Early effects of a community-based marine protected area on the food security of participating households

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Abstract

There is general agreement among conservation practitioners that community-based marine protected areas (CB-MPAs) can improve food security in coastal communities. However, little attention has been given to how communities respond to CB-MPAs, particularly how households try to meet their livelihood needs following the establishment of a restrictive management regime. In this paper, we explore the early effects of a CB-MPA geared toward the management of marine resources harvested by women, as measured by perceived income and food availability. We strive to better understand (1) the contribution of women's fishing activities to livelihood needs, particularly the harvest of blood cockles (*Anadara granosa*) and mud clams (*Polymesoda* spp.) (the species under management); (2) differences in how households respond to a CB-MPA; and (3) the relationship between food security and certain aspects of reef health. To illustrate our case, we draw upon our research experience with social and biological impact assessments and our experience in establishing marine protection in the Western Solomon Islands.

Introduction

The use of community-based marine protected areas (CB-MPAs) for managing coastal marine resources has increased in recent years in many Pacific Island countries. These have had various degrees of success. CB-MPAs contrast with more conventional, top-down approaches to establishing marine protected areas in that they generally aim to incorporate the community and empower participants in the decision-making process. Community participation, however, has not assured the success of management programmes, and CB-MPAs have often failed socially (e.g. in terms of social equity and institutional endurance) and, concomitantly, have resulted in biological failure (e.g. in terms of fisheries management and biodiversity conservation). Social scientists working with MPAs have insisted on the need to focus on the intrinsic characteristics of communities and levels of project inputs (Christie et al. 2003; Mascia 2003) to understand why these management regimes succeed or fail.

Researchers are increasingly recognising that cultural and economic heterogeneity in community characteristics and participation often exists and determines the social and biological outcomes of introduced resource management regimes (Agrawal and Gibson 1999; Cooke et al. 2000; Kellert et al. 2000; Pomeroy et al. 2004; Pomeroy et al. 1997). An emerging area of social impact assessment in MPA studies is measuring how stakeholders share the economic costs and benefits following the implementation of a CB-MPA (e.g. Pollnac et al. 2001). To sharpen this focus, it is imperative to understand how household heterogeneity in productive activities promotes household well-being (i.e. food and livelihood security). Further, it is necessary to question the assumption that an improvement in biological resources (e.g. enhanced fish stocks) within a protected area will equally improve the well-being of all members of a participating community.

Food security is one measure of social well-being or the ability of households to access adequate food at all times and to meet their members' dietary requirements, by either self-production, purchase, gathering, exchange, or a combination of these (Baro 1996; Maxwell and Frankenberger 1992). This definition encompasses issues of food availability, accessibility, and consumption and reflects the household's decision-making and risk-taking processes regarding use and management of resources and assets (Davies 1996; Maxwell 1996; Negash and Niehof 2004). More generally, food security is an essential component of livelihood strategies, or a system in which assets (e.g. natural and financial resources, social capital, etc.),

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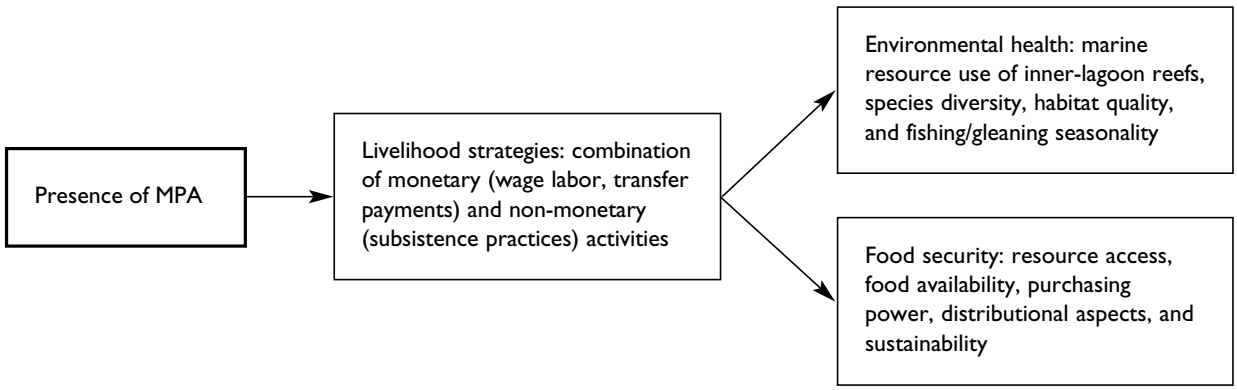

Figure 1. **Conceptual flowchart of livelihood strategies, food security, and marine resource health following the establishment of an MPA**

human activities (e.g. subsistence behaviour), and the accessibility of resources, as mediated by various governance institutions, influence the living conditions attained by a household (Chambers and Conway 1992; Davies 1996). Hence, asymmetries in people's assets and access to resources determine a household's ability to cope with shock, risks and stress induced either by external forces, such as the introduction of government-sponsored conservation measures, or internal ones, such as resource conflicts between people (Allison and Ellis 2001).

A CB-MPA is a type of governance institution that frequently affects household resource use patterns, although the impacts of changes on well-being are seldom quantified. In the case of development programmes that target agricultural production for subsistence farmers (Quandt and Ritenbaugh 1986), limited or enhanced access to resources or increased or decreased food yields (depending upon the biological outcomes of the management prescription) often disproportionately impact the food security of households within a community. These asymmetries clearly influence the overall environmental health of a given area, as households strive to meet their livelihood needs by using other resources or areas differently (e.g. more frequently). A change in habitat quality and species diversity, therefore, occurs not only within a reserve; it is also often the case that the spatial relocation of effort following the implementation of a management regime impacts environmental health outside the managed area. Therefore, it seems logical that we should conduct a dual analysis of social and biophysical dimensions when appraising the 'social' outcomes of a CB-MPA, particularly with regard to coastal communities that are dependent upon the health of the marine habitat for their overall well-being (Fig. 1) (Weiant 2005).

In this paper, we explore the early effect of marine resource management on food security by assessing households' responses to a CB-MPA. First, we ask about issues of household well-being and the contribution of women's fishing activities to household income and food supplies, and how a CB-MPA influences these factors generally. Second, we explore the relationship between food security and a CB-MPA. Third, we preliminarily explore some aspects of lagoon reef health outside the CB-MPA to develop an understanding of the spatial relocation of effort outside of the managed area. To illustrate our case, we present results of our first rapid social impact assessment (RSIA) (2001) of a CB-MPA established in Baraulu and Bulelavata villages in 1999, and we draw upon our experience in establishing marine protected areas in the Western Solomon Islands (Aswani and Hamilton 2004a, 2004b) (Fig. 2). In general, we argue that a community's overall well-being, as measured by income and food availability, can be improved through the establishment of CB-MPAs over the long term, as demonstrated by our most recent and comprehensive nutrition and health monitoring survey in the Roviana and Vonavona areas (2005) (Aswani and Furusawa, n.d). In this paper, however, we argue that the benefits afforded by the MPA can impact households differentially and may vary intra- and inter-annually. Such livelihood shifts not only affect people's well-being but also have the potential to have a detrimental effect on unprotected habitats.

