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Systematic conservation planning within a Fijian customary governance context

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Abstract. Although conservation planning research has influenced conservation actions globally in the last two decades, successful implementation of systematic conservation plans in regions where customary marine tenure exists has been minimal. In such regions, local community knowledge and understanding of socioeconomic realities may offer the best spatially explicit information for analysis, since required socioeconomic data are not available at scales relevant to conservation planning. Here we describe the process undertaken by the Kadavu Yaubula Management Support Team, a team of researchers from The University of the South Pacific and the local communities to assess whether systematic conservation planning tools can be effectively applied and useful in a customary governance context, using a case study from Fiji. Through a participatory approach and with the aim of meeting local-scale conservation and fisheries needs, a spatial conservation planning tool, Marxan with Zones, was used to reconfigure a collection of locally designed marine protected areas in the province of Kadavu in order to achieve broader objectives. At the local scale, the real value of such tools has been in the process of identifying and conceptualising management issues, working with communities to collate data through participatory techniques, and in engaging communities in management decision making. The output and use of the tool has been of secondary value. The outcome was invaluable for developing marine protected area network design approaches that combine traditional knowledge with ecological features in a manner appropriate to a Melanesian context.

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Introduction

Conservation planning is the process by which conservation areas are located, configured and managed in some way to promote the persistence of natural features (Bottrill and Pressey 2009). Systematic approaches to conservation planning (Margules and Pressey 2000), which involve working through a structured, transparent and defensible process of decision-making, increasingly underpin the conservation and management of marine and coastal ecosystems worldwide (Bottrill and Pressey 2009). However, whilst the Pacific islands have a long history of community-based marine resource management (Johannes 2002), systematic conservation planning has had very little influence in this region.

There are substantial challenges to undertaking systematic conservation planning in the Western Pacific (Weeks *et al.* 2014): local communities are highly dependent upon natural resources; management of marine resources is typically decentralised and often under customary systems of governance; few ecological or socioeconomic datasets are available across the regional extents required by systematic conservation planning; and in-country capacity to undertake planning is lacking. Nevertheless, new approaches are needed to address the growing threats to the region's resources, and conservation planning might provide a means to better coordinate community-based management actions to increase their overall impact.

In Pacific Island Countries increased local subsistence harvests and commercial fishing have left most coastal waters in the region overfished (Gillett 2009; Bell *et al.* 2011). In response, a growing number of villages have begun to regulate the use of their marine areas through the establishment of locally-managed marine areas (LMMAs). To date there are hundreds of these LMMAs in operation around the region (http://www.lmmanetwork.org/). Management measures employed within LMMAs include permanent no-take marine protected areas (MPAs), periodically harvested fisheries closures, species-specific regulations such as size limits, fishing gear and access restrictions (Jupiter *et al.* 2014).

The benefits of permanent, no-take MPAs have been widely demonstrated in the literature. Over time, MPAs have shown conservation benefits through increased abundance, biomass, density, body size, species diversity and richness of targeted fishes and invertebrates (Russ and Alcala 2003*a*; McClanahan and Graham 2005). MPAs have also offered fisheries benefits through spillover effects outside MPA boundaries (McClanahan and Kaunda-Arara 1996; McClanahan and Mangi 2000) and may contribute towards poverty alleviation and increase the quality of life of surrounding communities (Allison *et al.* 1998; Leisher *et al.* 2007; Gurney *et al.* 2014).

In Fiji, as the number of LMMAs and MPAs has increased, there has been a shift in focus towards management of these sites at the provincial level. The Province of Kadavu has been leading the way in this regard. The Kadavu Provincial Administration (with support from the Institute of Applied Science of the University of the South Pacific, IAS-USP) established the Kadavu *Yaubula* (living-wealth) Management Support Team (KYMST) to promote the sustainable development and utilisation of Kadavu's natural resources. Since its establishment, the KYMST has taken a lead role in resource management initiatives, environmental awareness and protection activities in the Province.

Since 1997, 60 MPAs have been established within LMMAs with support from the provincial office. The boundaries of these MPAs were selected by the local communities to meet local-scale conservation and fisheries needs, as determined through community-based adaptive-management processes (Govan *et al.* 2008) and informed by community-level political boundaries and governance considerations. Each *iqoliqoli* (traditional fishing ground) in Kadavu is now under some form of management, with many having at least one MPA within their boundaries.

As this ground-swell of management has grown, greater consideration has been given to principles of MPA placement and the nature of management interventions being undertaken. Many management interventions are believed to contribute towards food security at the individual community level (Tawake *et al.* 2005; Leisher *et al.* 2007; UNEP/GRID-Arendal 2008). For instance, results from five LMMA sites across Kadavu saw a 55% increase in fish abundance within MPAs compared with 30% increase in harvested areas between 2003 and 2007 (Tawake *et al.* 2005). Similarly, there was a 30% increase in invertebrates within MPAs and 10% increase in adjacent harvest areas (Tawake *et al.* 2005). However, individual MPAs lack the coordinated island-wide outcomes sought by the province and the biodiversity conservation benefits associated with an integrated network of MPAs. Furthermore, some of the existing MPAs were located far offshore and were thus subject to poaching, others had disputed boundaries, and some communities had lifted their MPAs after observing no change in fish populations after one or two years of protection.

Here we describe the process undertaken by the IAS-USP, the KYMST and the communities of Kadavu to strengthen the MPA network design to better achieve both local and provincial objectives. This represents one of the first attempts to use systematic conservation planning tools to inform customary governance of natural resources, providing an opportunity to evaluate the effectiveness of these tools in this context.

