservan especies y ecosistemas, mientras que las áreas fuera de los cierres, abiertas a diferentes niveles de extracción de recursos, no conservan; y (3) las acciones que permiten diferentes niveles de extracción de recursos varían en su capacidad para conservar especies y ecosistemas. Bajo el supuesto 1, se excedieron los objetivos nacionales de conservación en Fiji en todos los ecosistemas marinos; bajo el supuesto 2, no se alcanzó ninguno de los objetivos de Fiji; y bajo el supuesto 3, con base en los valores asignados por los expertos, Fiji alcanzó el 10%, no el 30%, de los objetivos para los ecosistemas. La comprensión de la contribución relativa de las acciones de conservación en el logro de los objetivos de conservación es crítica para la evaluación de los alcances de la conservación a nivel nacional, en el que se requerirán múltiples acciones de manejo para alcanzar los objetivos de conservación.*

Palabras Clave: acciones de conservación, áreas marinas protegidas, cierres, diseño de área de conservación, efectividad, manejo de recursos

Unsustainable levels of fishing have contributed to rapid declines of global marine biological diversity, including the ecosystem functions that benefit humans (e.g., decrease in productivity of fisheries) (Sala & Knowlton 2006). Consequently, many countries have committed to reducing declines in marine biological diversity, for example, by signing the Convention on Biological Diversity (CBD). Signatories to the CBD commit to establishing networks of "representative and effectively managed" protected areas in marine environments (CBD 2008) aimed at the conservation of all levels of biological diversity. Protected areas are defined as areas "designated or regulated and managed to achieve specific conservation objectives" (CBD 2008). Approaches used to maintain and increase biological diversity generally rely on measures of the representation of selected species and ecosystems within protected areas as surrogates for data on overall genetic and species diversity (Margules & Pressey 2000). We assessed Fiji's progress toward meeting its marine conservation goals, which reflect its commitments to the CBD. We conducted gap analyses (e.g., Scott et al. 1993) under different assumptions about the relative effectiveness of community-based actions for managing marine resources.

Many countries, including Fiji, set a broad national goal of effectively managing 30% of inshore marine ecosystems (Jupiter et al. 2010; Rondinini & Chiozza 2010). For gap analyses, such goals must be translated into quantitative conservation objectives, at least for measures of biological diversity for which spatial data on distributions are available. Objectives defined as fixed percentages of each ecosystem imply that society believes all ecosystems warrant equal levels of conservation. To reflect the unequal distributions of species across ecosystem types, explicit criteria can be developed to formulate objectives that vary among ecosystems (Desmet & Cowling 2004). Although limited biological data often make the development or measurement of such criteria difficult (Rondinini & Chiozza 2010), criteria that are based on the rarity of and threats to an ecosystem can ensure that ecosystems subject to high levels of human use are managed extensively (Pressey & Taffs 2001).

Actions intended to protect biological diversity are not equally effective (Shahabuddin & Rao 2010). Gap analyses can be used not only to show the representation of species and ecosystems within protected areas (Scott et al. 1993), but also, by inference, to assess the relative effectiveness of different management actions in achieving representation objectives. We use the term *effectiveness* to describe the level of effect a management action has on biological, social, and economic conditions, including the persistence of biological diversity (Hockings et al. 2006). Effective management relies partly on human behavior and partly on ecology (e.g., species' life histories and behavioral responses to management actions). We focused on the ecological aspects of management effectiveness (hereafter ecological effectiveness), which we define as the relative contribution of a management action to realizing conservation objectives.

Ecological effectiveness of different management actions is likely to vary widely across species and ecosystems. Marine management actions include permanent and periodic closures to fishing, size limits on fish harvested, seasonal bans on fishing during breeding seasons, bans on taking certain species, and restrictions on fishing gear. There are few empirical studies on the ecological effectiveness of such actions. Results of some studies show that periodic closures can be as effective as permanent closures in increasing the abundance and biomass of target species (e.g., Bartlett et al. 2009). Results of other studies show that no-entry areas protect some species more effectively than permanent closures, where entry is allowed but resource extraction is not, and that permanent closures are more effective than partial-take areas (McCook et al. 2010). Global analyses indicate variability in the effectiveness of permanent closures in increasing species richness and the biomass, density, and size of organisms within their boundaries, perhaps because of differences, both within and outside closures, in the degree of previous resource use (Russ & Alcala 1999; Lester et al. 2009).

Conservation assessments are based on different assumptions about ecological effectiveness and researchers generally assume a positive correlation between the effectiveness and extent of protection. The simplest and most common approach to gap analysis is to assume that effectiveness is binary: Areas are either protected or not. Previous marine gap analyses focused on the extent of permanent closures and managed areas in aggregate (e.g., Mora et al. 2006; Wood et al. 2008; Weeks et al. 2010). To the best of our knowledge, marine gap analyses have not previously included the relative contribution of different actions to conservation objectives.

We based our examination of Fiji's progress toward its national conservation goal on the extent to which different actions resulted in inclusion of species groups and ecosystems in protected areas and the ecological effectiveness of those actions. We used Fiji as a case study because one of the authors (S.D.J.) is leading the Marine Working Group of the Fiji Protected Area Committee, which is charged with expanding the national network of marine protected areas (MPAs). Fiji is a good case study because the national government has committed to protecting 30% of its inshore and offshore waters within MPAs by 2020 (Jupiter et al. 2010) and it is the country with the greatest spatial coverage of community-based management actions in the Pacific. These actions were established by communities, primarily to maintain livelihoods (Govan et al. 2009). We believe our results will help in the understanding of how community-driven conservation efforts can contribute to national conservation objectives.

