

Locally-managed marine areas: multiple objectives and diverse strategies

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Community-based management and co-management are mainstream approaches to marine conservation and sustainable resource management. In the tropical Pacific, these approaches have proliferated through locally-managed marine areas (LMMAs). LMMAs have garnered support because of their adaptability to different contexts and focus on locally identified objectives, negotiated and implemented by stakeholders. While LMMA managers may be knowledgeable about their specific sites, broader understanding of objectives, management actions and outcomes of local management efforts remain limited. We interviewed 50 practitioners from the tropical Pacific and identified eight overarching objectives for LMMA establishment and implementation: (1) enhancing long-term sustainability of resource use; (2) increasing short-term harvesting efficiency; (3) restoring biodiversity and ecosystems; (4) maintaining or restoring breeding biomass of fish or invertebrates; (5) enhancing the economy and livelihoods; (6) reinforcing customs; (7) asserting access and tenure rights; and (8) empowering communities. We reviewed outcomes for single or multiple objectives from published studies of LMMAs and go on to highlight synergies and trade-offs among objectives. The management actions or 'tools' implemented for particular objectives broadly included: permanent closures; periodically-harvested closures; restrictions on gear, access or species; livelihood diversification strategies; and participatory and engagement processes. Although LMMAs are numerous and proliferating, we found relatively few cases in the tropical Pacific that adequately described how objectives and management tools were negotiated, reported the tools implemented, or empirically tested outcomes and seldom within a regional context. This paper provides some direction for addressing these research gaps.

Key words: community-based natural resource management, fisheries management, biodiversity conservation, livelihoods, customary management, tropical Pacific

INTRODUCTION

COMMUNITY-BASED and co-management approaches are key strategies for marine conservation and sustainable management (Evans *et al.* 2011; Gutierrez *et al.* 2011). Consequently, they are an increasing proportion of coastal and marine management in the tropical Pacific (Govan *et al.* 2009a; Johannes 2002) and elsewhere (Chape *et al.* 2008). This is particularly prevalent in the tropical Pacific (Govan 2009), where centralized management has typically failed in managing subsistence and domestically-marketed fisheries (Ruddle 1998; Gillett and Cartwright 2010).

Many local management initiatives are recognized within a regional practitioner's network, the Locally-Managed Marine Area (LMMA) network (Parks and Salafsky 2001). Founders of the term LMMA deliberately chose "local" over "community", recognizing co-management arrangements involving communities partnering with government or other external agencies such as non-government organizations (NGOs) (Pomeroy and Rivera-Guieb 2006). An LMMA is an "area of nearshore waters being actively managed by local communities or resource-owning groups, or being collaboratively managed by resident communities with local government and/or

partner organizations" (Govan *et al.* 2006; Govan *et al.* 2009a). In addition to sites within, there are probably hundreds to thousands of communities implementing their own coastal and marine management which may fall within this definition, but are not on any official lists (Govan *et al.* 2009a). Commonly, LMMAs are designed to meet local management objectives, managed through locally negotiated rules that integrate customary or local governance, often established without formal legal status, and adaptively managed through learning-by-doing (Govan *et al.* 2009a). LMMAs are synonymous with community-based marine resource or fisheries management. Management focusses on resource-use and access rules and other management measures, within a defined space, typically including village fishing areas often bounded by local land and marine tenure (Figure 1). Sometimes, these local management boundaries cover ecologically meaningful scales, linking watersheds to downstream marine ecosystems (Ruddle *et al.* 1992), while in other cases tenure areas are much smaller.

Throughout the Pacific, resource use can be controlled through a diversity of local institutions, including customary governance and tenure systems, bans on sectors of society consuming or fishing certain species, restrictions on certain gear types, and spatial and temporal

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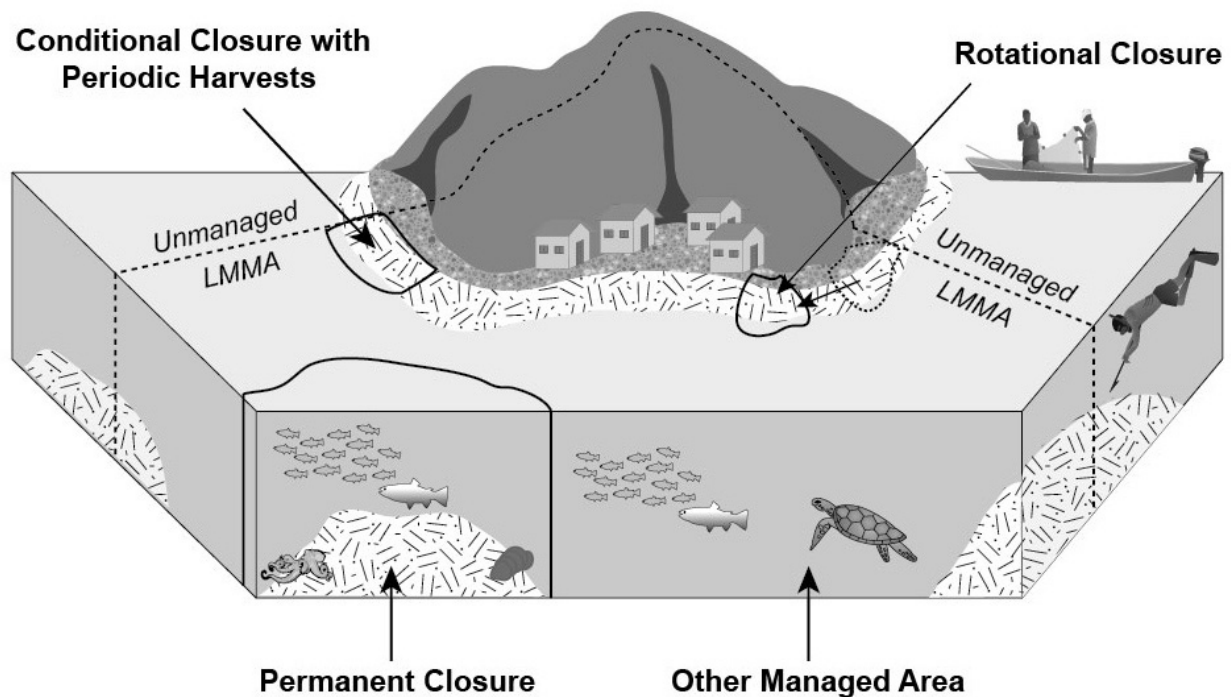


Fig. 1. Schematic of management actions that may be employed within a locally-managed marine area (LMMA) on a Pacific Island, showing the boundary of the LMMA and adjacent land tenure area (dashed line). Permanent closures have complete prohibitions on resource extraction in perpetuity. Conditional closures with periodic harvests are no-take areas occasionally opened for socio-cultural needs. Rotational closures are no-take closures that are lifted and moved after a pre-defined time. Other managed area indicates space inside LMMA boundaries outside of spatial closures that may include other management actions such as gear restrictions or species harvest bans. Adapted from Govan and Jupiter (2013).

closures, placed over specific fishing grounds (Figure 1; Johannes 1978; Johannes 1982; Cinner and Aswani 2007). Tenure regimes can allow the community, clan or family with primary rights to a particular area to create access and use rules (Macintyre and Foale 2007), though these may be difficult to enforce (Aswani 2002). Spatial and temporal closures have long been practiced in the Pacific, respecting the death of prominent community members, protecting sacred sites, affirming rights and controlling access to fishing grounds, or for preparing customary feasts (Johannes 1978; Hviding 1998). While tenure, closures and other regulatory institutions control access to and use of resources, their historical use was more socially and culturally motivated, rather than to manage resources sustainably (Ruttan 1998; Foale *et al.* 2011). With contemporary, competitive resource use, local institutions may not achieve sustainability or conservation outcomes without some integration of contemporary scientific knowledge and management practice (Polunin 1984; Foale *et al.* 2011). Improving management and conservation often will entail strengthening governance of local tenure or rights-based regimes and other local institutions to provide a regulatory framework that reinforces or introduces stewardship of resources (Baines 1990; Johannes 2002; Bell *et al.* 2008;

Govan 2009). By building on this framework, LMMAs can integrate local and scientific knowledge with customary and contemporary practices.

To achieve this, LMMAs are often supported and guided by co-management partners (e.g., NGOs, government agencies or research institutes) who promote a diverse range of objectives, including biodiversity conservation, fisheries management, livelihood diversification and climate change adaptation (Green *et al.* 2013; Weeks and Jupiter 2013). Yet, community-based management is not a panacea (Berkes 2007), and there are inherent trade-offs among multiple objectives. For example, LMMA objectives for enhanced fisheries-supported livelihoods may clash with conservation of biodiversity, while LMMAs established to promote short-term increases in catch may not be able to also enhance long-term sustainability of fisheries. To explore these trade-offs and potential synergies among objectives, we first examined the diversity of contemporary objectives for LMMAs and then reviewed published progress towards single and multiple objectives for LMMAs. We then examined the management actions or 'tools' used to progress objectives and evaluated the empirical evidence for their effectiveness.

METHODS

In December 2011, we facilitated a workshop with 50 people, including four from governments, 20 from academia and 26 people who represented NGOs, regional organizations or were consultants focussed on improved effectiveness of LMMAs in the tropical Pacific for biodiversity conservation, fisheries management, and climate adaptation. Each participant identified at least three objectives for LMMAs, articulated by communities with whom they worked or based on their knowledge of the literature. We grouped these into eight overarching objectives that we cross-checked against the published literature and our own personal experience working directly with local communities (Table 1). Participants then described which resource management actions or tools were used within LMMAs. We grouped

these into six categories (permanent closures, periodically-harvested closures, species-specific restrictions, gear restrictions, access restrictions, alternative livelihood strategies). We then ranked the relative effectiveness of management actions for addressing each of the eight objectives, using the workshop rankings and reports of effectiveness from the published literature (Table 2).