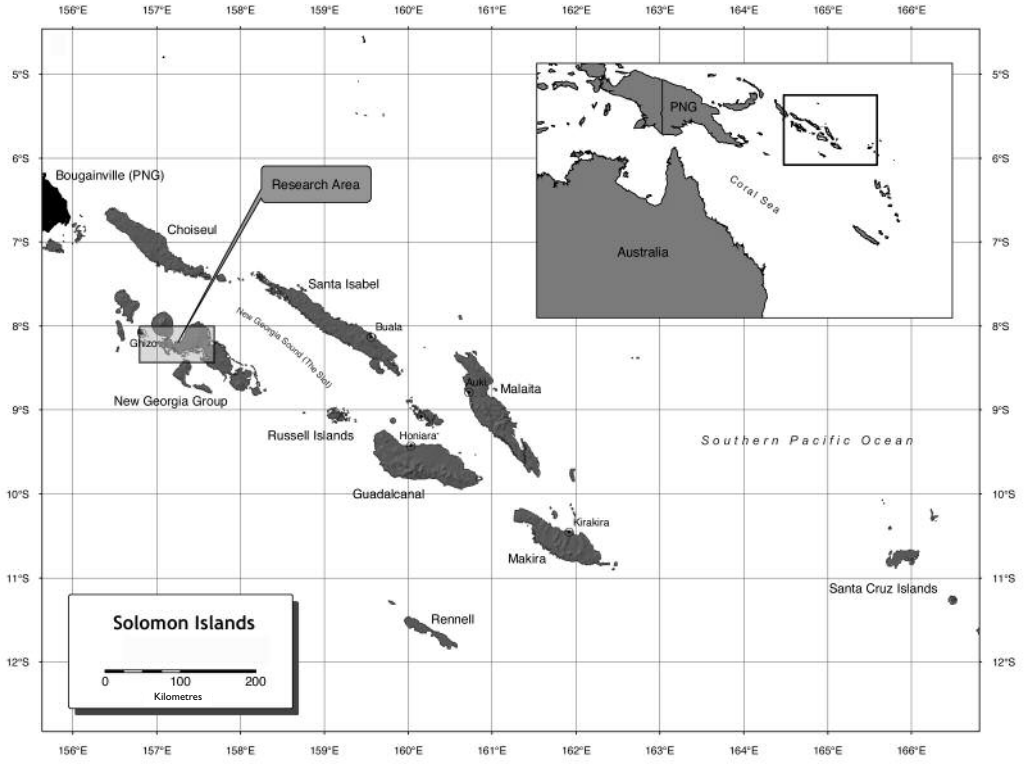

Figure 2. **Solomon Islands**

Study site

The villages of Baraulu and Bulelavata in the Roviana Lagoon, Western Solomon Islands, lie at the intersection of the Kalikoqu and Saikile chieftain districts (Fig. 3). The villages are formed by a single kin-related community and jointly have over 700 residents, a number of whom reside intermittently in the provincial and national capitals. Houses are single boarded with roofs made of sago palm or tin. In these homes, generations of families often live together and share the same kitchen. Household livelihood is semi-subsistence, with locals living off the land and sea while also generating cash from gardening, copra production, shell diving and remittances, among other activities. Fishing is vital for the livelihood of individual households and is of great cultural significance. Marine organisms provide the bulk of animal protein intake, and use of seafood in Roviana is similar to the national per capita consumption of between 32–40 kg a year (FAO 2002). Local leaders exercise control over their customary land and sea territories (customary sea tenure), although they share tenure rights with neighbouring villages (see Aswani 1999, 2005). In recent times, community-based governance has not assured the sustainable use of natural resources, and rising population and development pressures are increasingly hindering the livelihoods of women and children, in particular, their ability to harvest inner-lagoon invertebrate resources.

The harvest of shellfish is an activity typically conducted by women and children. Women predominantly glean in mangroves and in the outer barrier island intertidal flats. The mangrove bivalves collected include blood cockles (*Anadara granosa* and *A. antiquata*), mud clams (*Polymesoda* spp.), oysters (e.g. *Saccostrea cucullata*), Venus shells (*Gafrarium tumidum*) and mudwhelks (*Terebralia palustris*). The first three species are the most important economically and culturally. The growing perception that these species were being over-exploited encouraged Baraulu and Bulelavata community leaders to discuss the establishment of some sort of resource management programme in the late 1990s. With the assistance of the 'Roviana and Vonavona Marine Resource Management Programme' (established by Aswani in 1999), local leaders, including women representatives, decided upon the area and the conservation strategy that they thought would meet the needs of the women, the community and the marine resources.

The 'Baraulu and Bulelavata Women's Shellfish Project' was established in July 1999. It included a temporal and permanent closure designed to protect key invertebrate species. It also included a sewing component to simultaneously assist women to offset the income they would lose by not selling shells collected from the management areas. The bays of Duduli and Rereghana (Fig. 4) were closed to gleaning and fishing, particularly for the harvest of *Anadara granosa* (blood cockle,