Methods

Study Region

Fiji's nearshore waters are divided into 410 traditional fishing grounds, the boundaries of which are legally demarcated by the Native Lands and Fisheries Commission from the low water mark to outer barrier reefs (Fig. 1). Traditional fishing grounds are areas where fishing rights for indigenous Fijians are legally recognized by the Fiji Fisheries Act, but the state owns the seabed and overlying waters.

Over 10,000 km^2 of Fijian waters are included within locally managed marine areas (LMMAs). The number of LMMAs in Fiji grew from 1 in 1997 to over 100 by 2009. This growth came from community requests for assistance to the Fiji LMMA network to stem a perceived decline in fish (Govan et al. 2009). The Fiji LMMA network is a group of resource management and conservation practitioners who focus on lessons learned about the benefits and shortcomings of marine management actions in Fiji. An LMMA in Fiji is defined as an area of inshore waters governed by local residents and involving a collective understanding of, and commitment to, management interventions in response to threats to marine resources (Fig. 2). Equivalent to MPAs, LMMAs can be subject to multiple, simultaneous management actions. Within the boundaries of an LMMA, community members may choose to establish permanent closures or closures in which periodic harvest is allowed. The application of periodic harvest is based on long-standing Pacific traditions of resource management (e.g., Clarke & Jupiter 2010). Permanent closures prohibit all extractive use of resources indefinitely. We call periodically harvested closures that allow harvests once per year or less as dictated by a management plan or collective decision at the community level conditional closures with controlled harvesting. Many of the periodically harvested areas in Fiji are harvested without any predefined frequency and duration. We refer to these as conditional closures with uncontrolled harvesting. Other management is the suite of management actions, including bans on fishing gear, take of certain species, and seasonal prohibitions, that operate in LMMAs but outside closures. Other types of management actions not associated with the LMMA network exist (e.g., licensing controls), but spatial data on their implementation are unavailable.

Fiji's Inshore Marine Ecosystems

Fiji's Protected Area Committee has identified 7 priority ecosystems (i.e., ecosystems of high priority for conservation because of their ecological role, cultural significance, uniqueness, and rarity) in Fijian coastal and inshore marine waters (Jupiter et al. 2010) (Supporting Information). National-level spatial information (from the