We used the eight overarching objectives, commonly identified management tools and the qualitative assessments of management effectiveness to structure our review. We used peer-reviewed primary and openly accessible grey literature to highlight: (a) where local management pursued each of the eight objectives; and (b) the effectiveness of this management in achieving objectives, reflected in tools and actions used.

Table 1. Overarching objectives, in relation to specific objectives for Locally-Managed Marine Areas (LMMAs), refined from those proposed by 50 workshop participants. Case studies from the tropical Pacific are listed that report each overarching objective, and/or empirically examine or explore outcomes towards each objective.

Overarching objective	Specific objectives	Case studies
(1) Increase long-term sustainable fisheries yield for cash and food	Increase catch abundance/size for sustainable livelihoods Increase catch abundance/size for food security	Cinner <i>et al.</i> 2006; Weiant and Aswani 2006; Aswani and Furusawa 2007; Bartlett <i>et al.</i> 2009b; Jupiter <i>et al.</i> 2012; Cohen and Alexander 2013; Cohen <i>et al.</i> 2013
(2) Increase efficiency of harvests and recovery of fish and invertebrate populations for short-term gain/contingency needs	Ensure adequate fish and invertebrates to meet fundraising targets Provide adequate stock for village feasts Ensure resource availability as contingency for bad weather Decrease variability in food supply Ensure resource availability for unplanned community event/needs	Polunin 1984; Neitschmann 1985; Wright 1985; Tawake <i>et al.</i> 2001; Cinner <i>et al.</i> 2005b; Cinner <i>et al.</i> 2006; Bartlett <i>et al.</i> 2009b; Feary <i>et al.</i> 2011; Januchowski-Hartley <i>et al.</i> 2011; Jupiter <i>et al.</i> 2012; Cohen and Alexander 2013; Cohen <i>et al.</i> 2013; Januchowski-Hartley <i>et al.</i> 2013
(3) Maintain/restore biodiversity, habitats and ecosystem function; improve resilience	Conserve biodiversity/species Protect/restore habitats Maintain/restore ecosystem functions (e.g., productivity, herbivory, water filtration) Maintain/restore ecosystem services (e.g., coastal protection) Maintain/restore ecosystem resilience Adapt to climate change	Aswani <i>et al.</i> 2007; Jupiter and Egli 2011; Goetze and Fullwood 2013; Rasher <i>et al.</i> 2013; Weeks and Jupiter 2013
(4) Maintain/restore biomass and breeding populations of targeted species	Protect habitat for sensitive life history stages (breeding and nursery grounds) Increase stock of targeted species Maintain/increase size for greater reproductive capacity	Tawake <i>et al.</i> 2001; Weiant and Aswani 2006; Aswani and Hamilton 2004; Caillaud <i>et al.</i> 2004; Aswani <i>et al.</i> 2007; Bartlett <i>et al.</i> 2009a; Dumas <i>et al.</i> 2010; Hamilton <i>et al.</i> 2011; Jupiter and Egli 2011; Clements <i>et al.</i> 2012; Friedlander <i>et al.</i> 2013
(5) Enhance economy and livelihoods	Earn income from participation in management (e.g., paid ranger position) Earn income from access fees Earn income through ecotourism activities (e.g., guided tours) Earn income through alternative livelihood activities (e.g., sewing cooperatives)	Aswani 2000; Foale 2001; Aswani and Weiant 2003; Horowitz 2008; Bartlett <i>et al.</i> 2009a; Neisten and Gjertsen 2010; Weeks and Jupiter 2013
(6) Maintain or reinforce customs and tradition	Preserve traditional practice Demonstrate stewardship Protect sacred sites Secure or enhance respect for traditional leaders Enforce custom, magic, or totems as part of cultural practice	Hviding 1989; Veitayaki 1997; Johannes 1998; Bartlett <i>et al.</i> 2009a; Léopold <i>et al.</i> 2010

Table 1 continued overleaf

Table 1 continued

Overarching objective	Specific objectives	Case studies
(7) Assert access rights	Limit or exclude outsiders from accessing resources Assert tenure rights	Anderson and Mees 1999; Bartlett <i>et al.</i> 2009a; Steenbergen 2011
(8) Increase community organization, cohesiveness and empowerment	Provide equitable access to resources Strengthen community governance Strengthen community participation Strengthen engagement with community support networks Obtain access to information to support management decisions Attract NGO support and their resources	Anderson and Mees 1999; Cohen <i>et al.</i> 2012; Cohen <i>et al.</i> 2013

OVERARCHING OBJECTIVES FOR LMMAS

Objectives for establishing LMMAs vary between communities and partner organizations, as well as within and among communities. Supporting partners may have objectives ranging from enhancing livelihoods and food security to sustainable community development and/or biodiversity conservation (Axford *et al.* 2008; Govan *et al.* 2009a). Community objectives may not be explicit, with communities articulating coincident objectives with partners to access benefits (e.g., knowledge, cash, prestige, travel opportunities) or show agreement with management or conservation initiatives (Macintyre and Foale 2004). It is vital to understand explicit and implicit objectives, those pursued by communities, and those influenced or promoted by partner agencies, because the success and longevity of LMMAs depends on perceptions or real benefits to community or key stakeholders outweighing the opportunity costs (Lal and Keen 2002).

Workshop participants perceived that explicit community objectives tend to focus on maintaining or improving fisheries and livelihood benefits, while biodiversity or species-specific protection objectives are more often promoted through the conservation discourse of external agencies (see also Govan *et al.* 2009b). Implicit objectives often emerge later during LMMA implementation, and can include: restricting access of immigrant or neighbouring communities to resources; garnering 'project' benefits; gaining prestige; reinforcing or establishing property rights; recovering traditional knowledge or reinforcing local governance; improving community organization and identity; improving human and social capital; and responding to stewardship of traditional Pacific people (Govan *et al.* 2009a; O'Garra 2012). We discuss the pursuit and progress towards some of these objectives below and highlight cases where they are described (Table 1).

(1) Increase long-term sustainability of fisheries

Communities across the tropical Pacific rely heavily on marine resources for food and income, but coastal fisheries may not sustain growing populations and developing markets (Bell *et al.* 2009; Brewer *et al.* 2009). LMMAs are a common response, particularly where there are local declines in abundance of fisheries resources (e.g., Bartlett *et al.* 2009a) whose long-term sustainability needs to be secured to support associated livelihoods and food security (Table 1). Objectives such as "ensure fish for the future" are commonly cited as a primary objective of local communities and co-management partners (Table 1; Parks and Salafsky 2001). Management tools promoted within LMMAs, such as banning the use of destructive or non-selective harvesting methods and the capture of juvenile fish and invertebrates (Govan *et al.* 2008), are well regarded in contemporary fisheries science as effective (e.g., Cochrane and Garcia 2009). Where implemented, long-term sustainability of fisheries should be enhanced, but this is not guaranteed. There is limited empirical evidence suggesting that short-term localized increases in abundance improve fisheries-supported livelihoods and food security. Some suggest that nutrition is better in communities employing local management (e.g., Weiant and Aswani 2006; Aswani and Furusawa 2007), but causal links are yet to be well understood and demonstrated. Coastal fisheries may not meet the needs of many Pacific countries by 2030, even if well managed (Bell *et al.* 2009). While improving management should help to minimize this deficit, pressures at local (e.g., increased fishing pressure) and global scales (e.g., climate change) threaten long-term sustainability (Bell *et al.* 2011). In addition, other factors operating beyond local scales (e.g., interactions with commercial fisheries, government policies) or outside of fisheries systems (e.g., market fluctuations, population growth, natural disasters) also strongly influence fisheries sustainability, and therefore food security and livelihoods

(Andrew *et al.* 2007; Schwarz *et al.* 2011). The cumulative impact of multiple LMMAs in contributing towards such broad objectives is worthy of future analysis.

(2) Increase efficiency of harvests for short-term yield

Many communities use LMMAs, and most commonly periodically-harvested closures, to act as a “bank in the water” to ensure a supply of fish and invertebrates for special occasions (Table 1; Govan 2009). Catch efficiency has been observed to increase, particularly for spearfishing, after a period of closure (Cinner *et al.* 2006; Gelcich *et al.* 2010; Foale *et al.* 2011) for three reasons. First, fish and mobile invertebrates may move into closed areas where disturbance is low (“spill-in”), elevating localized abundance (Denny *et al.* 2004; Eggleston and Parsons 2008). Second, the behaviour of individual fish can change during periods of closure (i.e., reduced flight distance), making them easier for spearfishers to catch (Feary *et al.* 2011; Januchowski-Hartley *et al.* 2011). This was the explicit objective in Muluk, Papua New Guinea, where an area was closed to fishing to “tame” fish and make them easier to catch when the reef was reopened (Cinner *et al.* 2006). This increased catchability benefits fishers in the short term but could lead to overharvesting (Feary *et al.* 2011; Jupiter *et al.* 2012). Finally, catch rates may be elevated because reproduction and growth have increased abundance and size of taxa (Cohen and Alexander 2013). Whether short-term improvements in catch efficiency correspond with sustainable or improved yields in the long term is a pressing question for managers.