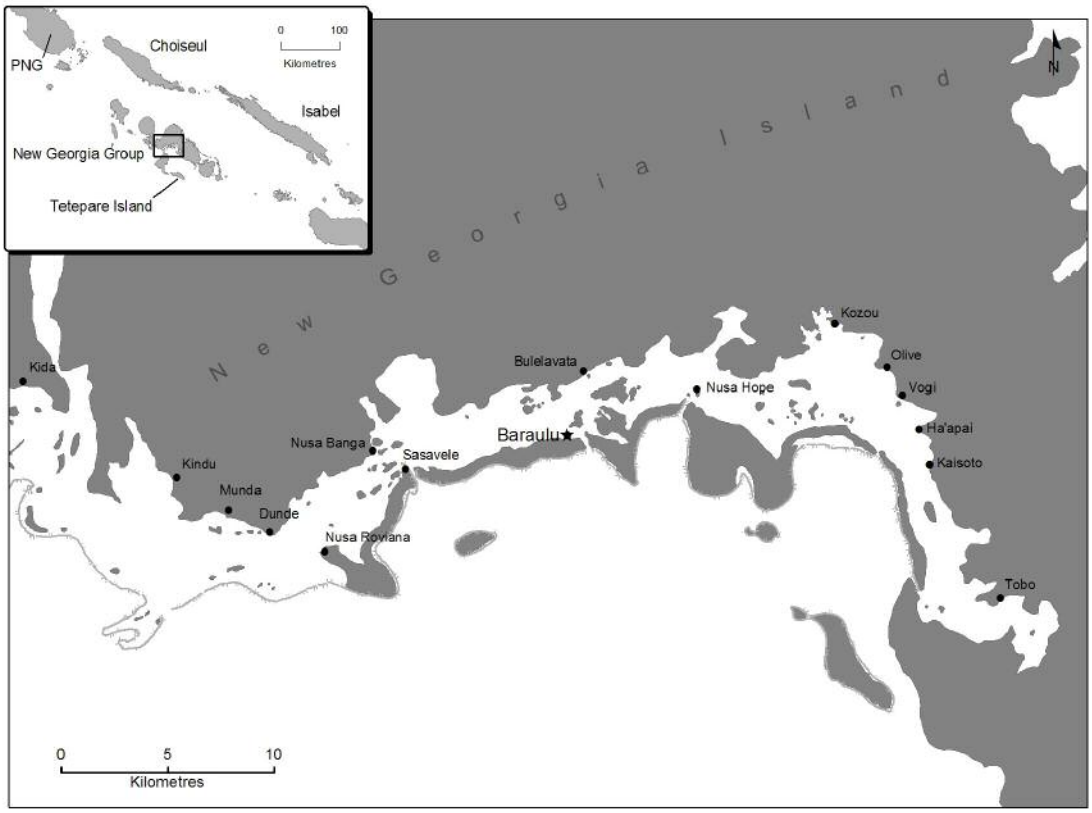

Figure 3. Roviana Lagoon

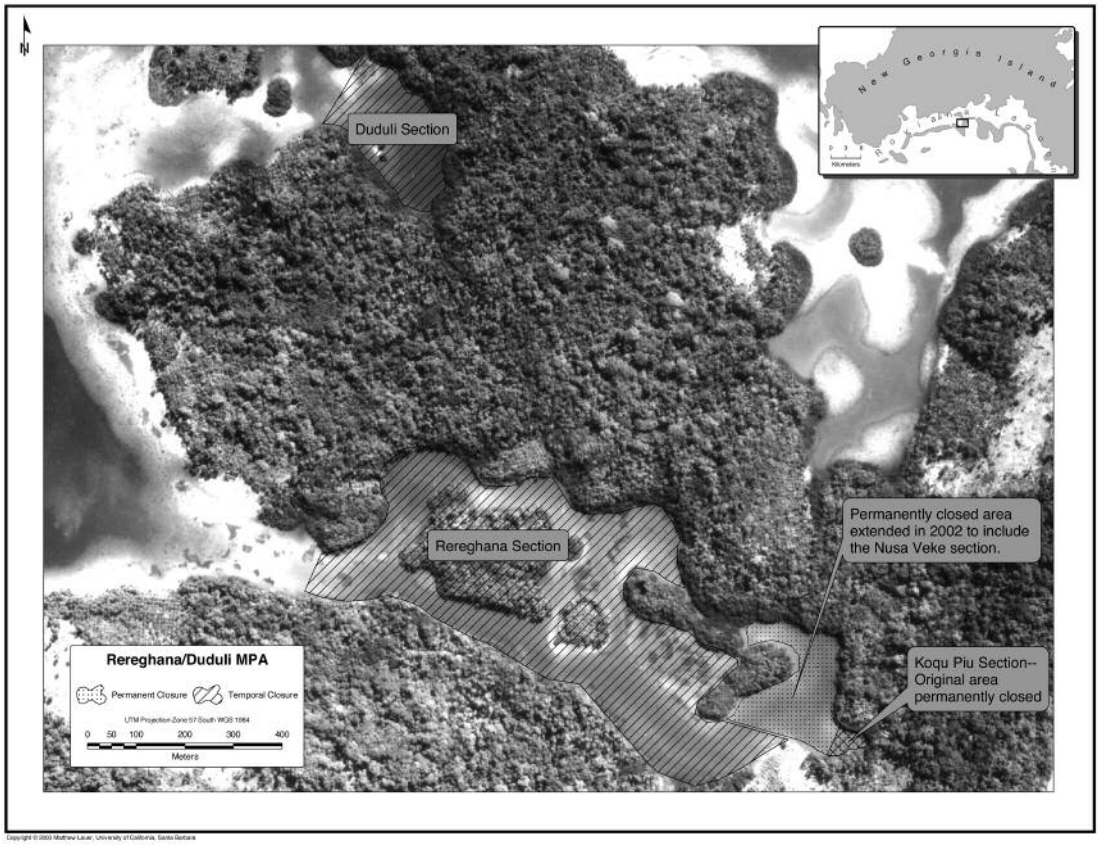

Figure 4. Rereghana and Duduli spatio-temporal community-based marine protected areas

locally referred to as *riki kosiri*) and *Polymesoda* spp. (mud clam, locally referred to as *deo*) shells. The bays were selected based on the perceived decrease in shell size and abundance that had resulted from fishing pressure, site preferences and proximity to villages. The management regime prohibits foraging for eight months (September–April) and opens the areas for four months (May–August) of each year.[3] Note that during the 'open' harvest season there are no limits on the take and this results in over-harvesting of *riki* and *deo*, thus potentially offsetting any increase in shellfish abundance that occurs when the area is closed. To counter this, local authorities have placed certain 'source' areas within the closures off-bounds permanently (locally referred to as *vetu moho* or 'clinics'). In general, the programme has been successful in sustaining the biological resources and in promoting strong community support (refer to Aswani and Weiant 2003, 2004 for further discussion).

Methods

A combination of qualitative and quantitative research methods was employed in the preliminary social impact assessment of the Baraulu and Bulelavata CB-MPA. Our aims were (1) to measure household dependence upon *riki*, *deo* and the other reef resources traditionally harvested by the women for household food security; (2) to assess how the newly established CB-MPA impacted the ability of households to secure food and income; and (3) to investigate how the CB-MPA may have initially affected ecological aspects of certain inner-lagoon habitats situated outside the managed area, especially those harvested by the women. We employed various interview techniques, food diaries and *in situ* inner-lagoon reef monitoring.

First, village households and their associated kitchens were drawn on a map to identify informants for interviewing. A systematic sampling design was employed to select a head woman from every third kitchen, and these women were then contacted for an interview. Note that the 'kitchen' was used as the sampling unit because kitchens are both single- and multi-family units within which all members share the responsibilities of providing and preparing food. We used structured and semi-structured interviews to elicit household data on (1) demographics, (2) economic strategies (e.g., income and time-allocation to productive activities), (3) food procurement strategies, (4) lagoon usage and knowledge, and (5) CB-MPA management issues. These questions were asked in reference to pre- and post-CB-MPA establishment and 'open' and 'closed' season intervals, since the goal was to understand changes in food security over time due to the management strategy. Second, food diaries were used to account for variation in the household's diet as a result of the management regime. Two one-week food diary schedules were distributed to the same kitchens, issued once when the CB-MPA was 'opened' and once when it was 'closed.' The food diary schedules were handed out at the beginning of the week for households to input the meals prepared. The data were then entered into a food matrix in which food items were tallied by household and compared.

Finally, we assessed the possible biological consequences of the spatial relocation of effort caused by the establishment of the CB-MPA.[4] We monitored certain aspects of the benthos and associated species in selected inner-lagoon reefs. The purpose of the monitoring was to collect biophysical data on habitats situated outside the designated protected areas in order to detect possible effects caused by shifting foraging patterns. The sampled sites were selected for monitoring based on the interview data on marine resource use and knowledge. Informants circled sites on maps, gave site names and ranked their preferred fishing areas during the 'closed' fishing season. The most frequently named sites were selected for monitoring. We employed a standard species identification scheme and a line-transect survey method, as detailed in the Reef Check Manual (Hodgson et al. 2003) for underwater research. The reef health of selected sites was assessed by observing species richness, habitat quality and other anthropogenic threats.