Methods

Study site

Kadavu is a volcanic island arc in the Fiji Island group located in the South-west Pacific (Fig. 1). The island province is the fourth largest island in Fiji and is considered to be an area of great natural beauty and resource wealth. The island consists of 75 villages in nine districts, with a total population of ~10 200, most of whom rely almost entirely on fishing and farming for their livelihood. Kadavu has a land mass of 475 km^2 and 31 *iqoliqolis* covering an area of 719 km^2. Under the *Fiji Fisheries Act* these *iqoliqolis*, which range in size from 0.01 km^2

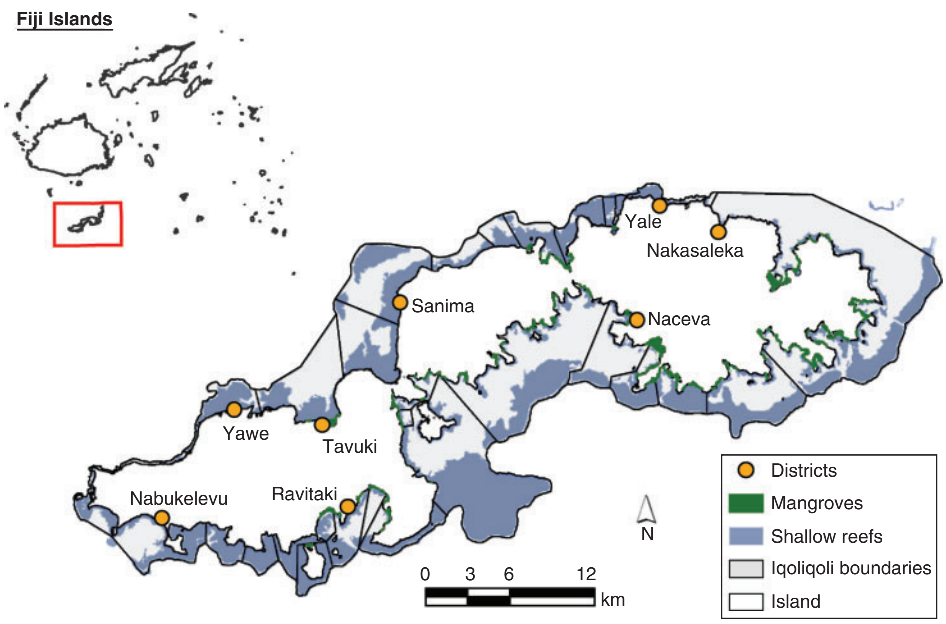

Fig. 1. The study site (main island of Kadavu) south of Viti Levu on the Fiji Islands.

to 88 km^2, are under a system of customary usage rights (Clarke and Jupiter 2010). Typically, many villages will share usage rights over an *iqoliqoli*. In this case the *iqoliqoli* is further subdivided into *ikanakana* (or grounds from which food can be caught). It is estimated that there are 75 *ikanakana* around Kadavu, approximately one per village. However, *ikanakana* are not legally recognised or demarcated, and in many cases their boundaries may be disputed. Our study region covers the main island of Kadavu which includes 29 inshore *iqoliqolis* with a total shallow reef area of ~200 km^2 (Fig. 1).

Community engagement and resource-use mapping

In Fiji, the customary marine tenure system qualifies the people of Kadavu to be the primary stakeholders because of their customary fishing rights over the *iqoliqolis* and the resources within (South and Veitayaki 1998). Initial engagement with local communities began in 2007, when a visioning exercise was conducted by the research team from the IAS-USP as part of a workshop facilitated by individuals from the US National Oceanic and Atmospheric Administration. This workshop brought together government representatives, local community leaders and individuals working within the Province who were instrumental in the development of the KYMST. The workshop reconfirmed the province-wide principles of marine resource management. However, perhaps the most important concept was that the workshop went as far as to explore the potential for trans-*iqoliqoli*-boundary MPA networks if these were likely to have a greater management potential than the sum of the existing individual MPAs.

At this workshop, stakeholders expressed a commitment to undertaking an island-wide initiative to establish a network of interconnected MPAs across the province to maximise fisheries benefits. Their goal was to protect 30% of their *iqoliqoli* shallow reef habitats within a network of MPAs that considered, where possible, the International Union for Conservation of Nature–World Commission on Protected Areas criteria for MPA network design (IUCN–WCPA 2008). An additional target was to protect at least 80% of known reef fish spawning aggregation sites (SPAGs). The communities requested assistance with spatial planning to identify ecologically significant areas to protect, whilst emphasising the need to consider site-based traditional governance and ecological knowledge in the design of the network.

In 2009, one-day workshops were conducted by the team from the IAS-USP in each of the eight districts around the main island of Kadavu. Key representatives were invited from each district to gather information on resource-use patterns, governance and cultural considerations across *iqoliqolis* (Wendt 2013). In order to maximise attendance, the most accessible and centrally located village was chosen as the workshop venue in each district. The maximum number of attendees per district workshop was 25, including different stakeholder groups based on the following criteria and covering a wide range of age groups and both former and current marine resource users: three chiefs from villages within the district; three representatives from District Environment Committees; three village headman from the district; three village fishermen from the district; two commercial fishermen from the district; two members of the KYMST from that district; three community representatives who conduct biological monitoring; three *iqoliqoli* owners; and three fisherwomen representatives.

Where socioeconomic data are not available at scales relevant to conservation planning (Cameron *et al.* 2008; Polasky 2008; Ban *et al.* 2009; Weeks *et al.* 2010*b*), local knowledge may offer the best information available. During the workshop, participatory mapping techniques were used whereby participants were divided into groups according to *iqoliqoli* user rights ownership. Copies of laminated maps showing satellite imagery and *iqoliqoli* boundaries overlaid with hexagonal grids were provided to participants to identify areas that the communities felt were important to include or exclude in the MPA network design. A list of questions prompted each group to indicate on the map areas that were important fishing grounds for different gear types and sites of ecological significance (e.g. turtle nesting sites, fish spawning aggregations) of which they were aware, to consider whether they were able to enforce any existing MPAs, and whether any governance boundaries were disputed (see Appendix 1). The information collected from communities was brought back to IAS-USP so that community responses could be digitised and used to identify priority areas for conservation.

