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INVESTIGATING CORAL REEF ETHNOBIOLOGY IN THE WESTERN SOLOMON ISLANDS FOR ENHANCING LIVELIHOOD RESILIENCE

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Coral reefs are of great socio-economic and cultural importance for many coastal communities across the tropics, yet little is known about the way people classify reefs locally and their close ecological and social relationships with these habitats. In a world in which coral reefs are increasingly threatened (Hughes *et al.* 2003, McClanahan *et al.* 2008), understanding how people perceive and use coral reefs is essential for predicting future ecological and social impacts, as well as for understanding human adaptation mechanisms to ecological change in these tropical marine ecosystems. This is particularly true for Oceanic islands, which are vulnerable socially and ecologically to deteriorating coral reefs, rising sea levels, and increasingly unpredictable climatic and geological phenomena (Lazarus 2012, McClanahan and Cinner 2012). Increasing human vulnerability to changing coral reefs, consequently, has resulted in numerous calls for comprehensive management using tools that include fishing regulations and quotas, marine protected areas (MPAs), and ecosystem-based management (EBM) for protecting coral reefs and other marine ecosystems. Other interventions, such as social safety nets, evacuation from vulnerable sites and diversification within fisheries, have been proposed to enhance adaptive capacity, ameliorate social and economic sensitivity, and reduce exposure to changing coral reefs (Cinner *et al.* 2012).

In the last few decades, authors have recurrently advocated the use of local/traditional/indigenous knowledge in the management of coastal ecosystems to ameliorate their degradation (Berkes 1999, Drew 2005, Narchi *et al.* 2014, Ruddle and Johannes 1985) and build resilience to human generated environmental and climate change (Alexander, Bynum, Johnson *et al.* 2011; Mercer *et al.* 2010). Research has shown that documenting indigenous ecological knowledge is crucial to understand human decision-making processes in coral reef-human interactions. Human foraging practices are constrained by the flow of information between fishers and the environment, the variability of spatio-temporal events, and the uneven distribution of prey species across coral reef ecosystems (Aswani and Hamilton 2004). Ethnographic research also has shown that for coastal people the sea is not an inert world but a dynamic and ever-changing one—a realm that in addition to providing daily sustenance is historically and spiritually meaningful to

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those who interact with it (Hviding 1996, Ruddle and Satria 2010). For many coastal peoples, then, coral reefs are more than just resource exploitation areas. They also are geomorphologic features that allow or bar people from navigating, markers that define property rights of the seascape in relation to other coastal and terrestrial habitats, and cultural and historical features that embody tribal identity and ideology (Aswani and Lauer 2006a).

In this article, I describe people's ecological and social relationships with coral reefs in two extensive lagoon ecosystems in the Western Solomon Islands (Fig.1) that while relatively unspoiled are increasingly being degraded by human actions. Building upon more than two decades of unpublished and published research that describe particular aspects of a long-term research programme in human ecology (e.g., Aswani 1998, Aswani and Vaccaro 2008), I combine ecological and ethnographic data to analyse the people's environmental perceptions and the dominant characteristics of coral reef habitats in the region. These include the productive practices carried out in these habitats by local inhabitants, the prevalent climatic and environmental phenomena associated with reefs and their transformation, and the socio-cultural meaning of reefs for lagoon peoples from the standpoint of local ecological knowledge. Documenting people's ecological classification and socio-economic and cultural use of coral reefs is not just a descriptive effort, but rather is relevant for understanding human-environmental interactions and for creating comprehensive base resource maps of people's perceptions and behaviour.

From the perspective of building socio-ecological theory, understanding people's capacity to perceive and classify their coral reefs, as well as their ability to identify environmental changes, has implications for how knowledge systems mediate between marine ecosystems and human communities—a capacity that can affect people's resilience and vulnerability as coral reefs become increasingly threatened by environmental and climate change (Aswani and Lauer 2014). From the perspective of management, this information can be used for designing hybrid marine and terrestrial conservation plans that integrate local forms of knowledge and management with Western approaches to fisheries managements including marine protected areas and ecosystems based management plans (Aswani and Ruddle 2013). Ultimately, building upon local people's knowledge and institutions not only fosters inclusiveness and equity in resource management and conservation, but also can result in greater resource management success and concomitant livelihood resilience to climate and other environmental change.