Species richness was documented in terms of presence or absence of fish, invertebrates, and substrates listed by Reef Check's Indo-Pacific List (Hodgson et al. 2003) (referred to as target key species) but modified to better reflect the local area. Target key fish species included butterfly fish (Chaetodontidae), sweetlips (Haemulidae), snapper (Lutjanidae), and parrotfish (Scaridae), and target key invertebrate species included diadema urchins, sea cucumber, and lobsters. To better reflect local resource use, locally important fish, invertebrates and crustaceans were also noted, with species that included *makoto noa* (titan triggerfish), *kakaha* (mangrove jack), and *pakopako* (anchor tuskfish), among others (referred to as target local species) (Table 1). Nine classes of substrate (e.g. hard coral, rock and

3. In recent years, the length of the open season has been shortened from 4 to 2–3 months.
4. Note that conclusions drawn from the ecological survey are only tentative in that we had no pre-CB-MPA ecological baseline data on the monitored sites for statistical comparison (before and after closure).

Table 1. **Monitored target and local species list (modified from Reef Check, 2003)**

	Common name	Scientific name	Local name
Fish species			
Target key	Bumphead parrotfish	*Bolbometopon muricatum*	*Kitakita* (juv)/*topa* (adult)
	Parrotfish (>20 cm) (various)	Scaridae	*Malakihi, birake, sinoku*
	Barramundi cod	*Cromileptes altivelis*	*Pazara horehoreqoqoro*
	Grouper (>30cm) (various)	Serranidae	*Pazara* (generic)
	Humphead wrasse	*Cheilinus undulatus*	*Habili*
	Wrasses	Labridae	*Sisiri*
	Snapper (various)	Lutjanidae	*Kakaha*, *heheoku*, *gasagasa*, *odongo*
	Sweetlips (various)	Haemulidae	*Pipirikoho*, *Pehu*
	Butterfly fish (generic)	Chaetodontidae	*Belkekere*
Target local	Thumbprint emperor	*Lethrinus harak*	*Osanga*
	Orange-striped emperor	*Lethrinus obsoletus*	*Ramusi*
	Blue-tail/mangrove mullets	*Valamugil seheli* and *Mugil* spp.	*Lipa*
	Coral breams (various)	*Scolopsis* spp.	*Dongopusi*
	Anchor tuskfish	*Choerodon anchorago*	*Pakopako*
	Titan triggerfish	*Balistoides viridescens*	*Makoto noa*
	Triggerfishes	Balistidae	*Kororo*, *kuluma*
	Blackbanded seaperch	*Lutjanus semicinctus*	*Kulele*
	Sabre squirrelfish	*Sargocentron spiniferum*	*Hori*
	Dash-dog goatfish	*Parupeneus barberinus*	*Pakao*
	Trevally (various)	Carangidae	*Mara* (generic)
	Orange-socket surgeonfish	*Acanthurus auranticavus*	*Tarasi*
	Damselfishes	Pomacentridae	*Kipa* (generic)
	Moon wrasse	*Thalassoma lunare*	*Solori*
	Box and puffer fishes (generic)	Ostraciidae and Tetraodontidae	*Poto patu*, *poto barata*
	Scorpionfishes (generic)	Scorpaenidae	*Kolohagege*
Invertebrates and other			
Target key	Diadema urchins	Diadema urchins	*Evaka*
	Pencil urchin	*Heterocentrotus mammilatus*	*Zore zanga zagna*
	Sea cucumber	Holothurians	*Puhaka* (generic)
	Painted rock lobster	*Panulirus versicolor*	*Hikama koqu*
Target local	Musk crab	*Thalamia crenata*	*Kalipete*
	Arch shell (sand)	*Anadara* spp.	*Riki repi ngohara*
	Arch shell (mud)	*Anadara granosa*	*Riki kosiri (riki)*
	Mud clam	*Polymesoda* spp.	*Deo*
	Mudwhelks	*Terebralia palustris*	*Ropi*
	Oyster	*Saccostrea cucullata*	*Roza*

sand) were monitored, as stated by Reef Check. The presence/ absence of six types of biotic cover were noted, including several Cymodoceaceae and Hydrocharitaceae sea grasses (e.g. *Enhalus acoroides*), coralline algae (e.g. *Halimeda macroloba*), macroalgae (e.g. *Caulerpa racemosa*), and sponge weeds (e.g. *Ceratodictyon spongiosum*). *Habitat quality* was assessed by examining reef damage, occurrence of disease (if identifiable) and presence of garbage/fishing lines. *Threat* was determined by identifying nearby land-based uses, proximity to village and boat use. Data were recorded in ACCESS, and sites were sorted based on the presence or absence of the biological parameters mentioned. Each site was treated as unique, and the sites were not compared, which provided preliminary baseline data for understanding current and future reef conditions.

Results

The Baraulu and Bulelavata livelihood system is no longer completely subsistence based. Nonetheless, household well-being is strongly linked to the exploitation of local marine resources, particularly the harvest by women of *riki*, *deo* and inner-lagoon reef fish, which proved to be critical resources for food and income.

General livelihoods and women

Interview data showed that women play a crucial role in securing income and food for their households and communities. They are largely responsible for child rearing and household duties (e.g. doing laundry, preparing meals and cleaning the house) as well as for tending gardens, harvesting marine resources and selling goods at the market (Table 2). Pre-CB-MPA time-allocation data showed that, on average, women spent more time gardening than men did and that young women spent as much time fishing and gleaning as their male counterparts (Table 3). Initial analysis of post-CB-MPA time-allocation data suggests a similar pattern to that existing before the establishment of the MPA (Aswani, unpublished data).

In general, women were responsible for harvesting marine resources in the inner lagoon areas (shellfish, crustaceans and reef fish). Women harvested *riki* in shallow bays by digging with their feet and hands and *deo* in mangrove forests by digging in the mud with their hands. Women also hand-lined for lagoon fish and gleaned in the inner- and outer-lagoon intertidal zones. While men foraged ubiquitously, they generally preferred to fish in the lagoon passage, outer-lagoon reef drops, and in open waters for pelagic and demersal fish, and to collect coconut crabs (*Birgus latro*) on the outer-lagoon seashore. Children harvested shells on the rocky, seaward side of the lagoon barrier islands (e.g. Turbinidae, *Nerites* spp. and chitons) and fished in the inner-lagoon shore with small handlines. Fishing behaviour, overall, is dictated by seasons, tides, wind, weather and lunar cycles. For instance, the best time to harvest *Nerites* spp. (*sise*) is during the full moon, and women prefer to harvest *riki* at low tide during and after rain.