In order to assess how well the existing system of community-based MPAs represented coral reef habitats, we undertook extensive field surveys to ground-truth the distributions of key shallow reef habitats derived from satellite imagery, using methodology adapted from Roelfsema *et al.* (2013). This led to the production of maps of reef geomorphic zones, shallow reef benthic structures and habitat types. These maps were then used to assess the existing system of MPAs against the IUCN ecological networking principles for MPAs; gaps in the current protection status for important marine areas were also evaluated.

Spatial prioritisation using Marxan with Zones

Marxan is a decision support tool that has been used in the design of marine reserves worldwide (Airamé *et al.* 2003; Leslie 2005). Marxan with Zones (Marxan Z) is an extension of the Marxan software that is able to assign planning units to multiple zones (i.e. MPAs and fishing areas) and incorporate multiple costs into a systematic planning framework (Watts *et al.* 2008). When running Marxan Z, the software allocates each planning unit in the study region to a particular zone in order to meet several ecological, social and economic objectives at a minimum total cost. We used Marxan Z to identify MPA networks that would achieve conservation and fisheries objectives specified by the communities on Kadavu, integrating habitat data derived from ground-truthed satellite imagery with local knowledge of ecologically, economically and culturally important sites.

As a result of the 2009 socio-cultural and resource-use workshops, six important geographic information systems (GIS) layers were identified: three layers of significant sites that should be included in the MPA network, and three layers associated with costs of MPA establishment. Significant sites identified by the communities included: (1) SPAGs, (2) turtle nesting sites, and (3) sites of cultural importance. Information on significant sites gained from community traditional knowledge was a priority inclusion as input conservation features in the Marxan Z analysis and in the redesign process of the community-based MPA network.

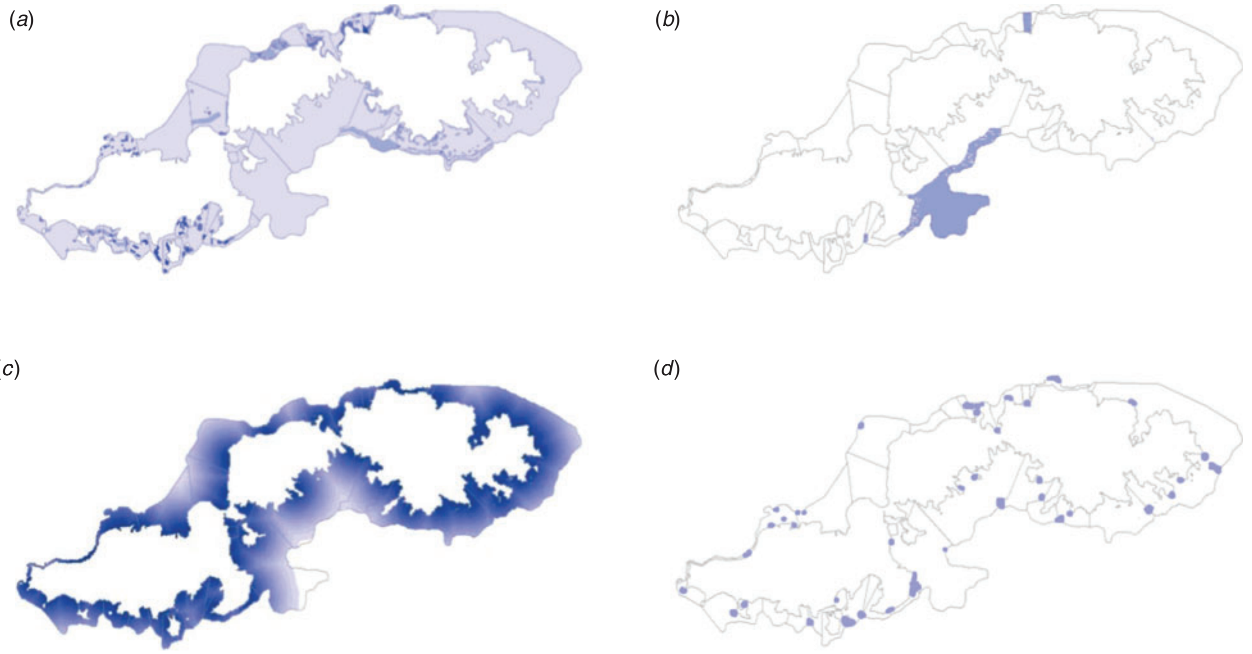

Fig. 2. Socioeconomic cost and priority feature layers derived from the participatory discussion with communities: (*a*) important fishing areas; (*b*) disputed areas; (*c*) enforceability distance; (*d*) significant sites.

The cost layers included: (1) fishing use intensity (i.e. opportunity cost), (2) disputed areas, and (3) enforceability (Fig. 2). Fishing grounds identified in each *iqoliqoli* were assigned to grid cells, validated using a rule set that constrained fishing gears to the appropriate depth zone (e.g. gleaning can only be undertaken in depths <5 m), summed and weighted to give equal importance to avoiding opportunity costs in each *iqoliqoli*. There were certain areas within an *iqoliqoli* where there have been historic disputes regarding traditional ownership. These disputed areas were assigned a high cost due to the perceived difficulty of implementing and enforcing an MPA in these areas. In most of the villages in the study area, the ability of the local community to enforce MPAs is limited. Few have access to boats, and those that do have limited access to fuel to undertake enforcement patrols. It was therefore considered important that any MPA be established within a relatively short distance from a village, and certainly within line-of-sight. Thus, an enforceability cost layer was created as the distance of each planning unit from the nearest village. The three cost layers were scaled from 0 to 1 to be used in the Marxan Z analysis.