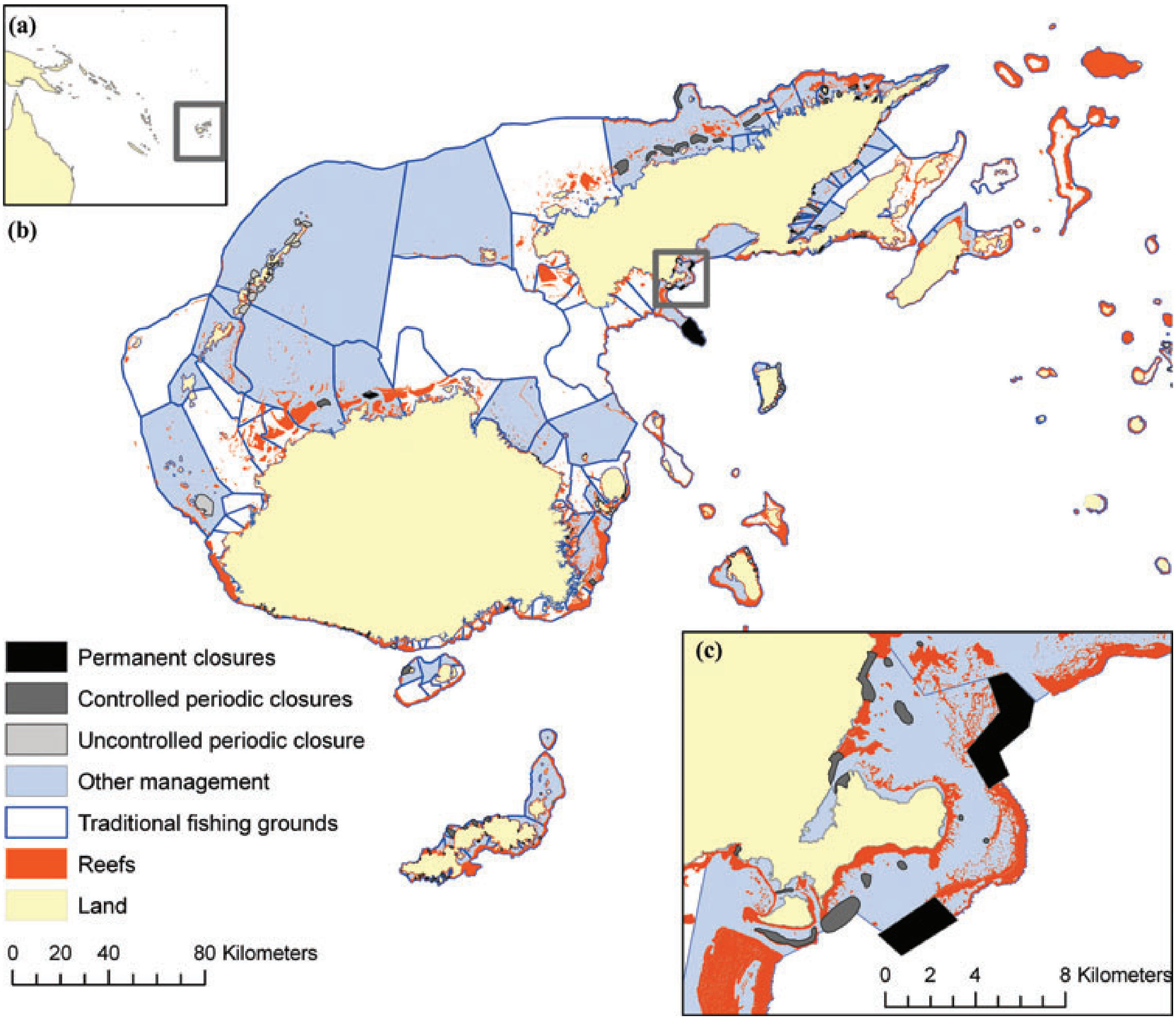

Figure 1. Location of (a) Fiji in the western Pacific Ocean; (b) map of Fiji showing current locally managed marine areas, which include all permanent closures, conditional closures with controlled harvesting, conditional closures with uncontrolled harvesting, and other management (unshaded areas are traditional fishing grounds with no known management actions); and (c) part of the Kubulau traditional fishing ground and its permanent and conditional closures (square on map [b]).

Fijian Federal Government and the Intergovernmental Oceanographic Commission) is available only for mangroves, fringing reefs, nonfringing reefs, intertidal areas, and other benthic substrata (soft-bottom lagoons and seagrass combined in 4 depth classes [0–5 m, 5–10 m, 10–20 m, and 20–30 m]; Supporting Information). We processed these data in ArcInfo 9.3 (ESRI, Redmond, California) (details in Supporting Information) and assembled them into a map of Fijian marine ecosystems used for the gap analysis. Data processing took approximately 2 months.

Conservation Objectives and Effectiveness of Actions

We held a workshop in Suva, Fiji, in March 2010 with 12 experts in local flora and fauna and extensive experience with local resource management (Supporting Information has additional information details on experts). The workshop had 2 main purposes: identification of ecosystem-specific conservation objectives on the basis of the national government's goal of managing 30% of inshore waters and assignment, by expert participants, of values of ecological effectiveness to selected species groups in each ecosystem (Jupiter et al. 2010). We call the assigned values (Table 1) ecological effectiveness scores. Experts selected species groups that they considered of national importance (e.g., fish). Identification of species groups allowed experts to more easily estimate the potential effects of different management actions, effects that vary depending on, for example, the species' probability of being harvested by the fishing gear used in an ecosystem (Table 1).