General income patterns

Among Baraulu and Bulelavata households, there was diversity in economic strategies. In 2001, monetary income (all expressed as rounded percentages) was common among all households interviewed, including sales at local markets (90%), wage labour and/or remittances from at least one household member (60% regularly), gifts such as store food (40% regularly) and logging

Table 2. **Division of labor between males and females in Roviana Villages (Aswani 1997)**

Males	Females	Both
Clearing forest	Washing clothes	Cooking
House building	Washing plates	Child care
Making canoes	Sweeping	Collecting/chopping firewood
Making tools	Weaving mats	Fetching water
Carving	Weaving baskets	Planting crops
Hunting	Gathering *motu* leafs	Weeding and brushing gardens
Climbing coconut palms	Marketing produce	Harvesting crops
Climbing *Areca* palms	Gleaning for marine invertebrates	Picking nuts/fruits
Driving engine boat		Collecting *Pandanus*
Copra production		Collecting sago palm leafs
		Skinning coconuts
		Cooking copra
		Weaving sago for roofing
		Fishing
		Shell diving

Table 3. **Average number of weekly hours allocated to gardening and fishing/gleaning according to age and sex in Baraulu Village (Aswani 1997)**

Activity	7–16 years		17–26 years		27–45 years		46–75 years	
	Males	Females	Males	Females	Males	Females	Males	Females
Gardening	2.1	4.8	5.8	12.7	11.7	16.3	18.4	18.4
Fishing and gleaning	5.2	4.8	6.9	6.6	12.8	6.6	13.5	7.5

royalties (100% once or twice a year), among other activities. There was variation in types of employment, in which construction (20%), logging (20%), store ownership (15%) and teaching (15%) were the most common. Of these, 60% were permanent and 15% were temporary/seasonal jobs. Time-allocation and income-expenditure data have consistently shown since 1994 that gardening and marketing of food such as potatoes, eggplant, tomatoes, beans and bananas are of major importance for all households for accessing daily operational income (Aswani, unpublished data). Women sold most garden produce in Munda and at the Beulah Secondary School near Bulelavata on the New Georgia mainland. Fruits were marketed from the numerous orange and grapefruit trees surrounding the village. Less significant economic activities included weaving mats, house building, selling chickens, and diving for commercial shells. Income was used to buy household items such as soap, canned tuna, sugar and tea, and for church donations and schools fees. Some households saved up to buy iron water tanks, corrugated roofing and outboard motors, among other things.

Food security

Households had mixed preferences with regards to food procurement strategies, with half of the households eating equal amounts of store-bought and local foods and the others eating more locally harvested foods. In general, monetary income played a large role in food procurement. Rice, canned tuna, and noodles had prominent positions in the diet. Households largely purchased store food for taste, for convenience, and as symbols of purchasing power. For all households, the regular availability of rice and sweet potatoes allowed them to cope with periods of low food availability. Results showed that only 5% of the households sampled did not have sufficient food throughout the year and that such shortages often resulted from household size and available income. It was not unusual, however, for most households to experience occasional food supply shortages, often as a result of events that prevented women from tending their gardens and harvesting marine resources; such events included bad weather, religious festivals, a death in the community, community service days, or simply a lack of cash. In gardening, the ownership of plots (number, size and location) and access to a canoe (to travel to mainland gardens) dictated the type and extent of produce grown for each household. For fishing, households were able to access a number of inner- and outer-lagoon marine habitats year-round, and the limiting factor was access to a canoe and fishing gear, rather than access rights to marine resources.

Overall, households had few concerns about the quality of their diets or whether or not the CB-MPA was having an effect on their food consumption patterns. Based on the food diaries, households exhibited variation in types and frequency of foods prepared, particularly between the CB-MPA's 'open' and 'closed' periods. Regardless of season and household, rice and potatoes were consumed at least during one meal per day. Household meals ranged from basic (e.g. rice and tea for breakfast and dinner, as people do not generally eat 'lunch'), to more complex (e.g. tomatoes, *riki*, noodles, rice, and tea) meals. Households with food diet schedules that were less diverse and abundant tended to be economically disadvantaged as a result of household size (number of household members in the work force), sources of income and household composition (percentage of elderly or young children). The food diary results showed that during the CB-MPA's 'open' season, households generally prepared meals with more variety and protein than during the 'closed' season.

Significance of riki *and* deo *for household livelihoods*

The survey results showed that *riki* and *deo* were significant contributors to household food and income. Women explained that they often harvested *riki* and *deo* when the household was in need of food or income. Over 80% of households stated that these mollusks were 'very important' to their household diet and income. Over 90% of them harvested *riki* and *deo* year-round, and 75% of households sold these invertebrates at the market. Of the households sampled, over 60% sold these shells on a regular basis (≥3 times per week), and over 75% of them stated that their sale was 'important' or 'very important' to their household operational income. *Deo* was identified as the preferred species for selling in the market because it takes fewer shells to fill a palm-woven basket, due to this species' regular size.

Other marine resources harvested by women (e.g. shellfish, crustaceans and inner-lagoon fish) and men (e.g. outer-lagoon reef and pelagic fish) were sold at the market, but less often. We also found that the variation in significance of *riki* and *deo* to household diet and income reflected differing degrees of impact and coping strategies resulting from the CB-MPA. In particular, households that were larger in size, without babies and/or small children, that had regular wage employment, and that received gifts, were better off. This is attributed to greater diversification of livelihoods and, therefore, more abundant sources of food for household consumption.

Spatial relocation of effort

In regard to the relationship between food security and the invertebrate CB-MPA, 90% of households stated that they had more marine resources available during the seasonal opening of Duduli and Rereghana (Fig. 4). During the closed season, however, a change in the availability and use of marine resource occurred in a majority of households. Over 80% of households found it more difficult to collect *riki* and *deo* and thus to meet their household's dietary needs. Over 65% of households revealed that during the closed season, they harvested other inner-lagoon species from areas outside the project area more frequently. For example, one household harvested *riki repi ngohara* (*Anadara antiquata*) only during the closed season, while another harvested lagoon fish once or twice a week during the open season and four to five times per week during the closed season. While a majority of women (60%) believed that there were 'abundant' populations of *riki* and *deo* at Duduli and Rereghana as a result of the CB-MPA, they also recognised that many of the marine resources situated outside of the protected area are harvested more heavily during the closed season. Women also considered the state of other marine resources they harvested as 'not abundant' (e.g. *Anadara antiquata*, Turbinidae, *Nerites* spp. and chitons) or 'declining' (a number of lagoon fish species and *Saccostrea cucullata* oysters).

Women named 34 fishing locations that were preferred when the shellfish beds were 'closed.' The six sites most frequently mentioned for habitat quality and/or abundance of target resources (Kolekoleo, Miho Osanga, Sagauru Onone, Pakopako, Umabongi, and Tototu [Sagauru Onone is now under a permanent MPA]) (Fig. 5) are described in Table 4. The *in-situ* monitoring results showed that Miho Osanga and Onone, followed by Tototu, supported the greatest number and diversity of target key species, while Onone, followed by Tototu and Kolekoleo, had the greatest number and diversity of local species (Tables 5 and 6). The survey also revealed that the overall condition of the reef system at these six sites was poor, characterised largely by dead coral (rock), sand and rubble. At Umabongi, for instance, live and dead corals were covered in various macro- and filamentous algae and this also occurred at the other sites. Little anthropogenic damage was observed in terms of garbage and fishing lines. Some of these sites experience sustained boat traffic and human use and are in close proximity to several villages, which could explain the condition of the reef. In general, the findings show that all sites supported greater species richness and diversity of target local species than key species, which suggests that the inner-lagoon reef system remains important for household well-being, regardless of poor reef health.