(3) Maintain/restore biodiversity and ecosystem functions

Conservation is defined under the IUCN protected area guidelines as the “in-situ maintenance of ecosystems and natural and semi-natural habitats and of viable populations of species in their natural surroundings” (Dudley 2008). Despite this reported objective of some LMMAs (Table 1; e.g., Aswani *et al.* 2007; Bartlett *et al.* 2009a; Jupiter and Egli 2011), this is not typically a primary objective of communities (Govan and Jupiter 2013). It is difficult to discern if this objective is truly locally motivated or heavily influenced by the conservation discourse of partners. Nonetheless, there is some limited evidence that various LMMA tools could contribute towards maintenance of biodiversity and ecosystem function. For example, sufficiently representing different habitat types within protected areas is often a surrogate measure for biodiversity protection (Margules and Pressey 2000). By this measure, LMMAs in Fiji contributed substantially to the government’s target to protect 30% of marine

habitats (Mills *et al.* 2011). In addition, management actions that reduce fishing pressure may have cascading impacts to other biodiversity and ecosystem function. For example, increased biomass of top predators has been associated with increases in prey abundance following local management (Goetze and Fullwood 2013). Further, observed increases in herbivory within no-take areas (Rasher *et al.* 2013) reduced harmful interactions between algae and corals, reduced sediment accumulation and increased crustose coralline algae establishment (Rasher *et al.* 2012), supporting ecosystem function and potentially increasing resilience (McClanahan *et al.* 2012). However, local management efforts may not mitigate chronic or intense disturbance from fishing or climate change, explosions of coral predators, or land-based runoff (Jones *et al.* 2004; Halpern *et al.* 2013). Understanding the relative impact of these large-scale disturbances would be benefitted by further research.

(4) Maintain/restore biomass and breeding populations

A commonly voiced community objective for LMMAs is to restore abundance and biomass of harvested species of fish and invertebrates. Some longstanding local traditions regulate the harvest of important species and are incorporated into contemporary management (Johannes 1978; Caillaud *et al.* 2004). For example, indigenous Hawaiians traditionally restricted the harvest of large female moi (*Polydactylus sexfilis*) to protect breeding stock, including during their spawning season, a measure now integrated into local management (Friedlander *et al.* 2013). However, local ecological knowledge often focusses on enhancing catch efficiency and maximizing catch (Foale 1998), which can intensify pressure on resources and lead to depletion, particularly of fish spawning aggregations (Sadovy and Domeier 2005). Where contemporary scientific understandings are integrated with local knowledge, local fishers recognize the problems associated with removing large numbers of reproductive adults from the population (e.g., Fox *et al.* 2012), but often do not stop their intensive fishing (Kinch *et al.* 2006). Increasing understandings of reproductive and ecological processes is a common strategy, intended to influence local management for long-term sustainability objectives (e.g., Parks and Salafsky 2001; Foale *et al.* 2011). Where co-management partners have explained ecological processes, some communities have established spatial and/or seasonal management over breeding and nursery sites for vulnerable species (e.g., bumphead parrotfish: *Bolbometopon muricatum*, large aggregating grouper: *Epinephelus fuscoguttatus*, *E. polyphkekadion*, *Plectropomus areolatus*; Aswani and Hamilton 2004; Hamilton *et al.* 2011).

(5) Enhance economy and livelihoods

Many tropical Pacific countries are developing nations, where many people are highly reliant on natural resources with relatively few alternatives for food and income (Bell *et al.* 2009). Not surprisingly, many local communities are amenable to LMMA establishment, hoping to improve local economies and livelihoods (Table 1). Livelihood objectives are based on explicit arrangements (or expectations) including: receiving payments to cease extraction of resources; generating revenue from eco-tourism (e.g., tourist access fees for diving, fishing and surfing); employment associated with management; or participating in alternative income-generating activities (e.g., from sewing cooperatives, handicraft production) introduced by co-management partners. For example, potential financial gain from tourism convinced local communities to participate in co-management for conservation in the Loyalty Islands of New Caledonia (Horowitz 2008). LMMAs and their eco-tourism arrangements have produced: user fee payments from divers in the Namena Marine Reserve, Fiji (Weeks and Jupiter 2013); a 25 year lease agreement to establish the 425 km² Misool EcoResort No-Take Zone in Raja Ampat, Indonesia (Nielsen and Gjertsen 2010); and cash payments in exchange for agreements not to fish and for exclusive access rights for a tourism operator to bring divers to Shark Reef Marine Reserve, Fiji (Brunnschweiler 2010). Sometimes, tourism employs community members and introduces markets for fish and handicrafts (Horowitz 2008; Nielsen and Gjertsen 2010; Vianna *et al.* 2012). However, tourism will not provide widespread opportunities, particularly in remote or environmentally degraded areas. In a remote region in the Solomon Islands, co-management partners established alternative livelihood activities, including women's sewing projects and payment for community health and education services (Aswani 2000; Aswani and Weiant 2003).

(6) Maintain or reinforce customs

Practices that control resource use (e.g., asserting tenure claims, protection of sacred areas, restrictions on harvesting particular species) occur across the tropical Pacific (Hviding 1989; Zann 1989; Veitayaki 1997; Colding and Folke 2001). Yet, as belief systems have evolved, including increasing incorporation of Christian values and Western norms of capitalism and acculturation, many traditional practices are eroding (Foale 2006; Bartlett *et al.* 2010). For example, a longstanding ban on mullet net fishing in the Teuta LMMA of New Caledonia, linked to the tribe's allegiance to local chiefly leaders, was lifted due to weakening social

hierarchies and loss of local ecological knowledge (Léopold *et al.* 2010). Nevertheless, contemporary LMMAs can often strengthen, re-establish or further evolve customary practices (Table 1; Johannes 2002). For example, the communities of Totoya Island, Fiji, originally declared the Daveta Tabu a sacred passage following the sea burial of the stillborn child of a chief, and later reinforced this closure within their LMMA arrangements (J. Cinavilakeba, pers. comm.). The adaptation and application of periodically-harvested closures with historical origins are common in contemporary community-based management (Cohen and Foale 2013). Sometimes, customary practices, such as customary marine tenure to restrict access, have strengthened through a fusion of Christian doctrines, ancestor worship and authority of the chiefs (Hviding 1998). However, few cases adequately describe the processes and nature of these hybridizations with LMMA frameworks.

(7) Assert access rights

LMMAs are generally established adjacent to communities, often including areas over which tenure rights are held by community members. Customary marine tenure systems are recognized in the constitution of some Pacific countries (e.g., Solomon Islands, Lane 2006) while others legally recognize traditional fishing rights (e.g., Fiji; Clarke and Jupiter 2010) or ways for establishing community rights to explicitly manage coastal areas (e.g., Tonga; Govan 2009). These systems allow the community, clan or family with primary rights to a particular area to limit access and regulate overuse (Macintyre and Foale 2007), essential foundations for LMMAs. Tenure arrangements for rights (i.e., their custodians, nature, and location) are dynamic and informal because they are generally unwritten (Baines 1990), allowing flexible responses to new environmental pressures or changed social, economic or ecological conditions (Hviding 1998). Codifying and/or clarifying tenure claims may be an important, but perhaps not overtly stated, local objective for LMMA establishment and formal management (Table 1; Steenbergen 2011). However, clarifying tenure sometimes clashes with objectives of enhanced community cohesiveness, leading to protracted negotiations and disputes (Carrier 1987; McDougall 2005; Macintyre and Foale 2007). Depending on the local context (e.g., different people often hold different rights within one community), and how management is established, the benefits and costs of management may be unequally distributed by gender, clan or ethnicity (Anderson and Mees 1999; Koczberski *et al.* 2006; Vunisea 2008; Cohen *et al.* 2013).

(8) Increase community organization, cohesiveness and empowerment

Many support partners seek to empower communities and strengthen local governance through participation in LMMA establishment and management (Table 1; Govan *et al.* 2008). These processes include education, awareness raising and learning for adaptation at local sites. The LMMA network prioritizes learning and information exchange at local, national and regional scales (Parks and Salafsky 2001). In Solomon Islands, national LMMA network members provided important pathways for information about resource management to reach communities, and the network provided a mechanism for representation of communities and their management efforts in higher-level

decision-making (Cohen *et al.* 2012). Further, processes for establishing LMMAs frequently include bringing communities together for visioning, planning, decision-making and consensus building (Govan *et al.* 2008). These processes can enhance participation of women in decision-making about resources (Leisher *et al.* 2007; Hilly *et al.* 2011). This is a marked achievement, given cultural barriers potentially limit their role in decision-making (Vunisea 2008), despite the fact that they are fishers and distributors of fisheries benefits (Weiant and Aswani 2006; Kronen and Vunisea 2007). In the Arnavon Islands LMMA in Solomon Islands, the resource management committee better dealt with resource-use issues through a participatory forum, which also addressed “other community issues” (Leisher *et al.* 2007; Govan *et al.* 2009b).

Table 2. Perceived effectiveness of management tools in achieving objectives for Locally-Managed Marine Areas (LMMA). Effectiveness of 5 rankings based on responses from workshop participants, supplemented with evidence from reported case studies.

	Permanent closures ^a	Periodically-harvested closures ^g	Species restrictions ⁱ	Gear restrictions ^o	Access restrictions ^r	Alternative livelihoods strategies
(1) Increase long-term sustainable yield	Very Good ^{b, c}	Poor–Good ^b	Poor–Good ^j	Poor–Good ^j	Poor–Good ^s	Poor–Intermediate
(2) Increase efficiency of harvests for short-term yield	Poor ^b	Very Good ^b	Poor	Poor	Poor	n/a
(3) Maintain biodiversity & ecosystem functions	Very Good ^{b, d}	Poor–Good ^{b, d, h}	Intermediate ^k	Intermediate ^{d, k}	Poor–Good ^s	Poor–Intermediate
(4) Maintain biomass & breeding populations	Very Good ^b	Poor–Good ^b	Intermediate ^l –Very Good	Intermediate ^{j, p} –Good	Poor–Good ^{s, t}	Poor–Intermediate
(5) Enhance economy & livelihoods	Good ^e	Poor–Good ^e	Poor	Poor	Poor	Poor–Good ^v
(6) Maintain or reinforce customs	Good ^f	Very Good ^f	Very Poor–Good ^m	Intermediate ^q	Very Good	Intermediate ^w
(7) Assert access rights	Very Good	Very Good	Poor	Intermediate	Very Good	n/a
(8) Increase community organization, cohesiveness and empowerment	Good ^f	Very Good	Good ⁿ	Poor–Intermediate	Poor–Good ^u	Poor–Good

^a No entry areas more effective than no-take areas for most objectives.