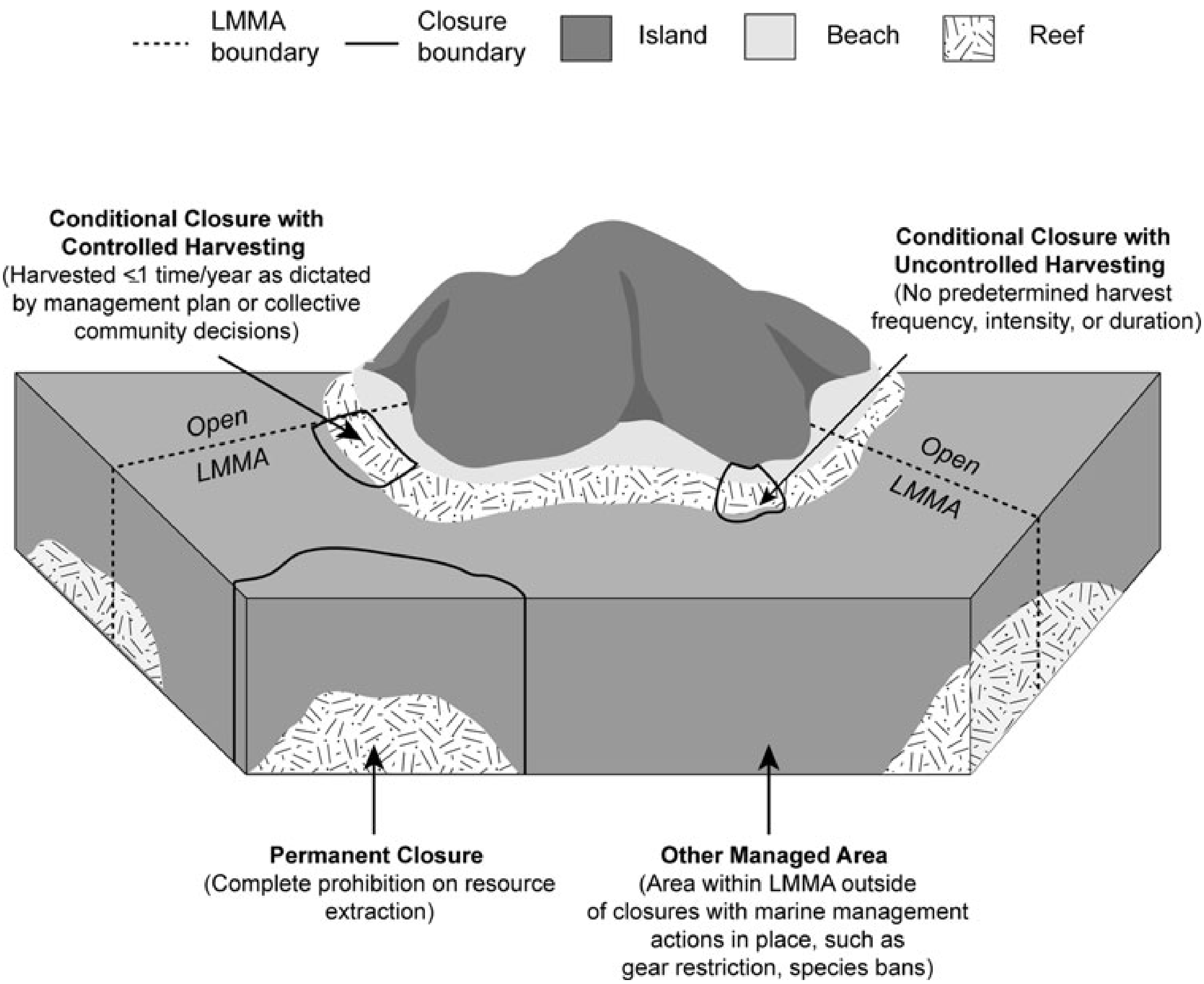

Figure 2. A schematic diagram of a locally managed marine area (LMMA). An LMMA is an area of inshore waters governed by those with traditional fishing rights and involving a collective understanding of, and commitment to, management intervention in response to threats to marine resources. As shown these areas can be subject to multiple, simultaneous resource-management actions.

Empirical data on ecological effectiveness in Fiji are unavailable at a national level. Expert opinion was therefore the only source of information. Experts are often consulted on the effectiveness of management actions because it is difficult to collect empirical data (Pomeroy et al. 1997; McClanahan et al. 2005*a*; Martin et al. 2005). Elicitation of expert opinion can be undertaken with different levels of quantitative rigor, depending on the amount of data available to support expert judgments (e.g., Martin et al. 2005).

Given the diversity of backgrounds of our experts, we initiated the workshop through dialectic inquiry (Mitroff et al. 1979; Schweiger et al. 1986), in which opposing views on ecological effectiveness for different species groups were presented and discussed. We considered this preferable to surveying each expert (Pomeroy et al. 1997; McClanahan et al. 2005*a*, 2005*b*) because it allowed evaluation of the information and assumptions by all experts and because group participation and discussion is critical for the acceptance of results and commitment to acting on them (Schweiger et al. 1986). This approach also helped link our study to practical outcomes.

We described our concept of ecological effectiveness to the experts and asked them to discuss and estimate effectiveness scores from 0 (ineffective) to 1 (maximum effectiveness) at 0.05 increments for the different management actions within LMMAs. Final scores represented the consensus on ecological effectiveness among the experts (Table 1). Scores were based on the response to fishing and mobility of different species within species groups, limitations and selectivity of fishing gear, changes to species' habitats associated with existing fishing practices, and accessibility of ecosystems to fishers. Permanent closures were given a score of 1. A score of 0.5 indicated that, per unit area, a management action would maintain populations at half the densities in permanent closures, averaged over time.

Table 1. Ecological effectiveness[a] of each management action for conservation of selected species groups in each ecosystem.

Ecosystem and species group[b]	*Permanent closures*	*Conditional closures with controlled harvesting*	*Conditional closures with uncontrolled harvesting*	*Other management*
Total area (km^2)	122	233	212	17159
Fringing reefs				
corals	1	0.80	0.50	0.40
targeted invertebrates	1	0.70	0.10	0.20
nontargeted invertebrates	1	0.90	0.60	0.45
targeted fish	1	0.80	0.15	0.20
nontargeted fish	1	0.90	0.50	0.45
coralline algae	1	0.80	0.50	0.40
range	1	0.70–0.90	0.10–60	0.20–0.45
Nonfringing reefs				
corals	1	0.80	0.55	0.40
targeted invertebrates	1	0.70	0.10	0.20
nontargeted invertebrates	1	0.90	0.80	0.45
targeted fish	1	0.80	0.15	0.20
nontargeted fish	1	0.90	0.60	0.45
coralline algae	1	0.80	0.55	0.40
range	1	0.70–0.90	0.10–0.80	0.20–0.45
Mangrove				
targeted invertebrates	1	0.80	0.15	0.20
nontargeted invertebrates	1	0.95	0.85	0.50
targeted fish	1	0.50	0.10	0.15
nontargeted fish	1	0.60	0.30	0.30
mangrove	1	0.95	0.85	0.25
seabirds	1	0.95	0.85	0.20
bats	1	0.95	0.85	0.25
range	1	0.50–0.95	0.10–0.85	0.15–0.50
Intertidal				
targeted invertebrates	1	0.70	0.10	0.20
nontargeted invertebrates	1	0.90	0.80	0.45
targeted fish	1	0.80	0.50	0.20
nontargeted fish	1	0.90	0.80	0.45
seabirds	1	0.95	0.20	0.25
range	1	0.70–0.90	0.10–0.80	0.20–0.45
Other benthic substrata[c]				
targeted invertebrates	1	0.70	0.30	0.20
nontargeted invertebrates	1	0.90	0.80	0.45
targeted fish	1	0.80	0.50	0.20
nontargeted fish	1	0.90	0.80	0.45
range	1	0.70–0.90	0.30–0.80	0.20–0.45

[a]*Effectiveness values range from 0 (management action not effective) to 1 (management action fully effective; assumed to be provided by permanent closures) and are given to the nearest 0.05.*
[b]*Species groups divided into targeted (i.e., species deliberately sought for subsistence or commercial purposes) and nontargeted because management of a fishing ground is likely to increase abundance of targeted species to a greater extent than nontargeted species.*
[c]*Other benthic substrata consists of 4 depth classes, all of which had the same selected species groups and effectiveness scores.*

These scores were based on an assumption of full compliance with management actions because we lacked spatial data on compliance. We believe that a high level of compliance is likely because the management actions are community driven (Johannes 2002). However, full compliance is unlikely to be achieved consistently.