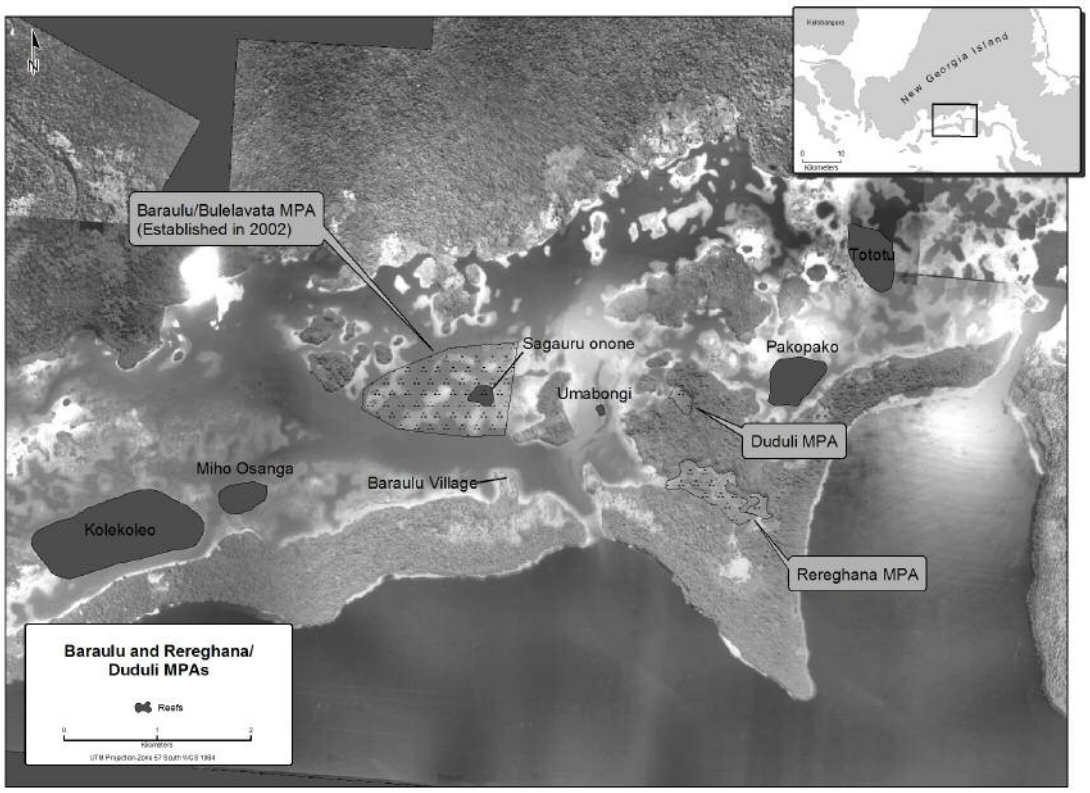

Figure 5. **Sites more often visited by Baraulu and Bulelavata women for fishing and gleaning (also the six monitored sites)**

Table 4. Resource and use characteristics of the six monitored sites (according to indigenous ecological knowledge)

Site name	Site rank	Resource harvested	Resource quality	Use /impacts	Overall human impact
Kolekoleo	**	Reef fish, ark shells (sand), and bêche-de-mer	Habitat quality: medium; fish abundance: high	Pollution from Sasavele; boat traffic; minimal poison fishing using *bunabuna* (piscicides); moderate harvest of invertebrates	Moderate
Miho Osanga	***	Reef fish, ark shells, and *Cardisoma* crabs	Habitat quality: high; fish abundance: high, large sized, arch shells (sand)	Motorized canoe highway; some poison fishing using *bunabuna* (piscicides) during low tide season (*masa rane*)	Low
Onone	*	Reef fish	Habitat quality: low; fish abundance: medium	Boat traffic, anchor dropping, fishing	Low
Pakopako	**	Reef fish, ark shells (mud), ark shells (sand), mud clams, oysters, and mud-whelks	Habitat quality: good but declining; fish abundance: high; shellfish abundance: high	Fished heavily by nearby villages: Nusa Hope, Bulelavata, Baraulu; net fishing; line fishing; anchor; walking; paddles; engines Increased use when Duduli/Rereghana beds are "closed"	Moderate
Umabongi	*	Reef fish and ark shells (sand)	Habitat quality: medium; fish abundance: medium-to-high; shellfish abundance: high, (sand arch shells)	Increased use when Duduli/Rereghana beds are "closed"	Low-to-moderate
Tototu	***	Reef fish, ark shells (sand), mud clams, oysters, and mud-whelks	Habitat quality: excellent; fish abundance: high; shellfish abundance: high	Motorized canoe —highway, and highly used fishing area; possible sewage from Nusa Hope, current dependent; net fishing; runoff from timber activities on mainland; increased use when Duduli/ Rereghana beds are "closed."	Moderate-to-high

* Intensity of visits to sites most frequently mentioned by women in terms of use and habitat quality.

Table 5. Summary inventory of fish and invertebrate species present at the six monitored sites

Biodiversity	Kolekoleo	Miho Osanga	Onone	Pakopako	Umabongi	Tototu
Fish						
Target key species						
Total number of species	13	6	16	10	5	6
Species richness †	23.2%	10.7%	28.6%	17.9%	8.9%	10.7%
Diversity ‡	42%	71%	71%	43%	15%	57%
Target local species						
Total number of species*	21	28	34	0	13	8
Species Richness	20.2%	26.9%	32.7%	0	12.5%	7.7%
Diversity	39%	33%	50%	0	44%	39%
Invertebrates						
Target key species						
Diadema urchin	0	0	0	0	3	0
Sea cucumber	0	0	0	0	0	1
Lobster	0	0	1	0	0	0
Other	-	-	-	-	-	**
Target local species						
Musk crab	++		+		++	
Ark shells (sand)		+			++	

† Species richness (relative measure of target species present): Total number of fish species at the site / Total number of fish species across all sites x 100 (all recorded key species)
‡ Species diversity: Number of target species at the site / Total number of species monitored x 100 (target key and local species).
* No minimum size criteria applied.
** Urchin resembling *Mespilia globulus* or *Tripneustes gratilla*.
+ = species present, ++ = species relatively "abundant," and +++ = species relatively "very abundant."

Table 6. **Substrates observed at the six monitored sites**

Biodiversity	Kolekoleo	Miho Osanga	Onone	Pakopako	Umabongi	Totoru
Substrate description[1]	Rock, rubble, sand, with some live and dead coral. Sea anemones present.	Rock and sand dominate. Abundant cover of sea grass and algae. Cabbage coral present.	Rock, sand, and very little live hard coral.	Mostly rubble, sand, rock, interspersed with hard, mostly dead, coral.	Rock, sand, and rubble. Most hard coral dead and covered in algae. Large areas covered by seagrass and algae.	Most hard coral is dead (rock) and covered with algae. Substantial presence of seagrass.
Coral						
Hard live coral	++	++		+		+
Cabbage coral		+				
Sponge			++			
Algae						
Halimeda macroloba		++	++		++	
Sea grass/macroalgae						
Cymodocea serrulata	++			+++		++
Enhalus acoroides	+	+			+	++
Halymenia durvillaei		+				
Caulerpa racemosa		++	++			
Ceratodictyon spongiosum	+	+				

1. Substrate class was based on Reef Check (2001): hard coral, soft coral, recently killed coral, rock, rubble, sand, silt, sponge, fleshy sea grass, and other. The categories of algae and sea grass were added to better document the local habitat.
+ = species present, ++ = species relatively "abundant," and +++ = species relatively "very abundant"

Discussion

The findings indicate that *riki* and *deo* are important for household food security, serving as important marine invertebrates for household consumption and sale at the market. In addition, the mollusks are important fall-back resources (as are rice and potatoes) that households exploit when food and income are scarce. Hence, the level of household livelihood has the potential to be diminished during the prescribed closures of shellfish beds. During this period, a diversity of livelihood strategies is of fundamental importance, and our results showed that households that were able to exploit other lagoon resources, could cultivate crops, or had access to a flow of monetary income were less impacted by the closures. In fact, households that had members working for wages or that received remittances from kin were better off during the closures than those that relied on subsistence resources overall.