The study region covering the entire inshore *iqoliqoli* areas was divided into 29 728 1.5-ha hexagonal planning units, to which information on the conservation features they contained and costs of inclusion in the MPA network were assigned. Conservation targets were to include in the MPA network 30% of the total extent of identified habitat types (continuous corals, patchy corals, sparse corals, patchy coralline algae, dense seagrass, sparse seagrass and patchy mangrove), and 80% of SPAGs, cultural sites and turtle nesting sites identified by communities. Targets were set for both the MPA and fishing zones with the aim to distribute costs and benefits more equitably across all *iqoliqolis*. In addition to minimising opportunity, enforceability, and disputed area costs, we specified fisheries objectives to ensure that at least 60% of each *iqoliqoli* remained open to fishing. Conservation targets for the MPA zone were set across the entire network, whilst the fishing targets were set for each *iqoliqoli*. We used Marxan's boundary length modifier to define a degree of clumping that produced compact areas that were more or less the same size as existing MPAs.

We produced two Marxan Z outputs, based on two different scenarios. First, the 'best' run solution (Ardron *et al.* 2010) was an output with the existing MPAs locked in and with conservation targets included. In this scenario, the contribution already made by the existing MPAs was recognised by Marxan Z and only additional areas to make up the shortfall between existing protection and the overall target were identified. It was decided early on in the study that, as many of the MPAs have been established for many years, the costs associated with relocating them would be considerable. This output was specifically produced for those communities who wanted to retain their existing MPAs but added additional areas to achieve the overall targets. Second, the selection frequency solution was an output without the existing MPAs locked in and with conservation targets included. In this scenario, only the overall feature targets were recognised by Marxan. This output was specifically for communities who expressed a desire to move the location of the existing MPAs within their *iqoliqoli* or for those communities who did not have any MPAs before this study.

Redesigning the MPA network

In February 2011, the team from IAS-USP worked with the KYMST and Kadavu Fisheries Department to conduct four community-level workshops to communicate the outputs from the reserve design scenarios and use these, through a collaborative planning process, to redesign the existing system of community-based MPAs to better protect identified

Fig. 3. MPA redesign process with communities. Photographs by H. K. Wendt.

conservation features and fisheries targets (Wendt 2013). A similar criterion to that used by the 2009 workshop was used to include the same stakeholders and decision makers in the network-redesign process. The redesign process used satellite imagery as base maps, with tracing paper overlays indicating priority conservation areas derived from the Marxan Z analyses (Fig. 3). These maps were used in the workshop to assist in the community discussions. In some instances communities wanted to retain their existing MPAs, and to add additional areas. Where this was the case, the best-run maps were most frequently used to guide the selection of areas for new MPAs. In other instances, some communities expressed a desire to move the location of their existing MPAs within their *iqoliqoli* to other areas that would contribute more towards conservation objectives. In these cases the selection-frequency maps were of most value in identifying these areas. Some villages that did not have any MPAs before this study used the best-run and the selection-frequency maps together. All modifications to the MPA network were endorsed at the relevant village meetings, and came into effect on 1 March 2011.

Results

The existing system of community-based MPAs protected 12% of key shallow reef habitats, 41% of SPAG sites, 24% of the area of turtle nesting sites and 7% of culturally important areas identified by communities (Table 1). Following the collaborative redesign workshops, a redesigned MPA network was finalised with communities based on the Marxan Z output scenarios. The number of MPAs increased from 60 to 77 (Fig. 4). Of the 60 existing MPAs at the start of the study, 35 were unchanged, whilst the remaining 25 were modified in some way (12 increased in size, three decreased in size, nine were moved, and one large area was split into four smaller areas). In addition, 14 new MPAs were established. Nine villages that did not have any MPAs before this study now have managed MPAs. The total area of shallow reefs within MPAs increased from 24 km^2 (12%) to 38 km^2 (19%) as a result of the redesign process.

Table 1 summarises the effects of redesigning the MPA network parameter by parameter. Most parameters assessed show that the post-redesign network is likely to perform better ecologically than the existing MPA system. However, the need to avoid placing MPAs offshore, where enforcement is more difficult, is one cause for caution. Given that different habitat types are arranged onshore to offshore, and that providing for ecological linkages between habitats is one of the fundamental design principles for MPA networks (Fernandes *et al.* 2005), this suggests that MPAs should be arranged to represent the inshore–offshore gradient. For Kadavu to establish and enforce MPAs offshore would require a different management model, with support from Provincial and National Fisheries Authorities. Further research on the connectivity of habitats, larval and adult home-range movements between MPAs might allow for the MPA network design to be refined without excessive enforcement costs.

Discussion

Although conservation planning research has influenced conservation actions on the ground in the last two decades (e.g. Fernandes *et al.* 2005; Bottrill and Pressey 2009) very few systematic conservation planning processes have been successfully implemented in regions with customary marine tenure. Thus, our study provides important insights into the utility of conservation planning tools and processes in such contexts. We first discuss three factors that might limit the use of conservation prioritisation tools such as Marxan Z: the difficulty of using computerised software in remote and rural regions; the need for technical capacity to use tools effectively; and the small scale of natural resource management decision-making. We then discuss lessons learnt in Kadavu regarding the process of planning: on constraints to 'scaling up' local management, and incorporating local knowledge of socioeconomic costs. Finally, we outline how the Kadavu MPA network might influence future conservation efforts in Fiji.