Gap Analyses

To assess whether objectives for representation of ecosystems set at the March 2010 workshop were achieved, we collated information on the distribution of ecosystems, management actions, and ecological effectiveness. We then applied 3 alternative gap analyses, each with different assumptions: (1) all parts of LMMAs (including closures and other management) conserve species and ecosystems effectively; (2) closures conserve species and ecosystems whereas areas outside of closures, open to varying levels of resource extraction, do not; and (3) different management actions permitting different levels of resource extraction vary in their ability to conserve species and ecosystems. Assumptions 1 and 2 are typical of gap analyses (e.g., Mora et al. 2006; Wood et al. 2008; Weeks et al. 2010). We based assumption 3 on the consensus about ecological effectiveness attained at the 2010 workshop.

Spatial data were available for 4 types of management actions: permanent closures, conditional closures with controlled harvesting, conditional closures with uncontrolled harvesting, and the combination of other management actions in parts of LMMAs outside mapped closures. We updated the boundaries of LMMAs and closures presented in Govan et al. (2009), which resulted in a total of 149 LMMAs and 216 closures (Fig. 1). In total the LMMAs and closures covered, respectively, about 60% (approximately 17,726 km^2) and 2% (approximately 567 km^2) of the total extent of traditional fishing grounds. We overlaid LMMAs, closure maps, and the ecosystem map in ArcInfo (version 9.3) and calculated the area of each ecosystem (Supporting Information) subject to each management action (Supporting Information).

To apply assumption 1, we calculated the area of each ecosystem type covered by LMMAs (e.g., 1 km^2 of mangrove within an LMMA counted as 1 km^2 of effectively managed mangrove). To apply assumption 2, we calculated the area of each ecosystem type covered by closures (e.g., 1 km^2 of mangrove within a closure counted as 1 km^2 of effectively managed mangrove). To apply assumption 3, we used different scores of ecological effectiveness for different species groups within the mapped ecosystems (Table 1). We calculated the areas that were effectively managed within each ecosystem type by multiplying the percent area of each ecosystem under each management action by the effectiveness scores attributed to each species group within that ecosystem:

$$E = \sum_{A \to D} \frac{(S_A)(t_A)}{T} \times 100, \qquad (1)$$

where E is the percentage of effectively managed area for the selected species group, $A \to D$ is the different management actions (Table 1), S is the effectiveness score attributed to a management action for the species group (Table 1), t is the area of the ecosystem covered by each management action, and T is the total area of the ecosystem within the Fijian traditional fishing grounds. We then identified the highest and lowest E (i.e., the maximum and minimum percent areas of each ecosystem type effectively protected across all species groups).

Results

Conservation Objectives and Ecological Effectiveness

Ecological effectiveness scores varied from 0.10 to 1 (Table 1). Conditional closures with controlled harvesting had relatively high scores (0.50–0.95). Conditional closures with uncontrolled harvesting and other management areas had scores of 0.10–0.85 and 0.15–0.50, respectively.

Experts provided 4 broad statements of opinion to support their effectiveness scores. First, conditional closures with uncontrolled harvesting are less effective at protecting targeted invertebrates than targeted fish because fish rapidly learn to avoid highly fished areas. Second, targeted invertebrates and fish are more effectively protected within managed areas outside closures and on nonreef substrata than on reefs protected by conditional closures with uncontrolled harvesting. This difference in effectiveness was attributed to intense concentration of fishing effort within conditional closures with uncontrolled harvesting during openings. Third, the effectiveness of conditional closures with controlled and uncontrolled harvesting in mangroves is similar for targeted and nontargeted fish because use of gill nets, a relatively unselective gear type, is high. Fourth, differences in ecological effectiveness between fringing and nonfringing reefs are due to the greater accessibility of fringing reefs and to greater effects from trampling during fishing activities.

Gap Analyses

The LMMAs ranged in size from 0.01 to 4168 km^2 (mean = 119 km^2, median = 11 km^2). When all parts of LMMAs were assumed to conserve species and ecosystems effectively (assumption 1), conservation objectives for all ecosystems were exceeded (Fig. 3) and coverage of all ecosystems was >40%. The highest coverage was for other benthic substrata at depths of 0–5 m and 5–10 m (59% and 60%, respectively).

Closures ranged from 0.01 to 66 km^2 (mean = 3 km^2, median = 0.73 km^2). When closures were assumed to conserve species and ecosystems, but areas outside closures were assumed to offer no protection (assumption 2), none of Fiji's conservation objectives were met (Fig. 3). Coverage ranged from a maximum of 6% for fringing reefs to 1% for intertidal ecosystems.

When different management actions were assumed to vary in their ability to conserve species and ecosystems (assumption 3), Fiji met or exceeded its conservation objectives only for other benthic substrata in all depth classes (Fig. 3 & Supporting Information). Additional coverage of between 10% and 20% of fringing reef, nonfringing reef, mangrove, and intertidal ecosystems was still required to meet objectives. For fringing reefs, one of the most heavily fished ecosystems, to meet the objective required the addition of either 402 km^2 of permanent closures, 574 km^2 of conditional closures with controlled harvesting, 1340 km^2 of conditional closures with uncontrolled harvesting, or 2010 km^2 of other management. The extent of unmanaged fringing reef in Fiji was 867 km^2.