Given these circumstances, how did women view the CB-MPA two years after its implementation? Involvement in the shellfish project had been high, with 60% of women involved in the planning and over 70% involved during monitoring between 2000 and 2003, which explains the large support for the project by women. About 75% of the women found that the populations of *riki* and *deo* in the project area were 'sufficient.' Further, according to other women, a range of benefits have been derived from the project including (1) the community's adoption of a conservation ethic, (2) easier access to *riki* and *deo* during the open season, (3) the perception that children will be better off in the future from conservation today, and (4), unlike other projects, the ability to address the issue of resources harvested by women (for further discussion see Aswani and Weiant 2004).

However, local opinions of the value of the spatio-temporal CB-MPA were mixed when respondents answered questions within the context of food and income. In terms of overall food security, 10% of women felt that food availability in their household had declined, about 65% that it had remained the same, and 25% that there had been some improvements. In addition, around 15% of households felt that their overall well-being had declined, 40% felt that it had remained the same, and around 45% felt that there had been a few improvements since the onset of the shellfish project. Drawbacks of the spatio-temporal CB-MPA voiced by households included (1) increased difficultly in meeting household needs when the shellfish beds were closed, (2) dissatisfaction with the diminished health of fishing grounds outside the

protected area, (3) uncontrolled harvest of *riki* and *deo* during the open season, and (4) an overall increase in competition over the shellfish harvest, as more women were selling *riki* and *deo* at the market than before the project started.

More generally, many households mentioned other factors that had negatively impacted their household income and food security. In particular, 45% of the households felt that the country's ethnic tension (1998–2003) had resulted in the loss of household income (remittances, wage labor income, and decreased sales at the market due to a decline in tourism) and that a change in household composition (return migration) had caused an increase in dependence upon local marine resources. In fact, the number of non-working individuals compared with working members (dependency ratio) increased between 1994 and 2001 (Fig. 6). A high birth rate (growth rate of 3% per annum) coupled with a change in the number of dependents may have exacerbated the degradation of neighboring reefs that were already being heavily used following the establishment of the spatio-temporal refugia in 1999.

Since the time of this assessment, the ethnic tension has ended (2003) and the CB-MPA programme has expanded across the Roviana and Vonavona lagoons. The CB-MPA programme now includes 21 MPAs (Aswani and Hamilton 2004b) — a majority of which are permanent 'no-take' marine reserves (Fig. 7) — and we are currently expanding the MPA network to other areas of the Western Solomon Islands. A new, permanent 'no take' MPA, which was established in Baraulu in 2002, covers an area of 103 hectares. As with other locations, the MPA site was chosen for its ecological and social importance using a combination of locally driven assessments (e.g. proximity to the village for monitoring and enforcement) and the information gained from our interdisciplinary research (see Aswani 2005; Aswani and Lauer 2006). We are confident of an increase in local support for the CB-MPA initiative because our 2005 social impact assessment (SIA) showed local support rates for the MPAs of between 70 and 90% in all regional villages.

In addition, our preliminary data analysis of a health and nutrition survey conducted in 2005 suggests that the MPAs are not having an adverse effect on health and food security and that, in fact, members of villages with effective MPAs have, on average, a greater intake of marine protein than those that do not. In terms of household food security asymmetries, our most recent survey found that dietary intake of marine-derived protein was slightly higher for males in larger households but not in smaller ones, even though this was only marginally significant ($p < 0.10$) (no differences detected for women and children). With regard to health status (i.e. body height and weight, body mass index or BMI, and body fat) there were no differences among adults (Aswani and Furusawa, n.d.). It is possible, then, that as economic conditions have improved in the Solomon Islands, and as the Baraulu and Bulelavata people have become accustomed to the CB-MPAs, the trend disfavouring certain households in terms of constant food availability has stabilised.

Finally, in terms of environmental health, our most recent survey indicated that for all habitat types no significant differences in substrate were observed between the newly protected reefs (2002) and unprotected zones. Damage, bleaching, and trash in coral reefs proved to be the same in protected and unprotected areas. In addition, the mean percentages of coral cover (all functional groups separately) on shallow reefs did not differ significantly from those on unprotected shallow

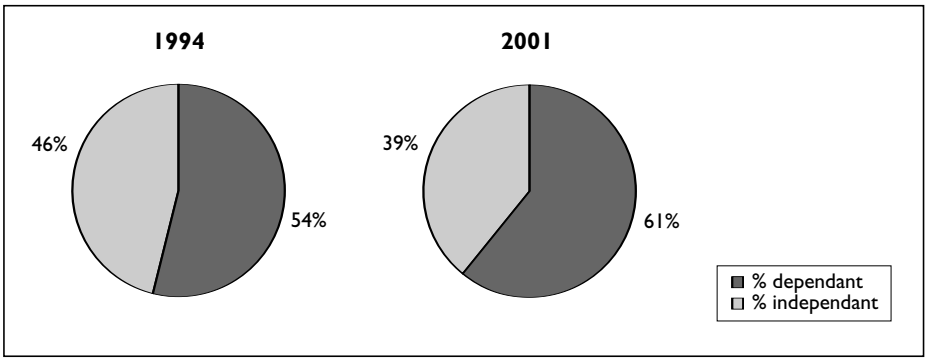

Figure 6. **Change in dependency ratio in Baraulu village between 1994 and 2001**