The utility of systematic conservation planning tools in customary governance contexts

Recent applications of conservation planning have been characterised by the use of planning support tools such as GIS and decision support software (e.g. Marxan). Our study

Table 1. Summary comparison between the preredesign and the postredesign MPA network

Metric	Preredesign	Postredesign	Change
No. of MPAs	60	77	17
Area of MPA (km^2)	24	38	14
% shallow reefs area protected	12	19	7
% Back reef protected	2	14	12
% Channel protected	8	29	21
% Fore reef protected	5	16	11
% Intertidal protected	15	22	7
% Lagoon protected	13	16	3
% Reef crest protected	5	16	11
% Reef flat protected	18	26	8
% Continuous coral protected	12	19	7
% Patchy coral protected	12	20	8
% Sparse coral protected	6	15	9
% Dense seagrass protected	16	23	7
% Sparse seagrass protected	15	34	19
% Patchy coralline protected	6	19	13
% Patchy mangrove protected	16	23	7
Area of significant sites protected (km^2)	0.5	1	0.5
% Shallow reefs area of significant sites protected	17	38	21
% Spawning aggregations sites protected	41	80	39
% Turtle nesting sites protected	24	61	37
% Cultural areas protected	7	21	14
Average % of distinct cover types protected	4	4	0
% of MPAs with 1 distinct cover type protected	10	12	2
% of MPAs with 2 distinct cover types protected	13	13	0
% of MPAs with 3 distinct cover types protected	28	22	−6
% of MPAs with 4 distinct cover types protected	29	28	−1
% of MPAs with 5 distinct cover types protected	17	19	2
% of MPAs with 6 distinct cover types protected	3	5	2
% of MPAs with 7 distinct cover types protected	0	1	1
Total % of hard substrate cover types protected for larval settlement	36	42	6
Maximum spacing distance (m)	10 456	10 543	87
Minimum spacing distance (m)	329	136	−193
Average spacing distance (m)	3130	2602	−529
Average dimension of MPAs (m)	983	1073	90

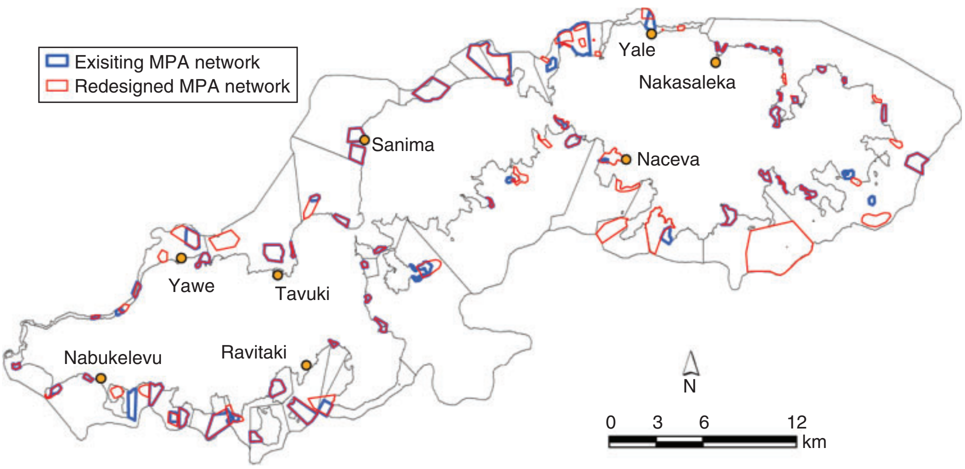

Fig. 4. Comparison overlay between existing collection of MPAs before the study and the redesigned network after the study.

demonstrates that such planning tools can be used 'offline' with local communities. With unreliable power supply and very little capacity within communities to operate computerised tools, workshop participants were provided with colour-printed maps of satellite imagery and *iqoliqoli* boundaries, with the MPA design scenarios on tracing paper overlays (Fig. 3). We believe that using this offline approach, whilst diminishing the possibility of on-site iterative planning, was critical to ensuring local ownership of the process and the success of the study. Other examples of non-computer-based community-based management tools have been used extensively in the region for years. Participatory mapping, threat analysis and Participatory Learning and Action rely on simple instruments such as paper and pens but could also be considered as planning 'tools' (Veitayaki *et al.* 2003).

Nevertheless, our study did employ the use of GIS and Marxan Z by the research team from the IAS-USP. Technical capacity to implement computer-based spatial planning tools is very limited in the Pacific Islands region. Many examples of tool use have relied on the work of researchers who are unlikely to have a sustained presence in the region (e.g. Game *et al.* 2011; Weeks and Jupiter 2013). It is considered unlikely, though not impossible, that capacity to use specialist conservation planning software can be mainstreamed into government agencies. One example of this is the Marine and Coastal Biodiversity in Pacific Island Countries (MACBIO) project, which is currently providing technical support to the governments of Fiji, Kiribati, Solomon Islands, Tonga and Vanuatu to undertake marine spatial planning.

In regions with customary marine tenure, management of natural resources is typically undertaken at small geographic scales equivalent to individual tenure units (Foale and Manele 2004), in this case *iqoliqolis*. After several demonstrations of conservation prioritisation tools at the local scale, there is a feeling that the use of computer-based tools is perhaps not necessary. We found that, at the local scale, the real value of conservation planning was in the process of identifying and conceptualising the management issue, working with communities to collate data through participatory techniques, and engaging communities in management decision-making. The Marxan Z outputs were of secondary value. However, as many countries in the region begin, under relevant national and international commitments, to examine the possibilities and strategies for scaling up from individual site-based management to national networks of conservation areas, the value of applying computer-based tools may be realised. We suggest that computer-based spatial planning tools are likely to be most useful in identifying conservation priorities at the subnational and national scale, rather than directing management actions at the site-specific scale.