Discussion

Our study was designed to inform an impending policy commitment by the Government of Fiji to complete a national marine gap analysis, but our approach is applicable to other countries where empirical data on ecological

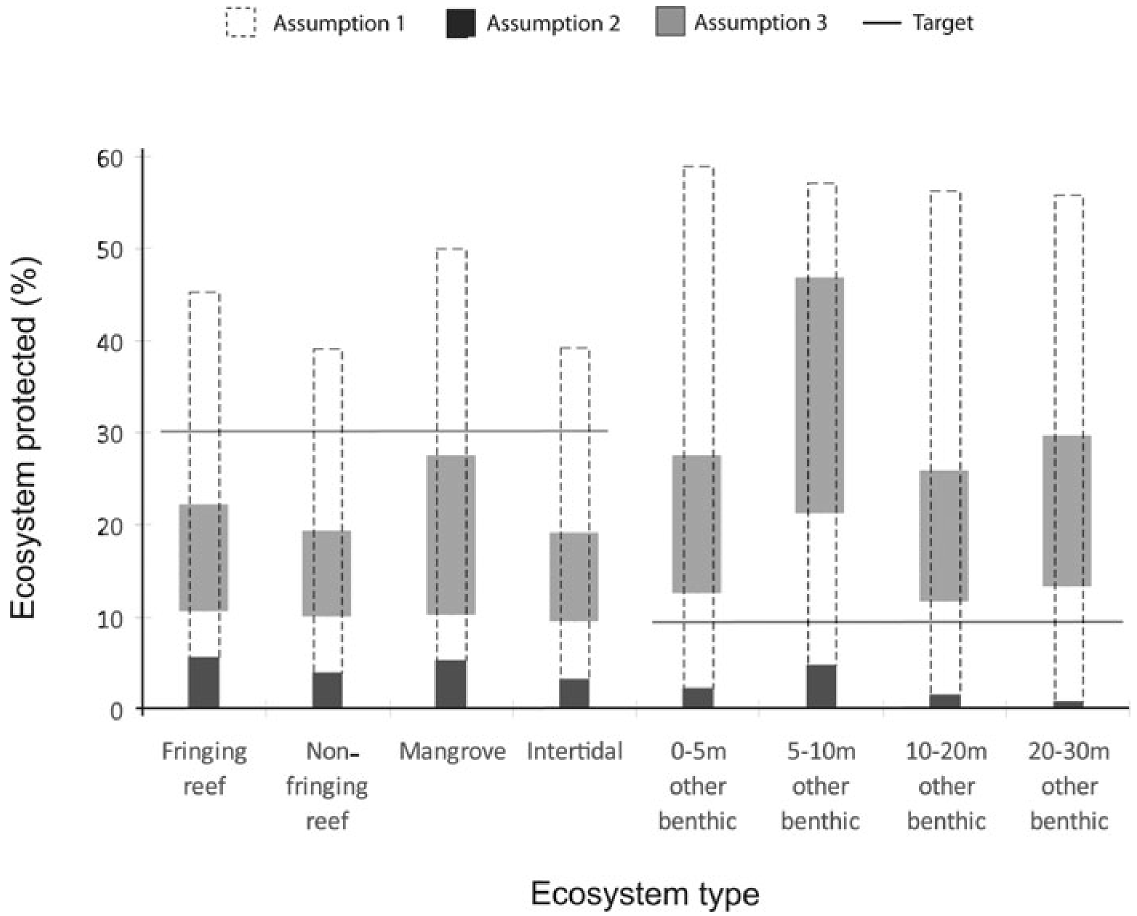

Figure 3. Percentages of 8 ecosystems protected effectively on the basis of 3 assumptions about ecological effectiveness of management actions: assumption 1, all parts of locally managed marine areas (including closures and other management) conserve species and ecosystems effectively; assumption 2, closures conserve species and ecosystems, whereas areas outside closures, open to varying levels of resource extraction, do not; assumption 3, different management actions permitting different levels of resource extraction vary in their ability to conserve species and ecosystems. Ranges of percentages for assumption 3 are based on upper and lower effectiveness scores in Table 1. Gray horizontal lines indicate objective for each ecosystem.

effectiveness are limited. Our 3 assumptions varied in their validity.

Assuming that all parts of LMMAs effectively conserve species and ecosystems leads to inferring that all conservation objectives were achieved. However, despite the rapid increase in the number of community-based conservation initiatives, the limited data available suggest that the abundances of species harvested on Fijian inshore reefs are declining, with many harvested invertebrates already at low abundances (Teh et al. 2009). Although Fijian LMMAs span large areas and LMMAs have been implemented by communities across the Pacific, declining resources indicate existing management measures within LMMAs may not be sufficient to ensure long-term sustainability of inshore fisheries.

Assuming that closures conserve species and ecosystems and areas outside closures open to varying levels of resource extraction do not, Fiji's conservation objectives were not achieved. Management through closures has 3 related limitations in Fiji. First, over 99% of the closures were extremely small (median size 0.73 km^2), similar to other parts of the Asia-Pacific region (Bartlett et al. 2009; Weeks et al. 2010). On the basis of larval and adult dispersal and the size of self-sustaining populations of benthic species, closures of 10–100 km^2 are recommended to protect most species associated with benthic ecosystems (Halpern & Warner 2003). The second limitation of closures was that communities in Fiji are unlikely to close 30% of their traditional fishing grounds periodically or permanently (Agardy et al. 2003). Third, communities are unlikely to distribute closures evenly across ecosystems because they prefer locations within view of villages to improve compliance (e.g., Aswani & Hamilton 2004). Communities could, however, be encouraged to adopt complementary actions (e.g., gear or species restrictions) that contribute to conservation objectives and are more socially acceptable (Johannes 2002).