^b Effectiveness influenced by size, location, and broader management context (e.g., fishing pressure outside closure).

^c Requires spillover into adjacent area open to fishing.

^d Likely to be effective at maintaining habitat structure and ecosystem resilience, but outcomes might be dictated more by external factors (e.g., stress from climate change impacts or land-based runoff).

^e Primarily through dive tourism and/or ecotourism-associated income; this is greater for areas that allow non-extractive activity than no-entry areas. Note, ecotourism feasibility is limited by infrastructure, access and habitat condition.

^f Provided that management tool or measure aligns with community traditions/custom, and is supported by the community.

^g Effectiveness varies with frequency and duration of openings and fishing effort whilst open.

^h Fishing often targets important functional species disproportionately. Harvests impacting top predators could have cascading effects.

ⁱ Effectiveness influenced by species targeted; note that restrictions must be context specific (e.g., minimum mesh size is not effective for all species, size limits must tailored to species size at reproduction) and can be harder to enforce than spatial management.

^j Some studies (e.g. Cohen *et al.* 2013; Léopold *et al.* 2013) indicate poor local compliance with many of these types of rules

^k If restrictions target functionally important species, e.g., certain herbivorous fishes.

^l Effectively protecting fish spawning aggregations through spatial or seasonal closures can be very effective at maintaining breeding populations; minimum size limits are less effective than slot limits.

^m Can provide protection for species of cultural importance, but potentially very poor if cultural preference for consumption of large individuals or particular animals (e.g., turtles) conflicts with size or species restrictions.

ⁿ Implementation of species restrictions may increase community organization and cohesion, particularly in cases where local communities rally around a campaign to protect particular species of cultural or economic importance.

^o Banning destructive gear types is critical for all objectives; effectiveness varies depending on types of gear restricted.

^p Can be very effective if applied appropriately (e.g., bans on night spearfishing, spearfishing lobsters).

^q Bans on monofilament nets & flashlights reinforce traditional gear use and control.

^r Necessary to facilitate any other management, but requires additional restrictions.

^s Effectiveness will depend on the intensity of local resource use.

^t Small tenure areas will not lead to substantial self-recruitment and will not be able to maintain biomass of highly mobile species.

^u Depending on the local context, the benefits and costs of management may be unequally distributed according to gender, clan or ethnicity, thus resulting in conflicts.

^v Some alternative livelihoods are not related to marine management activities. A range of positive to perverse outcomes has been observed from related livelihoods, depending on the context.

^w Could help maintain and reinforce customs if the alternative livelihoods revolves around a customary practice (e.g. traditional weaving for sale as handicrafts).

This is anecdotal evidence for governance improvements, though more critical evaluations of changes in governance capacity are warranted.

MANAGEMENT ACTIONS OR 'TOOLS'

Successful adaptive co-management (i.e., of which LMMAs can be a form) relies on: broad community consultation to define objectives; clear governance arrangements and decision-making pathways; influence and support from partner agencies; and access to a portfolio of management actions (Armitage *et al.* 2009). LMMA establishment and adaptation is intended to utilize, support and strengthen these features, helping to articulate objectives such as "assert access rights" and "increase community organization, cohesiveness and empowerment".

A general process for supporting the establishment and adaptation of LMMAs was documented at a meeting of LMMA network partners in May 2012 (S. Jupiter, unpublished data): (1) agreement to the LMMA network's core value that local communities should make the management decisions and their needs come first; (2) initial community engagement to define objectives, agree on expectations, assess enabling conditions and build trust; (3) empowerment of communities through skills development and participatory action planning; (4) community-based adaptive management through a cycle of planning, implementing, monitoring, evaluating, and revising based on learning; and (5) ongoing communication and skills development, including the promotion of community champions. This process may capture management arrangements in formalized or informal plans and/or management systems, with some level of recognition by state or other institutions, depending on the country (e.g., White *et al.* 2005; Techera 2009; Clarke and Jupiter 2010). Formalization can positively impact upon effectiveness of management actions, by enhancing legitimacy, providing enforcement capacity and clarifying or asserting access rights, but may reduce flexibility for rapid adaptive management.

Here we focus on the management actions identified (by workshop participants and through literature review) as those frequently negotiated and employed for LMMAs. We discuss how well the six major categories of management actions and tools have been observed to contribute towards each of the eight LMMA objectives (Table 2).

Permanent closures

Permanent no-take marine protected areas are employed within fisheries management and marine conservation strategies worldwide to protect species and habitats within their

boundaries (Lester *et al.* 2009), enhance fisheries through adult spillover (e.g., Halpern *et al.* 2010) and larval export (Harrison *et al.* 2012), and confer potential ecosystem resilience to climate change impacts through increased herbivory and associated cascading impacts (Rasher *et al.* 2012; Rasher *et al.* 2013). Yet, a range of factors influence their effectiveness for these purposes (Lester *et al.* 2009).

LMMA approaches frequently lead to the formation of small (<0.5 km²) no-take zones, often over coral reefs (Govan 2009; Weeks *et al.* 2010). Depending on currents, other oceanographic processes, larval dispersal distances and the placement of no-take marine reserves, local fish and invertebrate abundance may increase, even for small no-take areas (Almany *et al.* 2013). Whether increases in target species lead to food security and livelihood benefits depends on the level of increase and fishers' access to these stocks. In Vanuatu, very small (<0.05 km²) closures may not sufficiently restore breeding biomass and prevent population declines of invertebrates (Dumas *et al.* 2010). Yet, community perceptions of abundance increases within closed zones are commonly favourable (even unrealistically), and may even be catalysts for increasing interest, knowledge and awareness of resource management (World Bank 2000). Many no-take zones within LMMAs are closed indefinitely, even though communities may express the intention to open them in the future if circumstances change (Govan *et al.* 2009a). The short- to medium-term decrease in access to stocks and fishing grounds may limit use of large and/or permanent no-take closures in the Pacific (Foale and Manele 2004). Sometimes, permanent no-take areas can indirectly benefit local livelihoods, with alternative sources of income, typically related to dive tourism or ecotourism (e.g., Weeks and Jupiter 2013), however, tourism-associated benefits may be inequitably distributed (Fabinyi 2010). In contrast to periodically-harvested closures, permanent closures were not prevalent in historical management strategies in the Pacific (Johannes 1978), and there may be social barriers to their effective implementation (Foale and Manele 2004; Foale *et al.* 2011).

Periodically-harvested closures

Within LMMAs, periodically-harvested closures are a common but highly variable and flexible management tool. They fall on a spectrum between areas predominantly closed and those regularly opened to harvesting (Tiraa 2006; Cohen and Foale 2013). During closure, there may be a total ban on harvesting (Jupiter *et al.* 2012; Cohen *et al.* 2013), or restriction on certain methods (Cinner *et al.* 2005a) or species (Foale 1998). During openings, restrictions on

harvesting are sometimes applied but harvests can also be unconstrained (Jupiter *et al.* 2012; Cohen *et al.* 2013). Long-term sustainability and conservation outcomes will be highly variable, reflecting the diversity of management actions, the flexible nature of opening and closure cycles, the differing use of concurrent resource-use controls and the abundance of target taxa at sites (see review in Cohen and Foale 2013). Broadly, outcomes reflect the degree of replenishment during closures, relative to the level of depletion during openings. Perceived or quantified increases in resource abundance are evident over short time-scales, within small closures with light overall harvests (e.g., Tawake *et al.* 2001; Cinner *et al.* 2005a; Bartlett *et al.* 2009b). Herbivory and ecosystem resilience may increase within periodically-harvested closures (Game *et al.* 2009; Rasher *et al.* 2012). Short-term elevated catch rates occur in some periodically-harvested areas due, in particular, to increased abundance of invertebrates (Tawake *et al.* 2001; Cohen and Alexander 2013) and increased catchability of spear-caught fish (Januchowski-Hartley *et al.* 2011). In some cases, increased abundance and enhanced catchability has been observed to spill over beyond the boundaries of the closure (Tawake *et al.* 2001; Januchowski-Hartley *et al.* 2013).

Periodically-harvested areas can be implemented with relative enthusiasm, compared with other management actions (Cohen *et al.* 2013; Léopold *et al.* 2013). In many tropical Pacific countries, periodically-harvested closures have historical origins (Johannes 1982), and their contemporary application may maintain customs by providing food and income for celebrations (Govan 2009). In several cases, advice from partners to promote long-term sustainability objectives may have contributed to community plans to keep periodically-harvested closures predominantly closed (P. Cohen, unpublished data). Yet in practice, community objectives for increased catch efficiency and short-term benefits can be more immediate, and have led to closures being harvested more frequently, intensely or even destructively, than was planned with advice from partner agencies (Jupiter *et al.* 2012, Cohen *et al.* 2013). In some areas where tourism operates, periodically-harvested closures have attracted small fees paid by tourists, visiting these sites for their cultural and aesthetic values (Tiraa 2006). Income is generated from multi-species harvests (Jupiter *et al.* 2012) or commonly, the harvesting of invertebrates (e.g., trochus) when areas are opened (Foale 1998; Cohen and Foale 2013). Yet, harvesting pressure can be intense (even destructive), with removal of substantial biomass (Jupiter *et al.* 2012; Cohen *et al.* 2013). Where harvests were light and infrequent, conservation benefits of periodically-harvested closures

(species richness, live coral cover and coral diversity) did not differ significantly from areas open year-round (Cinner *et al.* 2006), but where harvests are intense, frequent and/or conducted using non-selective or destructive gears, maintenance of biodiversity and habitats is probably less achievable.