Constraints on 'scaling up' local management

Whilst it has previously been demonstrated that local management can achieve local objectives (Tawake *et al.* 2005; Leisher *et al.* 2007; UNEP/GRID-Arendal 2008), our study suggests that coordination of local management initiatives across greater spatial extents can result in greater conservation benefits. Nevertheless, we identified two important constraints on 'horizontal coordination' (i.e. adjacent districts working together): first, the clear need to avoid disputed areas, and, second, that communities were strongly opposed to the idea of merged, jointly managed MPAs. Whilst trans-boundary protected areas or 'peace parks' have been proposed as a means to scale-up local management to overcome social-ecological scale mismatches (Sandwith *et al.* 2001; Mackelworth 2012; Weeks *et al.* 2014), our experience in Kadavu suggests that placing MPAs over the boundaries of tenure areas/jurisdictions does not allow for clear ownership and responsibility for management to a particular community, potentially undermining compliance and enforcement of the area.

Equitability and socioeconomic costs

In Kadavu, it was considered critical to consider the equitability of costs and benefits of the MPA network. The inequitable distribution of conservation costs and benefits among stakeholders may cause disagreements between communities, poor compliance, and implementation failure (Cinner 2007; Klein *et al.* 2010; Grantham *et al.* 2013). For this reason, we standardised opportunity costs across the different *iqoliqolis*, and specified fisheries targets (for the amount of each *iqoliqoli* that must remain open to fishing) to avoid disproportionately impacting any one community. This was considered particularly important since resource-user rights do not extend beyond the boundaries of their *iqoliqoli* and communities may not be able to redistribute fishing effort to areas outside their *iqoliqoli* after MPA implementation.

During the redesign process, the location of individual MPAs was more important to communities than the design of the MPA network overall. While seeking to achieve the overall conservation targets without consideration of stakeholder interests within each *iqoliqoli* would have a lesser overall cost per unit area protected than seeking to minimise cost to each *iqoliqoli* individually, in regions where resource-use patterns are defined by traditional tenure systems, it is more important to minimise costs to each local community individually than to minimise the overall cost of an MPA network (Weeks *et al.* 2010*a*). This is in contrast with previous studies where minimising the overall cost of the entire marine reserve system was the primary objective (Stewart and Possingham 2005; Naidoo *et al.* 2006).

The final MPA network implemented by communities is costlier than the existing MPA system, when calculated as the sum of opportunity, enforceability, and disputed area costs of planning units included in the network. This increase in cost was the result of two villages choosing to establish offshore MPAs (with high enforcement cost) due to interest in potential dive tourism activities. Tourism, which is a potential industry on Kadavu, and might generate income to offset the costs associated with MPA enforcement, was not taken into account in the initial planning stage. Later in the redesign process stakeholders expressed their interest in tourism and the potential benefits it might bring to their villages. Thus, despite the inclusion of three socioeconomic cost layers mapped through participatory process, these did not adequately identify all costs and opportunities for communities. This emphasises the importance of engaging as many stakeholders as possible in the initial stages of conservation planning, and the need for several iterations of consultation and planning.

Moving forwards

All modifications to the Kadavu MPA network were endorsed at the relevant village meetings, and came into effect on 1 March 2011. In developed countries, conservation areas are usually established under national law (e.g. Airamé *et al.* 2003; Fernandes *et al.* 2005; Gleason *et al.* 2010), which can be a lengthy process. In Kadavu the presence of the chiefs and *iqoliqoli* owners, who are the ultimate decision makers regarding management of their *iqoliqolis*, during discussion throughout the MPA redesign process meant that changes and additions to the network were implemented quickly. This is perhaps the greatest advantage of conservation planning within a customary governance context.

At present, Kadavu Province has the highest number of MPAs to be established by a province in Fiji. It is envisaged that the work done in Kadavu will inform the successful integration of a networking approach with community-based marine resource management in other provinces, and finally at the national level in Fiji. The aim is that this will assist the national government of Fiji to implement its commitment to effectively conserve 30% of its inshore marine resources. Moving forwards, it will be important to understand the contribution of community management actions towards achieving conservation success at the national level (Mills *et al.* 2011). The inclusion of more permanent MPAs in the different management zones along with other management actions will likely be required to achieve the 30% national targets in the future.

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References

Airamé, S., Dugan, J. E., Lafferty, K. D., Leslie, H., McArdle, D. A., and Warner, R. R. (2003). Applying ecological criteria to marine reserve design: a case study from the California Channel Islands. *Ecological Applications* **13**(sp1), 170–184. doi:10.1890/1051-0761(2003)013[0170:AECTMR]2.0.CO;2

Allison, G. W., Lubchenco, J., and Carr, M. H. (1998). Marine reserves are necessary but not sufficient for marine conservation. *Ecological Applications* **8**(1), S79–S92. doi:10.2307/2641365

Ardron, J., Possingham, H. P. and Klein, C. J. (Eds), Version 2. (2010). Marxan good practices handbook. University of Queensland, Brisbane, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

Ban, N. C., Hansen, G. J. A., Jones, M., and Vincent, A. C. J. (2009). Systematic marine conservation planning in data-poor regions: socioeconomic data is essential. *Marine Policy* **33**, 794–800. doi:10.1016/J.MARPOL.2009.02.011

Bell, J. D., Johnson, J. E., and Hobday, A. J. (Eds) (2011). Vulnerability of tropical Pacific fisheries and aquaculture to climate change. Secretariat of the Pacific Community, Noumea, New Caledonia.