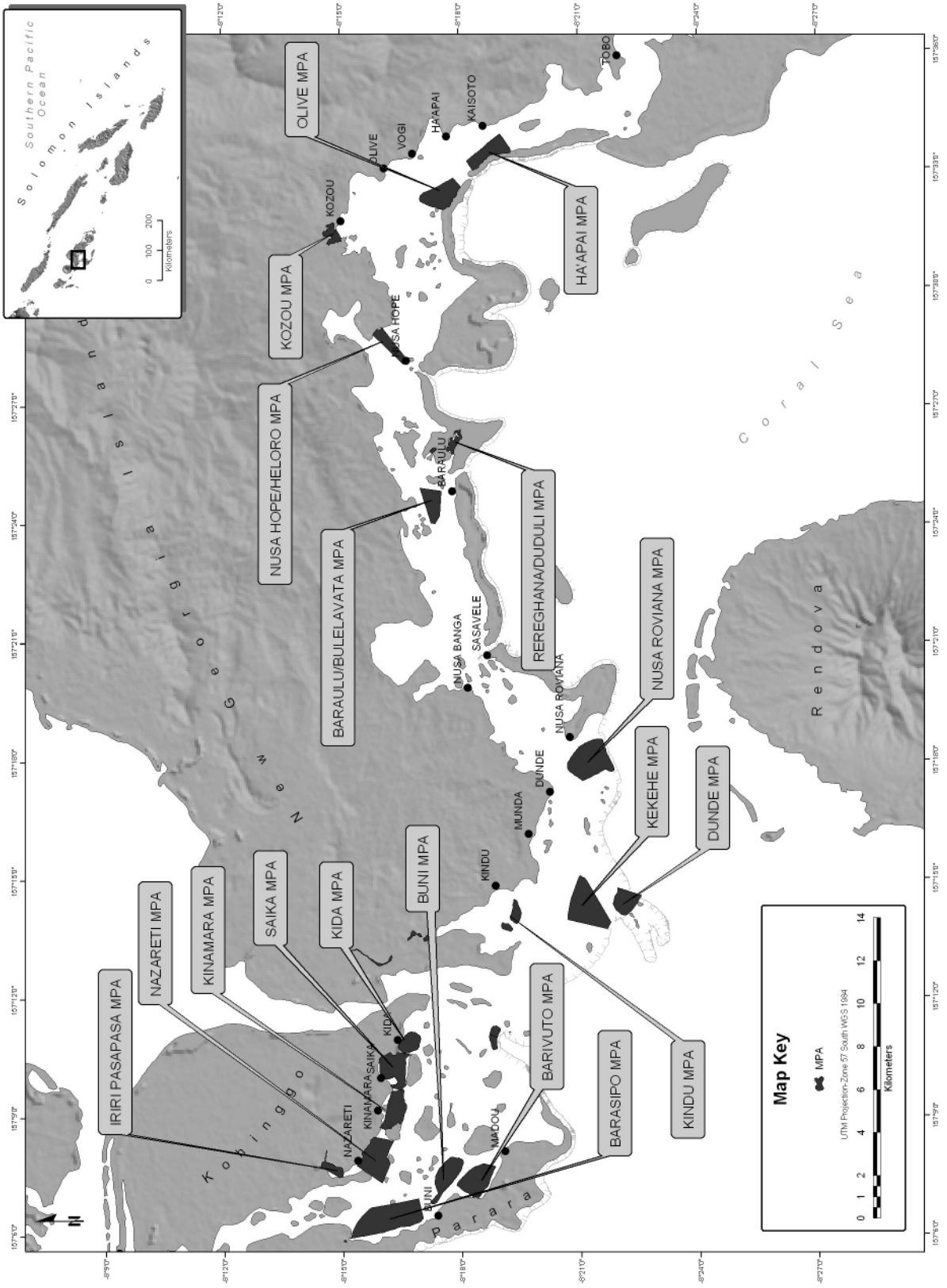

Figure 7. Roviana and Vonavona lagoons MPA system

reefs except for branching and encrusting corals, which were significantly more abundant on the protected mid-water reefs (Geelen, unpublished data). These results, among other factors, suggest that neighbouring sites were not being disproportionately degraded by human activities as a result of the MPAs.

In summary, the question of whether or not the implementation of the 1999 and 2002 CB-MPAs has had detrimental long-term environmental consequences for neighbouring reefs is still inconclusive. It is possible that during the initial stages following the implementation of the invertebrate CB-MPA in 1999 people readjusted their foraging strategies by placing more pressure on neighbouring reefs, thus leading to unexpected environmental deterioration (as suggested in this paper). However, as people became accustomed to the management regimes (both MPAs), they may have shifted or diversified their foraging strategies again. Anecdotal evidence suggests that many fishers are currently foraging at the boundary of the CB-MPA established in 2002. Fishers insist that the biological spillover effect of the MPA is leading to greater catches locally. Our first scientific monitoring (2004) showed that fish densities between MPA and non-MPA sites across Roviana were not significantly different, albeit fish tended to be larger inside the MPAs (Halpern et al. unpublished data). However, our most recent biological study (2006), in which we employed an underwater visual census in tandem with algal settlement tiles to asses the fish grazing intensity both within and outside the marine protected areas, suggests that the reefs within certain MPAs are characterised by greater fish diversity and higher biomass of fish (particularly grazing species), than the adjacent areas open to local fishing pressures (Aswani et al. unpublished data). Hence, it is too early to assess firmly whether local people's claims are accurate or not and whether or not the CB-MPAs are affecting neighbouring marine habitats negatively in the long-term.

Conclusion

This study shows how studying food security issues allowed us to better understand the impacts of the 1999 Duduli and Rereghana spatio-temporal refugia on participating households. We found that households responded and adapted to an introduced resource management regime differently. Our results verified that *riki*, *deo* and other inner-lagoon resources harvested by women are very important for the well-being of households and that they contribute significantly to their diet and income. The results also showed that to compensate for the decreased collection of shellfish during the temporal closures, activities varied with regard to how households used *riki* and *deo*. Some households appeared to trade-off the mollusks' value as sources of food and income, while other households opted to sell the mollusks rather than consuming them. The food security study hinted at ways in which some households were able to cope with and adapt to the shellfish harvest restrictions and were able to eat a healthy diet, obtain a decent standard of living, and experience less hardship than others, particularly during the initial years following the establishment of the first CB-MPA. This is an important finding, as women and the resources that they harvest are rarely integrated into management strategies.

CB-MPAs serve as one mediating process that governs the nature of resource extractive activities and access to resources. In the Baraulu and Bulelavata case, the spatial relocation of effort seems to have impacted areas outside the managed area, particularly during the CB-MPA's 'closed' season. As households strived to meet their dietary and income needs, they exploited other marine resources more frequently than before the shellfish project was established, and more during the closed periods than during the open periods. While the health of the preferred fishing areas of the inner-lagoon reef system appeared poor, both in terms of live coral and target fish species richness, these areas were of great importance to women. Causes of poor reef health may include overfishing, deforestation on the mainland and, to a lesser extent, sewage discharge from nearby villages. If the health of the inner-lagoon reef continues to decline, the populations of *riki* and *deo*, which appear to be doing well in the managed areas (Aswani and Weiant 2004), will become that much more important. Our management strategy should strive to better integrate the complete range of women's fishing practices to mitigate unnecessary trade-offs in the conservation of *riki* and *deo* and associated mangrove areas over other frequented inner-lagoon reef areas.

Studies of rural poverty diversification in marine-dependent communities are increasingly turning to livelihood system analysis to provide understanding of how diversification serves as a way to cope with variation and uncertainties in households' environments (e.g. Allison and Ellis 2001; Pollnac et al. 2001; Pomeroy et al. 1997). In this paper, we have argued similarly that social research on CB-MPAs must position the strategy as an event to which a household's livelihood system has to respond and adapt. We also suggest that more attention should be paid to the inter-relationships among social and biophysical processes in shaping livelihood systems of households and the environ-

mental health of their surrounding ecosystems when a CB-MPA is established.

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