Species-specific restrictions

Species-specific regulations, including size limits, are commonly used to maintain or increase breeding stock in centralized fisheries management, particularly for less mobile species (e.g., Cancino *et al.* 2007; Cochrane and Garcia 2009). Yet, setting appropriate size limits can be complex, particularly for species with highly variable growth rates that may mature at different sizes, depending on local productivity (Prince 2003), or those where the timing of sex changes is influenced by fishing pressure (e.g., Hamilton *et al.* 2007). Species-specific size restrictions within local management have met with mixed success. For example in West Nggela, Solomon Islands, there was poor compliance with size limits for trochus (*Trochus niloticus*), regulated by the national government (Foale 1998). Similar situations have been observed for Pacific sea cucumber fisheries (Kinch *et al.* 2008). Contrastingly, in LMMAs in Vanuatu, there was good compliance for national trochus size limits and a moratorium on sea cucumber harvesting, but lower levels of compliance with community-set size limits and temporary harvest bans for other species (Léopold *et al.* 2013). Léopold *et al.* (2013) suggested that increased enforcement capacity would be necessary to better regulate additional fishing restrictions because the marine reserves and periodically-harvested closures actively employed were unlikely to assure the long-term sustainability of yields.

Species-specific catch restrictions might maintain biodiversity and ecosystem function if regulations target functionally important or vulnerable species. For example, in one location in Fiji, four species of herbivorous fish accounted for 97% of macroalgal consumption within LMMA reserves; thus, bans on harvesting these species alone could effectively maintain herbivory on reefs, contributing to reef health by reducing harmful macroalgal interactions with coral (Rasher *et al.* 2013). Spatial or temporal bans on fishing of particular species during sensitive life history phases (e.g., spawning aggregations) can maintain biomass and breeding stocks. For instance in Papua New Guinea, the camouflage grouper *Epinephelus polyphkadion* increased ten-fold in density in a reserve over a spawning aggregation site (Hamilton *et al.* 2011). In Solomon Islands, a local regulation on harvesting clams was implemented in response to observed low abundance, but the effectiveness of the measure

was not determined (Cohen *et al.* 2013). Incorporating species-specific restrictions, based on totems or taboos, may reinforce customs, but little empirical evidence exists of effectiveness. The use of species-specific quotas is rare in local management initiatives, likely due to the need for data and data management systems.

Gear restrictions

Banning destructive methods (e.g., dynamite, fish poisons) and highly efficient gear (e.g., spearguns, small mesh nets) is known to be important for maintaining habitat structure, ecosystem function and breeding capacity (Fernandes *et al.* 2012). Such gear restrictions are often attempted within LMMAs (Johannes 2002; Govan *et al.* 2008). There are few assessments of their effectiveness in the Pacific (though see Carrier 1982), but elsewhere gear restrictions can increase long-term sustainable yield. For example in Kenya, fish size and catch per unit effort from permitted gears increased when beach seines were locally prohibited (McClanahan and Hicks 2011). Local enforcement and compliance with gear restrictions can be poor in Pacific LMMAs; for example Vanuatu and Solomon Islands communities initially set gear-based restrictions when they established LMMAs, but few restrictions were implemented (Cohen *et al.* 2013; Léopold *et al.* 2013). The context in which gear restrictions can be successfully implemented, and the contributions that makes towards fisheries, cultural and ecological objectives, remains an important area for future research.

Access restrictions

The ability to restrict access is a foundation of effective resource governance (Ostrom 1990), in a common input control in fisheries (Ruddle *et al.* 1992) and can support the implementation of concurrent management measures (World Bank 2000). Marine tenure can both reinforce local governance and provide the mechanism by which to limit access (Johannes 2002; Macintyre and Foale 2007). However, implementing access restrictions “will not necessarily change the volume harvested, just who harvests it” (Polunin 1984). Therefore, where local resource use is intense, access restrictions on their own may not maintain biomass or enhance sustainability. Despite the small size of marine tenure units, some species can recruit into managed areas where access has been restricted (Almany *et al.* 2013), while for others (particularly species with large home ranges or those with highly dispersing larvae), recruitment into small managed areas may be limited (White and Costello 2011). To account for this, networks of numerous small tenure-defined reserves may be more effective (Aswani and Hamilton 2004; Weeks *et al.* 2010).

Livelihood diversification strategies

Co-management partners sometimes promote livelihood diversification strategies with LMMAs to reduce fishing effort or offset perceived losses of revenue associated with management interventions (O’Garra 2007). The expectation is that diversifying income sources will lead to reduced fishing pressure on coastal ecosystems (Cinner 2014). For instance in Solomon Islands, there was increased catch per unit effort at fish aggregation devices (FADs) due to enhanced catches of pelagic fish, accompanied by a perception by fishers of decreased effort elsewhere (Prange *et al.* 2009). However, there are few documented examples that conclusively demonstrate that introduced alternative or supplemental livelihoods has led to more sustainable fisheries practice or improved resource condition (Gillett *et al.* 2008). Resource management may stall or fail if hopes for improved income do not materialize, and/or if conflict arises due to inequitable distribution of benefits (Foale 2001), as when a sewing project was introduced in Roviana Lagoon (Aswani and Weiant 2003; Niesten and Gjertsen 2010). Further, there is concern that livelihood projects may create a culture where communities demand payment for participation in management (Foale 2001), producing dependency on perpetual subsidies (Gillett *et al.* 2008). Livelihood projects may also fail to reduce fishing effort due to unforeseen outcomes or poor understanding of cultural attachments to fishing (Cinner 2014). For example, a seaweed farming project introduced in Indonesia and Philippines did not reduce fishing effort because it primarily involved women and children, rather than male fishers (Sievanen *et al.* 2005).

CONCLUSIONS

Globally, community-based and co-management approaches have gained increased recognition in practice and critical appraisal in the scientific literature. Management success depends on seven key factors: recognition of human agency; a well-defined and bounded community; perception of resource rights by community and government; functional conflict resolution mechanisms; support for community leadership; long-term commitment by co-management partners; and cohesion of community and co-management partner objectives (Ostrom 1990; Gutierrez *et al.* 2011; Cinner *et al.* 2012). We also identified that success of LMMAs has many meanings due to the multiplicity of objectives. Furthermore, progress can involve trade-offs or synergies between multiple objectives, where success towards one objective (e.g., short term increases in catch efficiency) may come at the

expense of achieving others (e.g., enhancing long-term sustainability of resource-use or maintaining breeding biomass). Further, outcomes depend on the effectiveness and variable application of the many management actions applied in practice within the framework of an LMMA.

The tropical Pacific hosts some of the most ecologically and culturally diverse places in the world. The acceptance and proliferation of LMMAs in the region is substantially attributable to the non-prescriptive nature of the approach (i.e., adaptable to a range of conditions and contexts and adjusted through time). Yet, this variability in contexts, and in the resultant form LMMAs can take, challenge generating overarching recommendations to realize objectives. Our case studies demonstrated where certain objectives and management measures support, or potentially hinder, the achievement of eight overarching LMMA objectives. Yet despite hundreds to thousands of LMMAs in the tropical Pacific, most local management still proceeds with little documentation or critical evaluation. As a result, there are relatively few empirical cases that describe how objectives and management tools are negotiated, report the objectives and tools ultimately engaged, or test outcomes towards objectives. And while we appreciate that heavy data requirements are inappropriate to the approach, LMMA objectives, management measures, outcomes and limitations represent important areas for on-going research and transparent reporting, particularly given that the approach is currently heavily relied on to achieve conservation and fisheries management outcomes within the region.