Bottrill, M., and Pressey, R. L. (**2009**). Designs for nature: Regional conservation planning, implementation and management. IUCN World Commission on Protected Areas (Best Practice Protected Areas Guidelines Series).

Cameron, S. E., William, K. J., and Mitchell, D. K. (2008). Efficiency and concordance of alternative methods for minimizing opportunity costs in conservation planning. *Conservation Biology* **22**, 886–896. doi:10.1111/J.1523-1739.2008.00982.X

Cinner, J. E. (2007). Designing marine reserves to reflect local socioeconomic conditions: lessons from long-enduring customary management systems. *Coral Reefs* **26**, 1035–1045. doi:10.1007/S00338-007-0213-2

Clarke, P., and Jupiter, S. D. (2010). Law, custom and community-based natural resource management in Kubulau District (Fiji). *Environmental Conservation* **37**, 98–106. doi:10.1017/S0376892910000354

Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., Cameron, D., Jago, B., Hall, J., Lowe, D., Innes, J., Tanzer, J., Chadwick, V., Thompson, L., Gorman, K., Simmons, M., Barnett, B., Sampson, K., De'ath, G., Mapstone, B., Marsh, H., Possingham, H., Ball, I., Ward, T., Dobbs, K., Aumend, J., Slater, D., and Stapleton, K. (2005). Establishing representative no-take areas in the Great Barrier Reef: large-scale implementation of theory on marine protected areas. *Conservation Biology* **19**, 1733–1744. doi:10.1111/J.1523-1739.2005.00302.X

Foale, S., and Manele, B. (2004). Social and political barriers to the use of marine protected areas for conservation and fishery management in Melanesia. *Asia Pacific Viewpoint* **45**, 373–386. doi:10.1111/J.1467-8373.2004.00247.X

Game, E. T., Lipsett-Moore, G., Hamilton, R., Peterson, N., Kereseka, J., Atu, W., Watts, M., and Possingham, H. (2011). Informed opportunism for conservation planning in the Solomon Islands. *Conservation Letters* **4**, 38–46. doi:10.1111/J.1755-263X.2010.00140.X

Gillett, R. (2009). Fisheries in the economies of Pacific island countries and territories. Asian Development Bank, Manila, 373.

Gleason, M., McCreary, S., Miller-Henson, M., Ugoretz, J., Fox, E., Merrifield, M., Will, M., Paulo, S., and Hoffman, K. (2010). Science-based and stakeholder-driven marine protected area network planning: a successful case study from north central California. *Ocean and Coastal Management* **53**, 52–68. doi:10.1016/J.OCECOAMAN.2009.12.001

Govan, H., Aalbersberg, W., Tawake, A., and Parks, J. (2008). Locally-managed marine areas: a guide for practitioners. The Locally-Managed Marine Area Network.

Grantham, H. S., Agostini, V. N., Wilson, J., Mangubhai, S., Hidayat, N., Muljadi, A., Muhajir, , Rotinsulu, C., Mongdong, M., Beck, M. W., and Possingham, H. P. (2013). A comparison of zoning analyses to inform the planning of a marine protected area network in Raja Ampat, Indonesia. *Marine Policy* **38**, 184–194. doi:10.1016/J.MARPOL.2012.05.035

Gurney, G. G., Cinner, J., Ban, N. C., Pressey, R. L., Pollnac, R., Campbell, S. J., Tasidjawa, S., and Setiawan, F. (2014). Poverty and protected areas: an evaluation of a marine integrated conservation and development project in Indonesia. *Global Environmental Change* **26**, 98–107. doi:10.1016/J.GLOENVCHA.2014.04.003

IUCN-WCPA (International Union for Conservation of Nature – World Commission on Protected Areas) (2008). Establishing marine protected area networks – making it happen. Washington, D.C: IUCN-WCPA, National Oceanic and Atmospheric Administration and The Nature Conservancy.

Johannes, R. E. (2002). The renaissance of community-based marine resource management in Oceania. *Annual Review of Ecology and Systematics* **33**, 317–340. doi:10.1146/ANNUREV.ECOLSYS.33.010802.150524

Jupiter, S. D., Cohen, P. J., Weeks, R., Tawake, A., and Govan, H. (2014). Locally-managed marine areas: multiple objectives and diverse strategies. *Pacific Conservation Biology* **20**, 165–179.

Klein, C. J., Steinback, C., Watts, M., Scholz, A. J., and Possingham, H. P. (2010). Spatial marine zoning for fisheries and conservation. *Frontiers in Ecology and the Environment* **8**, 349–353. doi:10.1890/090047

Leisher, C., Beukering, P.V. and Scherl, L.M. (2007). How marine protected areas contribute to poverty reduction. Nature's Investment Bank: Report to TNC.

Leslie, H. M. (2005). A synthesis of marine conservation planning approaches. *Conservation Biology* **19**, 1701–1713. doi:10.1111/J.1523-1739.2005.00268.X

Mackelworth, P. (2012). Peace parks and transboundary initiatives: implications for marine conservation and spatial planning. *Conservation Letters* **5**, 90–98. doi:10.1111/J.1755-263X.2012.00223.X

Margules, C. R., and Pressey, R. L. (2000). Systematic conservation planning. *Nature* **405**, 243–253. doi:10.1038/35012251

McClanahan, T. R., and Graham, N. A. J. (2005). Recovery trajectories of coral reef fish assemblages within Kenyan marine protected areas. *Marine Ecology Progress Series* **294**, 241–248. doi:10.3354/MEPS294241

McClanahan, T. R., and Kaunda-Arara, B. (1996). Fishery recovery in a coral reef marine park and its effect on adjacent fishery. *Conservation Biology* **10**, 1187–1199. doi:10.1046/J.1523-1739.1996.10041187.X