The assumption that different management actions vary in their effectiveness recognizes species- and ecosystem-specific variation in ecological effectiveness in Fiji, including the adverse effects of conditional closures with uncontrolled harvesting and the partial protection offered by management actions operating outside closures but within LMMAs. On the basis of this assumption, Fiji still did not achieve its conservation objectives, but considerable progress toward them was made. To meet conservation objectives, we recommend a combination of larger and more numerous permanent closures or conditional closures with controlled harvest within LMMAs and land-based management actions that mitigate pollution and nutrient runoff. These recommendations were recently presented to administrators from Fiji's 14 provinces to identify candidate sites for protection and management that could fill the gaps in the representation of ecosystems while meeting both local and national conservation goals (Jupiter et al. 2011).

The greatest challenge to incorporating ecological effectiveness into gap analyses or planning exercises is the paucity of empirical data (Agardy et al. 2003; Edwards et al. 2010). Within most of the scientific literature, conclusions have been drawn from observations made inside and outside permanent closures (Russ 2002; Lester et al. 2009), although research on the relative effectiveness of other management actions is emerging (e.g., Cinner et al. 2005; Bartlett et al. 2009). In this context, expert opinion is essential, but has limitations. First, experts are unlikely to have full understanding of all ecosystems and management approaches. Even if information is available, people have limited ability to access and process it (Einhorn et al. 1977). Second, not all individuals with the knowledge of the effects of management on different species can be included in a participatory process. Third, perceived effectiveness will be influenced by individuals' social and economic background, such as ethnicity or employment (e.g., McClanahan et al. 2005*b*). Finally, the opinions of individuals are likely to change given social pressures within a workshop or a community (Einhorn et al. 1977).

We suggest an adaptive-management approach where a few data on ecological effectiveness are available, whereby scores are elicited from experts and the results are then tested through field surveys and refined as data accumulate (Salafsky et al. 2002). Expert elicitation can provide impetus for collecting empirical data. Results from our study are already helping garner funds for field experiments on the ecological effectiveness of Fiji's management actions. For example, a proposal for funding to carry out experiments investigating ecological effectiveness of management in Fiji has been submitted to the LifeWeb initiative, an initiative promoted through the CBD that is designed to match donors to projects that build on the results of countries' gap analysis. We concentrated on ecological effectiveness in relation to mapped ecosystems, but recognize that the effectiveness of management depends ultimately on other factors, such as the productivity of ecosystems, the protection of biological processes, the social and economic characteristics of managed and surrounding areas, and compliance (Hockings et al. 2006). Barriers to compliance in Fiji include conflict between customary management rules and both national legal frameworks and incentives to fish from growing global markets (Clarke & Jupiter 2010). For example, the Fisheries Act does not grant authority to those with traditional fishing grounds to legally enforce customary management actions (Clarke & Jupiter 2010). Imminent legislative reform seeks to rectify this.

Considering the varying ecological contributions of management actions is important for 2 reasons. First, the achievement of conservation objectives can be evaluated in countries where large permanent closures are not feasible, as in many Pacific island nations (Johannes 2002). Second, it facilitates the design of complementary management actions for particular social and ecological contexts. Attempts to achieve all marine conservation objectives through permanent closures are likely to create unnecessary conflict (Agardy et al. 2003).

Acknowledgments

M.M. acknowledges support from the Australian National Network in Marine Science. S.D.J. acknowledges support from the Wildlife Conservation Society through the John D. and Catherine T. MacArthur Foundation (grant 10-94985-000-GSS) and support from the Fiji Protected Area Committee through an early action grant from United Nations Development Program-Global Environmental Facility. R.L.P. and N.C.B. acknowledge support from the Australian Research Council. All authors thank the Fiji LMMA network and Protected Area Committee members for their participation in this study and the input from A. Batibasaga and W. Aalbersberg.

Supporting Information

Spatial data on Fiji marine ecosystems (sources and data processing (Appendix S1); information on the institutions represented at the workshop (Appendix S2); and the percentage of contributions to quantitative objectives determined through expert assessment of the differential effectiveness of management actions (Appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Agardy, T., et al. 2003. Dangerous targets? Unresolved issues and ideological clashes around marine protected areas.

Aquatic Conservation-Marine and Freshwater Ecosystems **13:**353–367.

Aswani, S., and R. Hamilton. 2004. The value of many small vs. few large marine protected areas in the Western Solomon Islands. SPC Traditional Marine Resource Management and Knowledge Information Bulletin **16:**3–14.

Bartlett, C. Y., C. Manua, J. Cinner, S. Sutton, R. Jimmy, R. South, J. Nilsson, and J. Raina. 2009. Comparison of outcomes of permanently closed and periodically harvested coral reef reserves. Conservation Biology **23:**1475–1484.

CBD (Convention on Biological Diversity). 2008. Convention on biological diversity. Secretariat of the Convention on Biological Diversity, Bonn, North Rhine-Westphalia. Available from http://www.cbd.int/ (accessed July 2010).

Cinner, J. E., M. J. Marnane, and T. R. McClanahan. 2005. Conservation and community benefits from traditional coral reef management at Ahus Island, Papua New Guinea. Conservation Biology **19:**1714–1723.

Clarke, P., and S. D. Jupiter. 2010. Law, custom and community-based natural resource management in Kubulau district (Fiji). Environmental Conservation **37:**98–106.

Desmet, P., and R. Cowling. 2004. Using the species-area relationship to set baseline targets for conservation. Ecology and Society **9:** http://www.ecologyandsociety.org/vol9/iss2/art11/.

Edwards, H. J., I. A. Elliott, R. L. Pressey, and P. J Mumby. 2010. Incorporating ontogenetic dispersal, ecological processes and conservation zoning into reserve design. Biological Conservation **143:**457–470.

Einhorn, H. J., R. M. Hogarth, and E. Klempener. 1977. Quality of group judgment. Psychological Bulletin **84:**158–172.