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REFERENCES

- Almany, G. R., Hamilton, R. J., Bode, M., Matawai, M., Potuku, T., Saenz-Agudelo, P., Planes, S., Berumen, M. L., Rhodes, K. L., Thorrold, S. R., Russ, G. R. and Jones, G. P., 2013. Dispersal of grouper larvae drives local resource sharing in a coral reef fishery. *Curr. Biol.* **23**: 626–630.
- Anderson, J. A. and Mees, C. C., 1999. The performance of customary marine tenure in the management of community fishery resources in Melanesia. Final Technical Report. London: UK Department for International Development, MRAG Ltd., 34 pp.
- Andrew, N. L., Béné, C., Hall, S. J., Allison, E. H., Heck, S. and Ratner, B. D., 2007. Diagnosis and management of small-scale fisheries in developing countries. *Fish & Fisheries* **8**: 227–240.
- Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., Diduck, A. P., Doubleday, N. C., Johnson, D. S., Marschke, M., McConney, P., Pinkerton, E. W. and Wollenberg, E. K., 2009. Adaptive co-management for social-ecological complexity. *Frontiers in Ecol. & Env.* **7**: 95–102.
- Aswani, S., 2000. Women, rural development and community-based resource management in the Roviana Lagoon, Solomon Islands: establishing marine invertebrate refugia. *SPC Traditional Marine Resource Manage. & Knowledge Bull.* **12**: 11–22.
- Aswani, S., 2002. Assessing the effects of changing demographic and consumption patterns on sea tenure regimes in the Roviana Lagoon, Solomon Islands. *Ambio* **31**: 272–284.
- Aswani, S. and Weiant, P., 2003. Shellfish monitoring and women's participatory management in Roviana, Solomon Islands. *SPC Women in Fisheries Information Bull.* **12**: 3–11.
- Aswani, S. and Hamilton, R. J., 2004. Integrating indigenous ecological knowledge and customary sea tenure with marine and social science for conservation of bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands. *Env. Cons.* **31**: 69–83.
- Aswani, S. and Furusawa, T., 2007. Do marine protected areas affect human nutrition and health? A comparison between villages in Roviana, Solomon Islands. *Coastal Manage.* **35**: 545–565.
- Aswani, S., Albert, S., Sabetian, A. and Furusawa, T., 2007. Customary management as precautionary and adaptive principles for protecting coral reefs in Oceania. *Coral Reefs* **26**: 1009–1021.
- Axford, J. C., Hockings, M. T. and Carter, R. W., 2008. What constitutes success in Pacific island community conserved areas? *Ecol. & Soc.* **13**: art45.
- Baines, G. B. K., 1990. A traditional base for inshore fisheries management in the Solomon Islands. In: *Traditional Marine Resource Management in the Pacific Basin: An Anthology* (eds Ruddell, K., Johannes, R. E.), pp. 286–300, UNESCO/ROSTSEA, Jakarta.
- Bartlett, C. Y., Pakoa, K. and Manua, C., 2009a. Marine reserve phenomenon in the Pacific islands. *Marine Policy* **33**: 673–678.
- Bartlett, C. Y., Manua, C., Cinner, J. E., Sutton, S., Jimmy, R., South, R., Nilsson, J. and Raina, J., 2009b. Comparison of outcomes of permanently closed and periodically harvested coral reef reserves. *Cons. Biol.* **23**: 1475–1484.
- Bartlett, C. Y., Maltali, T., Petro, G. and Valentine, P., 2010. Policy implications of protected area discourse in the Pacific islands. *Marine Policy* **34**: 99–104.
- Bell, J. D., Purcell, S. W. and Nash, W. J., 2008. Restoring small-scale fisheries for tropical sea cucumbers. *Ocean & Coastal Manage.* **51**: 589–593.
- 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.

- Bell, J. D., Kronen, M., Vunisea, A., Nash, W. J., Keeble, G., Demmke, A., Pontifex, S. and Andréfouët, S., 2009. Planning the use of fish for food security in the Pacific. *Marine Policy* **33**: 64–76.
- Berkes, F., 2007. Community-based conservation in a globalized world. *Proc. Nat. Acad. Sci.* **104**: 15188–15193.
- Brewer, T. D., Cinner, J. E., Green, A. and Pandolfi, J. M., 2009. Thresholds and multiple scale interaction of environment, resource use, and market proximity on reef fishery resources in the Solomon Islands. *Biolog. Cons.* **142**: 1797–1807.
- Brunnschweiler, J. M., 2010. The Shark Reef Marine Reserve: a marine tourism project in Fiji involving local communities. *J. Sustainable Tourism* **18**: 29–42.
- Caillaud, A., Boengkih, S., Evans-Illidge, E., Genolagani, J., Havemann, P., Henao, D., Kwa, E., Llewellyn, D., Ridep-Morris, A., Rose, J., Nari, R., Skelton, P., South, R., Sulu, R., Tawake, A., Tobin, B., Tuivanuavou, S. and Wilkinson, C., 2004. Tabus or not taboos? How to use traditional environmental knowledge to support sustainable development of marine resources in Melanesia. *SPC Traditional Marine Resource Manage. & Knowledge Information Bull.* **17**: 14–35.
- Cancino, J. P., Uchida, H. and Wilen, J. E., 2007. TURFs and ITQs: Collective vs. individual decision making. *Marine Resource Economics* **22**: 391–406.
- Carrier, J., 1982. Fishing practices on Ponam Island (Manus Province), Papua New Guinea. *Anthropos* **77**: 904–915.
- Carrier, J., 1987. Marine tenure and conservation in Papua New Guinea: Problems in interpretation. Pp 142–167 in *The Question of the Commons: The Culture and Ecology of Communal Resources* ed by McCay, B. and Acheson, J. The University of Arizona Press, Tuscon, USA.
- Chape, S., Spalding, M. and Jenkins, M., 2008. The world's protected areas: status, values, and prospects in the 21st century. University of California Press, Berkeley, USA.
- Cinner, J., 2014. Coral reef livelihoods. *Curr. Opinion in Env. Sustainability* **7**: 65–71.
- Cinner, J. E. and Aswani, S., 2007. Integrating customary management into marine conservation. *Biolog. Cons.* **140**: 201–216.
- Cinner, J. E., Marnane, M. J. and McClanahan, T. R., 2005a. Conservation and community benefits from traditional coral reef management at Ahus Island, Papua New Guinea. *Cons. Biol.* **19**: 1714–1723.
- Cinner, J. E., Marnane, M. J., McClanahan, T. R., Clark, T. H. and Ben, J., 2005b. Trade, tenure, and tradition: influence of sociocultural factors on resource use in Melanesia. *Cons. Biol.* **19**: 1469–1477.
- Cinner, J. E., Marnane, M. J., McClanahan, T. R. and Almany, G. R., 2006. Periodic closures as adaptive coral reef management in the Indo-Pacific. *Ecol. & Soc.* **11**: art31.
- Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A. J., Daw, T. M., Mukminin, A., Feary, D. A., Rabearisoa, A. L., Wamukota, A., Jiddawi, N., Campbell, S. J., Baird, A. H., Januchowski-Hartley, F. A., Hamed, S., Lahari, R., Morove, T. and Kuange, J., 2012. Comanagement of coral reef social-ecological systems. *Proc. Nat. Acad. Sci.* **109**: 5219–5222.
- Clarke, P. and Jupiter, S. D., 2010. Law, custom and community-based natural resource management in Kubulau District (Fiji). *Env. Cons.* **37**: 98–106.
- Clements, C., Bonito, V., Grober-Dunsmore, R. and Sobey, M., 2012. Effects of small, Fijian community-based marine protected areas on exploited reef fishes. *Marine Ecol. Progress Series* **449**: 233–243.
- Cochrane, K. L. and Garcia, S. M., 2009. A fishery manager's guidebook. Wiley Blackwell, Oxford, UK.
- Cohen, P. J. and Alexander, T. J., 2013. Catch rates, composition and fish size from reefs managed with periodically-harvested closures. *PLoS ONE* **8**: e73383.
- Cohen, P. J. and Foale, S. J., 2013. Sustaining small-scale fisheries with periodically harvested marine reserves. *Marine Policy* **37**: 278–287.
- Cohen, P., Evans, L. and Mills, M., 2012. Social networks supporting governance of coastal ecosystems in Solomon Islands. *Cons. Letters* **5**: 376–386.
- Cohen, P., Cinner, J. and Foale, S., 2013. Fishing dynamics associated with periodically-harvested marine closures. *Global Env. Change* **23**: 1702–1713.
- Colding, J. and Folke, C., 2001. Social taboos: “Invisible” systems of local resource management and biological conservation. *Ecolog. Applications* **11**: 584–600.
- Denny, C. M., Willis, T. J. and Babcock, R. C., 2004. Rapid recolonization of snapper *Pagrus auratus*: Sparidae within an offshore island marine reserve after implementation of no-take status. *Marine Ecol. Progress Series* **272**: 183–190.
- Dudley, N., 2008. Guidelines for applying protected area management categories. IUCN, Gland, Switzerland.
- Dumas, P., Jimenez, H., Léopold, M., Petro, G. and Jimmy, R., 2010. Effectiveness of village-based marine reserves on reef invertebrates in Emau, Vanuatu. *Env. Cons.* **37**: 364–372.
- Eggleston, D. B. and Parsons, D. M., 2008. Disturbance-induced ‘spill-in’ of Caribbean spiny lobster to marine reserves. *Marine Ecol. Progress Series* **371**: 213–220.
- Evans, L., Cherrett, N. and Pems, D., 2011. Assessing the impact of fisheries co-management interventions in developing countries: A meta-analysis. *J. Env. Manage.* **92**: 1938–1949.
- Fabinyi, M., 2010. The intensification of fishing and the rise of tourism: Competing coastal livelihoods in the Calamianes Islands, Philippines. *Human Ecol.* **38**: 415–427.
- Feary, D. A., Cinner, J. E., Graham, N. A. J. and Januchowski-Hartley, F. A., 2011. Effects of customary marine closures on fish behavior, spear-fishing success, and underwater visual surveys. *Cons. Biol.* **25**: 341–349.
- Fernandes, L., Green, A., Tanzer, J., White, A., Alino, P. M., Jompa, J., Lokani, P., Soemodinoto, A., Knight, M., Pomeroy, B., Possingham, H. and Pressey, B., 2012. Biophysical principles for designing resilient networks of marine protected areas to integrate fisheries, biodiversity and climate change objectives in the Coral Triangle. Report prepared by The Nature Conservancy for the Coral Triangle Support Partnership.
- Foale, S. J., 1998. Assessment and management of the trochus fishery at West Nggela, Solomon Islands: an interdisciplinary approach. *Ocean & Coastal Manage.* **40**: 187–205.
- Foale, S., 2001. ‘Where’s our development?’. *Asia Pac. J. Anthropol.* **2**: 44–67.
- Foale, S., 2006. The intersection of scientific and indigenous ecological knowledge in coastal Melanesia: implications for contemporary marine resource management. *Internat. Social Sci. J.* **58**: 129–137.