McClanahan, T. R., and Mangi, S. (2000). Spillover of exploitable fishes from a marine park and its effect on the adjacent fishery. *Ecological Applications* **10**, 1792–1805. doi:10.1890/1051-0761(2000)010[1792:SOEFFA]2.0.CO;2

Mills, M., Jupiter, S. D., Pressey, R. L., Ban, N. C., and Comley, J. (2011). Incorporating effectiveness of community-based management in a national marine gap analysis for Fiji. *Conservation Biology* **25**, 1155–1164. doi:10.1111/J.1523-1739.2011.01749.X

Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H., and Rouget, M. (2006). Integrating economic costs into conservation planning. *Trends in Ecology & Evolution* **21**, 681–687. doi:10.1016/J.TREE.2006.10.003

Polasky, S. (2008). Why conservation planning needs socioeconomic data. *Proceedings of the National Academy of Sciences of the United States of America* **105**, 6505–6506. doi:10.1073/PNAS.0802815105

Roelfsema, C., Phinn, S., Jupiter, S., Comley, J., and Albert, S. (2013). Mapping coral reefs at reef to reef-system scales, 10s–1000s km^2, using object-based image analysis. *International Journal of Remote Sensing* **34**, 6367–6388. doi:10.1080/01431161.2013.800660

Russ, G. R., and Alcala, A. C. (2003*a*). Marine reserves have rapid and lasting effects. *Ecology Letters* **5**, 361–366.

Sandwith, T., Shine, C., Hamilton L., and Sheppard, D. (2001). 'Transboundary Protected Areas for Peace and Co-operation.' Best Practice Protected Area Guidelines Series No. 7. (IUCN: Gland, Switzerland and Cambridge, UK.)

South, R. G., and Veitayaki, J. (1998). The constitution and indigenous fisheries management in Fiji. *Ocean Yearbook* **13**, 452–466. doi:10.1163/221160098X00209

Stewart, R. R., and Possingham, H. P. (2005). Efficiency, costs and trade-offs in marine reserve system design. *Environmental Modeling and Assessment* **10**, 203–213. doi:10.1007/S10666-005-9001-Y

Tawake, A., Nailetica, L., Ravula, J., Dugmore, M. C. H., Pickering, K. and Tamanivalu, R. (2005). A report on the effectiveness and site suitability of 5 tabu areas (MPAs) in Kadavu. KYMST Report. October 2005.

UNEP/GRID-ARENDAL. (2008). Fishing for the future in Fiji. Environmental wealth of rural communities. Environment and Poverty Times No. 5., pp. 4–5.

Veitayaki, J., Aalbersberg, B., Tawake, A., Rupeni, E. and Tabunakawai, K. (2003). Mainstreaming resource conservation: the Fiji Locally Managed Marine Areas network and national policy development. Innovative governance: indigenous peoples, local communities, and protected areas, 105–123.

Watts, M.E., Klein, C. K., Stewart, R., Ball, I. R. and Possingham, H. P. (2008). Marxan with zones (V1.0.1). Conservation zoning using spatially explicit annealing, a manual.

Weeks, R., and Jupiter, S. D. (2013). Adaptive comanagement of a marine protected area network in Fiji. *Conservation Biology* **27**, 1234–1244. doi:10.1111/COBI.12153

Weeks, R., Russ, G. R., Bucol, A. A., and Alcala, A. C. (2010*a*). Incorporating local tenure in the systematic design of marine protected area networks. *Conservation Letters* **3**, 445–453. doi:10.1111/J.1755-263X.2010.00131.X

Weeks, R., Russ, G. R., Bucol, A. A., and Alcala, A. C. (2010*b*). Shortcuts for marine conservation planning: the effectiveness of socioeconomic data surrogates. *Biological Conservation* **143**, 1236–1244. doi:10.1016/J.BIOCON.2010.02.031

Weeks, R., Aliño, P. M., Atkinson, S., Beldia, P., Binson, A., II, Campos, W. L., Djohani, R., Green, A. L., Hamilton, R., Horigue, V., Jumin, R., Kalim, K., Kasasiah, A., Kereseka, J., Klein, C. J., Laroya, L., Magupin, S., Masike, B., Mohan, C., Da Silva Pinto, R. M., Vave-Karamui, A., Villanoy, C., Welly, M., and White, A. T. (2014). Developing marine protected area networks in the Coral Triangle: good practices for expanding the Coral Triangle Marine Protected Area System. *Coastal Management* **42**, 183–205. doi:10.1080/08920753.2014.877768

Wendt, H. K. (2013). Applying geographic information system and spatial conservation planning tools to strengthen the design of a community-based marine protected area network. A case study of the island province of Kadavu, Fiji. M.Sc. Thesis, University of the South Pacific.

Appendix 1. List of questions used to elucidate GIS and Marxan Z layers

Session 1: Important fishing and resource-use

1. What are the five most important gears you use for subsistence, artisanal and commercial fishing respectively? Please map where these gears are used in your *iqoliqoli*? Example: handline, spear fishing, etc

Session 2: Governance issue

2. Are the *iqoliqoli* boundaries by Native Lands and Fisheries Commission correct? If not, please mark out the boundaries that you know.
3. Are there any areas in your *iqoliqoli* that are disputed? Please map these disputed areas.
4. Are the MPA boundaries you see correct? If not, please mark out the changed/current boundaries that you know.
5. Are you able to enforce MPAs that are not within line-of-sight or far offshore?

Session 3: Mapping significant sites

6. Are there any significant sites in your *iqoliqoli*? For example SPAGs, turtle nesting sites, etc.? Are these sites fished or not?