Govan, H., et al. 2009. Status and potential of locally-managed marine areas in the South Pacific: meeting nature conservation and sustainable livelihood targets through wide-spread implementation of LMMAs. Document SPREP/WWF/WorldFish-Reefbase/CRISP. ReefBase Project, WorldFish Center, Penang, Malaysia.

Halpern, B. S., and R. R. Warner. 2003. Matching marine reserve design to reserve objectives. Proceedings of the Royal Society of London B Biological Sciences **270:**1871–1878.

Hockings, M., S. Stolton, F. Leverington, N. Dudley, and J. Courrau. 2006. Evaluating effectiveness: a framework for assessing management effectiveness of protected areas. International Union for Conservation of Nature, Gland, Switzerland.

Johannes, R. E. 2002. The renaissance of community-based marine resource management in Oceania. Annual Review of Ecology and Systematics **33:**317–340.

Jupiter, S., M. Mills, J. Comley, A. Batibasaga, and A. Jenkins. 2010. Fiji marine ecological gap assessment: interim progress report. Wildlife Conservation Society, Suva, Fiji.

Jupiter, S., K. Tora, M. Mills, R. Weeks, V. M. Adams, I. Qauqau, A. Nakeke, T. Tui, Y. Nand, and N. Yakub. 2011. Filling the gaps: identifying candidate sites to expand Fiji's national protected area network. Outcome report from provincial planning meeting, 20–21 September. Wildlife Conservation Society, Suva, Fiji.

Lester, S. E., B. S. Halpern, K. Grorud-Colvert, J. Lubchenco, B. I. Ruttenberg, S. D. Gaines, S. Airame, and R. R. Warner. 2009. Biological effects within no-take marine reserves: a global synthesis. Marine Ecology-Progress Series **384:**33–46.

Margules, C. R., and R. L. Pressey. 2000. Systematic conservation planning. Nature **405:**243–253.

Martin, T. G., P. M. Kuhnert, K. Mengersen, and H. P. Possingham. 2005. The power of expert opinion in ecological models using Bayesian methods: impact of grazing on birds. Ecological Applications **15:**266–280.

McClanahan, T., J. Davies, and J. Maina. 2005*a*. Factors influencing resource users and managers' perceptions towards marine protected area management in Kenya. Environmental Conservation **32:**42–49.

McClanahan, T. R., J. Maina, and J. Davies. 2005*b*. Perceptions of resource users and managers towards fisheries management options in Kenyan coral reefs. Fisheries Management and Ecology **12:**105–112.

McCook, L. J., et al. 2010. Adaptive management and monitoring of the Great Barrier Reef: a globally significant demonstration of the benefits of networks of marine reserves. Proceedings of the National Academy of Sciences of the United States of America **43:**18278–18285.

Mitroff, I. I., J. R. Emshoff, and R. H. Kilmann. 1979. Assumptional analysis: a methodology for strategic problem solving. Management Science **25:**583–593.

Mora, C., S. Andrefouet, M. J. Costello, C. Kranenburg, A. Rollo, J. Veron, K. J. Gaston, and R. A. Myers. 2006. Coral reefs and the global network of marine protected areas. Science **312:**1750–1751.

Pomeroy, R. S., R. B. Pollnac, B. M. Katon, and C. D. Predo. 1997. Evaluating factors contributing to the success of community-based coastal resource management: the central Visayas regional project-1, Philippines. Ocean & Coastal Management **36:**97–120.

Pressey, R. L., and K. H. Taffs. 2001. Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. Biological Conservation **100:**355–376.

Rondinini, C., and F. Chiozza. 2010. Quantitative methods for defining percentage area targets for habitat types in conservation planning. Biological Conservation **143:**1646–1653.

Russ, G. R. 2002. Yet another review of marine reserves as fishery management tools. Pages 421–443 in P. Sale, editor. Coral reef fishes. 2nd edition. Elsevier Science, New York.

Russ, G. R., and A. C. Alcala. 1999. Management histories of Sumilon and Apo marine reserves, Philippines, and their influence on national marine resource policy. Coral Reefs **18:**307–319.

Sala, E., and N. Knowlton. 2006. Global marine biodiversity trends. Annual Review of Environment and Resources **31:**93–122.

Salafsky, N., R. Margoluis, K. H. Redford, and J. G. Robinson. 2002. Improving the practice of conservation: a conceptual framework and research agenda for conservation science. Conservation Biology **16:**1469–1479.

Schweiger, D. M., W. R. Sandberg, and J. W. Ragan. 1986. Group approaches for improving strategic decision making: a comparative analysis of dialectical inquiry, devil's advocacy, and consensus. Academy of Management Journal **29:**51–71.

Scott, M. J., et al. 1993. Gap analysis: a geographic approach to protection of biological diversity. Wildlife Monographs **123:**3–41.

Shahabuddin, G., and M. Rao. 2010. Do community-conserved areas effectively conserve biological diversity? Global insights and the Indian context. Biological Conservation **143:**2926–2936.

Teh, L. C. L., L. S. L. Teh, B. Starkhouse, and U. R. Sumaila. 2009. An overview of socio-economic and ecological perspectives of Fiji's inshore reef fisheries. Marine Policy **33:**807–817.

Weeks, R., G. R. Russ, A. Alcala, and A. White. 2010. Effectiveness of marine protected areas in the Philippines for biodiversity conservation. Conservation Biology **24:**531–540.

Wood, L. J., L. Fish, J. Laughren, and D. Pauly. 2008. Assessing progress towards global marine protection targets: shortfalls in information and action. Oryx **42:**340–351.