- 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 Pac. Viewpoint* **45**: 373–386.
- Foale, S., Cohen, P., Januchowski-Hartley, S., Wenger, A. and Macintyre, M., 2011. Tenure and taboos: origins and implications for fisheries in the Pacific. *Fish & Fisheries* **12**: 357–369.
- Fox, M., Naisilisili, W., Batibasaga, A. and Jupiter, S., 2012. Opportunities and challenges of managing spawning aggregations in Fiji. In: Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia.
- Friedlander, A. M., Shackeroff, J. M. and Kittinger, J. N., 2013. Customary marine resource knowledge and use in contemporary Hawai'i. *Pac. Sci.* **67**: 441–460.
- Game, E. T., Bode, M., McDonald-Madden, E., Grantham, H. S. and Possingham, H. P., 2009. Dynamic marine protected areas can improve the resilience of coral reef systems. *Ecol. Letters* **12**: 1336–1346.
- Gelcich, S., Hughes, T. P., Olsson, P., Folke, C., Defeo, O., Fernandez, M., Foale, S., Gunderson, L. H., Rodriguez-Sickert, C., Scheffer, M., Steneck, R. S. and Castilla, J. C., 2010. Navigating transformations in governance of Chilean marine coastal resources. *Proc. Nat. Acad. Sci. U. S. A.* **107**: 16794–16799.
- Gillett, R. and Cartwright, I., 2010. The future of Pacific fisheries. Secretariat of the Pacific Community, Noumea.
- Gillett, R., Preston, G., Nash, W., Govan, H., Adams, T. and Lam, M., 2008. Livelihood diversification as a marine resource management tool in the Pacific Islands: Lessons learned. *SPC Fish News* **125**: 32–39.
- Goetze, J. S. and Fullwood, L. A. F., 2013. Fiji's largest marine reserve benefits reef sharks. *Coral Reefs* **32**: 121–125.
- Govan, H., 2009. Achieving the potential of locally managed marine areas in the South Pacific. *SPC Traditional Marine Resource Manage. & Knowledge Information Bull.* **25**: 16–25.
- Govan, H. and Jupiter, S., 2013. Can the IUCN 2008 protected areas management categories support Pacific island approaches to conservation? *PARKS* **19.1**: 73–80.
- Govan, H., Tawake, A. and Tabunakawai, K., 2006. Community-based marine resource management in the South Pacific. *PARKS* **16**: 21–27.
- Govan, H., Aalbersberg, W., Tawake, A. and Parks, J. E., 2008. Locally-managed marine areas: a guide to supporting community-based adaptive management. Locally-Managed Marine Area (LMMA) Network, Suva.
- Govan, H., Tawake, A., Tabunakawai, K., Jenkins, A., Lasgorceix, A., Schwarz, A.-M., Aalbersberg, B., Manele, B., Vieux, C., Notere, D., Afzal, D., Techera, E., Rasalato, E. T., Sykes, H., Walton, H., Tafea, H., Korovulavula, I., Comley, J., Kinch, J., Feehly, J., Petit, J., Heaps, L., Anderson, P., Cohen, P., Ifopo, P., Vave, R., Hills, R., Tawakelevu, S., Alefaio, S., Meo, S., Troniak, S., Malimali, S., Kukuian, S., George, S., Tauaefa, T. and Obed, T., 2009a. 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. SPREP/WWF/WorldFish-Reefbase/CRISP, Suva.
- Govan, H., Tawake, A., Tabunakawai, K., Jenkins, A., Lasgorceix, A., Techera, E., Tafea, H., Kinch, J., Feehly, J., Ifopo, P., Hills, R., Alefaio, S., Meo, S., Troniak, S., Malimali, S., George, S., Tauaefa, T. and Obed, T., 2009b. Community conserved areas: a review of status & needs in Melanesia and Polynesia. ICCA regional review for CENESTA / TILCEPA / TGER / IUCN / GEF-SGP, Suva.
- Green, A., White, A. and Kilarski, S., 2013. Designing marine protected area networks to achieve fisheries, biodiversity and climate change objectives in tropical ecosystems: A practitioner guide. The Nature Conservancy and the USAID Coral Triangle Support Partnership, Cebu City, Philippines.
- Gutierrez, N., Hilborn, R. and DeFeo, O., 2011. Leadership, social capital and incentives promote successful fisheries. *Nat.* **470**: 386–389.
- Halpern, B. S., Lester, S. E. and Kellner, J. B., 2010. Spillover from marine reserves and the replenishment of fished stocks. *Env. Cons.* **36**: 268–276.
- Halpern, B. S., Selkoe, K. A., White, C., Albert, S., Aswani, S. and Lauer, M., 2013. Marine protected areas and resilience to sedimentation in the Solomon Islands. *Coral Reefs* **32**: 61–69.
- Hamilton, R. J., Potuku, T. and Montambault, J. R., 2011. Community-based conservation results in the recovery of reef fish spawning aggregations in the Coral Triangle. *Biolog. Cons.* **144**: 1850–1858.
- Hamilton, S. L., Caselle, J. E., Standish, J. D., Schroeder, D. M., Love, M. S., Rosales-Casian, J. A. and Sosa-Nishizaki, O., 2007. Size-selective harvesting alters life histories of a temperate sex-changing fish. *Ecolog. Applications* **17**: 2268–2280.
- Harrison, H. B., Williamson, D. H., Evans, R. D., Almany, G. R., Thorrold, S. R., Russ, G. R., Feldheim, K. A., van Herwerden, L., Planes, S., Srinivasan, M., Berumen, M. L. and Jones, G. P., 2012. Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Curr. Biol.* **22**: 1023–1028.
- Hilly, Z., Schwarz, A.-M. and Boso, D., 2011. Strengthening the role of Women in Community Based Marine Resource Management: Lessons learned from community training workshops. *SPC Women in Fisheries Information Bull.* **22**: 29–35.
- Horowitz, L. S., 2008. "It's up to the clan to protect": Cultural heritage and the micropolitical ecology of conservation in New Caledonia. *Social Sci. J.* **45**: 258–278.
- Hviding, E., 1989. Keeping the sea: aspects of marine tenure in Marovo Lagoon, Solomon Islands. Pp 7–144 in Traditional marine resource management in the Pacific Basin: an anthology ed by K. Ruddle and R. E. Johannes. UNESCO/ROSTSEA, Jakarta, Indonesia.
- Hviding, E., 1998. Contextual flexibility: present status and future of customary marine tenure in Solomon Islands. *Ocean & Coastal Manage.* **40**: 253–269.
- Januchowski-Hartley, F. A., Graham, N. A. J., Feary, D. A., Morove, T. and Cinner, J. E., 2011. Fear of fishers: human predation explains behavioural changes in coral reef fishes. *PLoS ONE* **6**: e22761.
- Januchowski-Hartley, F. A., Graham, N. A. J., Cinner, J. E. and Russ, G. R., 2013. Spillover of fish naivete from marine reserves. *Ecol. Letters* **16**: 191–197.
- Johannes, R. E., 1978. Traditional marine conservation methods in Oceania and their demise. *Ann. Rev. Ecol. & Syst.* **9**: 349–364.
- Johannes, R. E., 1982. Traditional conservation methods and protected marine areas in Oceania. *Ambio* **11**: 258–261.
- Johannes, R. E., 1998. Government-supported, village-based management of marine resources in Vanuatu. *Ocean & Coastal Manage.* **40**: 165–186.
- Johannes, R. E., 2002. The renaissance of community-based marine resource management in Oceania. *Ann. Rev. Ecol. & Syst.* **33**: 317–340.

- Jones, G. P., McCormick, M. I., Srinivasan, M. and Eagle, J. V., 2004. Coral decline threatens fish biodiversity in marine reserves. *Proc. Nat. Acad. Sci.* **101**: 8251–8253.
- Jupiter, S. D. and Egli, D. P., 2011. Ecosystem-based management in Fiji: successes and challenges after five years of implementation. *J. Marine Biol.* **2011**: art940765
- Jupiter, S. D., Weeks, R., Jenkins, A. P., Egli, D. P. and Cakacaka, A., 2012. Effects of a single intensive harvest on fish populations inside a customary marine closure. *Coral Reefs* **31**: 321–334.
- Kinch, J., Mesia, P., Kere, N., Manioli, J. and Bulehite, K., 2006. Socio-economic baseline assessment for the eastern Marovo Lagoon, Western Province, the Solomon Islands. IWP-Pacific Technical Report No. 35. SPREP, Apia.
- Kinch, J., Purcell, S., Uthicke, S. and Friedman, K., 2008. Population Status, Fisheries and Trade of Sea Cucumbers in the Western Pacific. Pp 7–55 in *Sea Cucumbers: A Global Review of Fisheries and Trade*. FAO Fisheries Technical Paper, No. 516 ed by Toral-Granda, V., Lovatelli, A. and Vasconcellos, M. Food and Agriculture Organization, Rome.
- Koczberski, G., Curry, G., Warku, J. and Kwam, C., 2006. Village-based marine resource use and rural livelihoods, Kimbe Bay, west New Britain, Papua New Guinea TNC Pacific Island Countries Report No 5/06. The Nature Conservancy, Brisbane.
- Kronen, M. and Vunisea, A., 2007. Women never hunt — but fish: Highlighting equality for women in policy formulation and strategic planning in the coastal fisheries sector in Pacific Island countries. *SPC Women in Fisheries Information Bull.* **17**: 3–15.
- Lal, P. N. and Keen, M., 2002. Economic considerations in community based project planning and implementation. IWP Technical Report 5. Secretariat of the Pacific Regional Environment Program, Apia, Samoa.
- Lane, M. B., 2006. Towards integrated coastal management in the Solomon Islands: Identifying strategic issues for governance reform. *Ocean & Coastal Manage.* **49**: 421–441.
- Leisher, C., van Beukering, P. and Scherl, L. M., 2007. Nature's investment bank: how marine protected areas contribute to poverty reduction. The Nature Conservancy, Brisbane.
- Léopold, M., Herrenschmidt, J. M. and Thaman, R., 2010. The relevance of traditional ecological knowledge for modern management of coral reef fisheries in Melanesia. In: *Proceedings of the 11th International Coral Reef Symposium*, Ft. Lauderdale, USA.
- Léopold, M., Beckenstein, J., Kaltavara, J., Raubani, J. and Caillon, S., 2013. Community-based management of near-shore fisheries in Vanuatu: What works? *Marine Policy* **42**: 167–176.
- Lester, S. E., Halpern, B. S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B. I., Gaines, S. D., Airame, S. and Warner, R. R., 2009. Biological effects within no-take marine reserves: a global synthesis. *Marine Ecol. Progress Series* **384**: 33–46.
- Macintyre, M. A. and Foale, S. J., 2004. Global imperatives and local desires: competing economic and environmental interests in Melanesian communities. Pp. 149–164 in *Globalization and culture change in the Pacific Islands. Exploring cultures: A Prentice Hall Series in Anthropology* ed by V. Lockwood, Pearson Prentice Hall, Upper Saddle River, New Jersey.
- Macintyre, M. A. and Foale, S. J., 2007. Land and marine tenure, ownership and new forms of entitlement on Lihir: Changing notions of property in the context of a goldmining project. *Human Organization* **66**: 49–59.
- Margules, C. R. and Pressey, R. L., 2000. Systematic conservation planning. *Nat.* **405**: 243–253.
- McClanahan, T. R. and Hicks, C. C., 2011. Changes in life history and ecological characteristics of coral reef fish catch composition with increasing fishery management. *Fisheries Manage. & Ecol.* **18**: 50–60.
- McClanahan, T. R., Donner, S. D., Maynard, J. A., MacNeil, M. A., Graham, N. A. J., Maina, J., Baker, A. C., Alemu, J. B., Beger, M., Campbell, S. J., Darling, E. S., Eakin, C. M., Heron, S. F., Jupiter, S. D., Lundquist, C. J., McLeod, E., Mumby, P. J., Paddock, M. J., Selig, E. R. and van Woesik, R., 2012. Prioritizing key resilience indicators to support coral reef management in a changing climate. *PLoS ONE* **7**: e42884. doi: 10.1371/journal.pone.0042884.
- McDougall, D., 2005. The unintended consequences of clarification: Development, disputing and the dynamics of community in Ranongga, Solomon Islands. *Ethnohist.* **52**: 81–109.
- Mills, M., Jupiter, S. D., Pressey, R. L., Ban, N. C. and Comley, J., 2011. Incorporating effectiveness of community-based management strategies in a national marine gap analysis for Fiji. *Cons. Biol.* **25**: 1155–1164.
- Neitschmann, B., 1985. Torres Strait Islander sea resource management and sea rights. Pp 53–77 in *Traditional marine resource management in the Pacific Basin: an anthology* ed by K. Ruddle and R. E. Johannes. UNESCO/ROSTSEA, Jakarta, Indonesia.
- Nielsen, E. and Gjertsen, H., 2010. Case studies of three economic incentive approaches in marine conservation. Conservation International, Arlington, USA.
- O'Garra, T., 2007. Supplementary livelihood options for Pacific Island communities: A review of experiences. The Foundation of the Peoples of the South Pacific International, Suva.
- O'Garra, T., 2012. Economic valuation of a traditional fishing ground on the coral coast in Fiji. *Ocean & Coastal Manage.* **56**: 44–55.
- Ostrom, E., 1990. *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press, New York.
- Parks, J. E. and Salafsky, N., 2001. Fish for the future? A collaborative test of locally-managed marine areas as a biodiversity conservation and fisheries management tool in the Indo-Pacific region: Report on the initiation of a learning portfolio. The World Resources Institute, Washington DC.
- Polunin, N. V. C., 1984. Do traditional marine “reserves” conserve? A view of Indonesian and New Guinean evidence. Pp 267–283 in *Traditional marine resource management in the Pacific Basin: an anthology* ed by K. Ruddle and R. E. Johannes. UNESCO/ROSTSEA, Jakarta, Indonesia.
- Pomeroy, R. S. and Rivera-Guieb, R., 2006. *Fishery co-management: a practical handbook*. CABI Publishing and International Development Research Centre, Wallingford, UK.
- Prange, J. A., Oengpepa, C. P. and Rhodes, K. L., 2009. Near-shore fish aggregating devices: A means of habitat protection and food security in post-disaster Solomon Islands. *SPC Fisheries Newsletter* **130**: 19–20.
- Prince, J. D., 2003. The barefoot ecologist goes fishing. *Fish & Fisheries* **4**: 359–371.

- Rasher, D. B., Engel, S., Bonito, V., Fraser, G. J., Montoya, J. P. and Hay, M. E., 2012. Effects of herbivory, nutrients, and reef protection on algal proliferation and coral growth on a tropical reef. *Oecologia* **169**: 187–198.
- Rasher, D. B., Hoey, A. S. and Hay, M. E., 2013. Consumer diversity interacts with prey defenses to drive ecosystem function. *Ecol.* **94**: 1347–1358.
- Ruddle, K., 1998. The context of policy design for existing community-based fisheries management systems in the Pacific Islands. *Ocean & Coastal Manage.* **40**: 105–126.
- Ruddle, K., Hviding, E. and Johannes, R. E., 1992. Marine resource management in the context of customary tenure. *Marine Resource Economics* **7**: 249–273.
- Ruttan, L. M., 1998. Closing the commons: Cooperation for gain or restraint? *Human Ecol.* **26**: 43–66.
- Sadovy, Y. and Domeier, M., 2005. Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. *Coral Reefs* **24**: 254–262.
- Schwarz, A. M., Béné, C., Bennett, G., Boso, D., Hilly, Z., Paul, C., Posala, R., Sibiti, S. and Andrew, N., 2011. Vulnerability and resilience of remote rural communities to shocks and global changes: Empirical analysis from Solomon Islands. *Global Env. Change-Human Policy Dimensions* **21**: 1128–1140.
- Sievanen, L., Crawford, B., Pollnac, R. and Lowe, C., 2005. Weeding through assumptions of livelihood approaches in ICM: Seaweed farming in the Philippines and Indonesia. *Ocean & Coastal Manage.* **48**: 297–313.
- Steenbergen, D. J., 2011. Staying Afloat in Changing Tides. *Inside Indonesia* **106**.
- Tawake, A., Parks, J., Radikedike, P., Aalbersberg, W., Vuki, V. and Salafsky, N., 2001. Harvesting clams and data: involving local communities in monitoring: a case in Fiji. *Cons. Biol. In Practice* **2**: 32–35.
- Techera, E., 2009. Customary law and community-based fisheries management across the South Pacific region. *J. Austral. Law Teachers Assoc.* **2**: 279–292.
- Tiraa, A., 2006. Ra'ui in the Cook Islands — today's context in Rarotonga. *SPC Traditional Marine Resource Manage. & Knowledge Information Bull.* **19**: 11–15.
- Veitayaki, J., 1997. Traditional marine resource management practices used in the Pacific Islands: an agenda for change. *Ocean & Coastal Manage.* **37**: 123–136.
- Vianna, G. M. S., Meekan, M. G., Pannell, D. J., Marsh, S. P. and Meeuwig, J. J., 2012. Socio-economic value and community benefits from shark-diving tourism in Palau: A sustainable use of reef shark populations. *Biological Conservation* **145**: 267–277.
- Vunisea, A., 2008. The “culture of silence” and fisheries management. *SPC Women in Fisheries Information Bull.* **18**: 42–43.
- Weeks, R. and Jupiter, S. D., 2013. Adaptive comanagement of a marine protected area network in Fiji. *Cons. Biol.* **27**: 1234–1244.
- Weeks, R., Russ, G. R., Alcala, A. C. and White, A. T., 2010. The effectiveness of marine protected areas in the Philippines for biodiversity conservation. *Cons. Biol.* **24**: 531–540.
- Weiant, P. and Aswani, S., 2006. Early effects of a community-based marine protected area on the food security of participating households. *SPC Traditional Marine Resource Manage. & Knowledge Information Bull.* **19**: 16–31.
- White, A. T., Eisma-Osorio, R.-L. and Green, S. J., 2005. Integrated coastal management and marine protected areas: Complementarity in the Philippines. *Ocean & Coastal Manage.* **48**: 948–971.
- White, C. and Costello, C., 2011. Matching spatial property rights fisheries with scales of fish dispersal. *Ecolog. Applications* **21**: 350–362.
- World Bank, 2000. Voices from the village: a comparative study of coastal resource management in the Pacific Islands — Final Report Pacific Islands Discussion Paper Series No 9 East Asia and the Pacific Region. Papua New Guinea and Pacific Island Country Management Unit, WorldBank, Washington DC.
- Wright, A., 1985. Marine resource use in Papua New Guinea: can traditional concepts and contemporary development be integrated? Pp 53–77 in *Traditional marine resource management in the Pacific Basin: an anthology* ed by K. Ruddle and R. E. Johannes. UNESCO/ROSTSEA, Jakarta, Indonesia.
- Zann, L. P., 1989. Traditional management and conservation of fisheries in Kiribati and Tuvalu atolls. Pp 77–102 in *Traditional marine resource management in the Pacific Basin: an anthology* ed by K. Ruddle and R. E. Johannes RE. UNESCO/ROSTSEA, Jakarta.