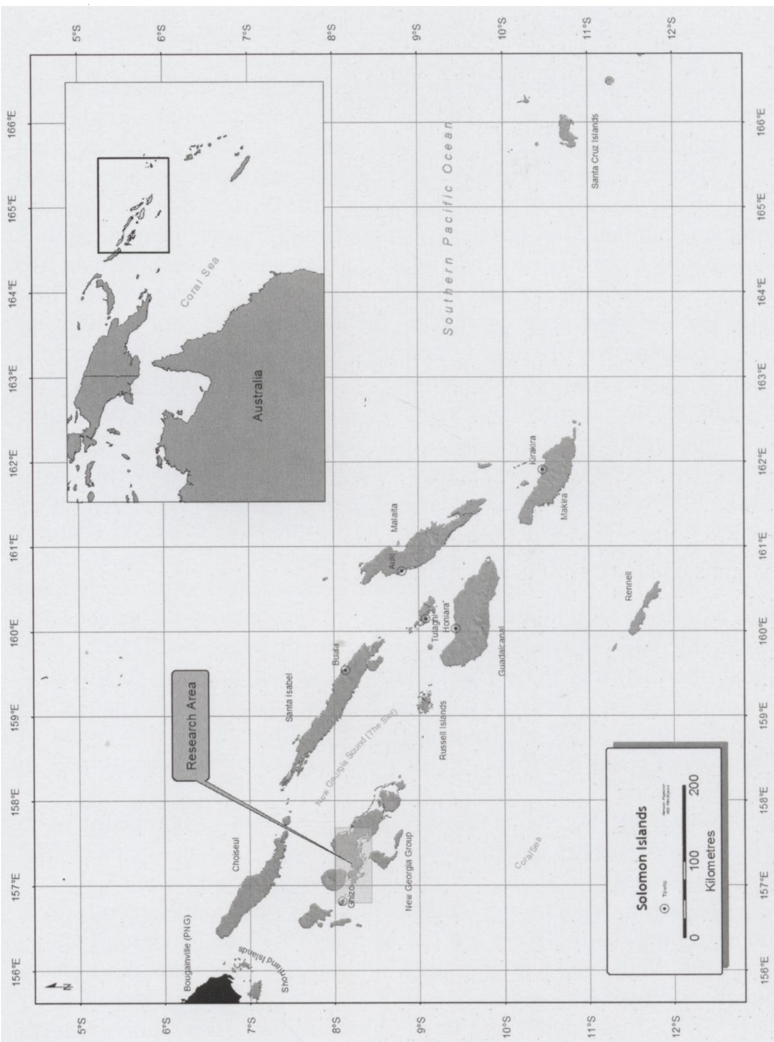

Figure 1. The Solomon Islands.

STUDY SITE

The Western Solomon Islands are mostly of volcanic origin and are covered with dense rainforest. Extensive lagoon systems, including the Marovo, Nono, Roviana and Vonavona lagoons (Fig. 1), shelter fish, shells, corals and other marine life, and make this region an important biodiversity hotspot within the Coral Triangle (Allen 2007). The lagoon ecosystems display a gradient of habitats, including mangrove forests, river mouths, mudflats, grassbeds, coral atolls, barrier reefs and marine lakes, and have characteristics of both coastal and coral atoll lagoons. The geomorphology of most Western Solomon lagoons resemble a combination of coastal "restricted" and "leaky" lagoons as they are shore parallel, have a distinctive tidal hydrology, and have more than two entrances connecting the lagoons with the open ocean (Kjerfve 1994). Their passages are wide and deep, permitting the movement of large volumes of water—a characteristic of estuarine and coral atoll ecosystems which permits unimpaired water exchange between the open ocean and the lagoons, thus allowing for the development of coral reef communities of diverse ecological characteristics in the entrances and central zones of the lagoons.

The Roviana Lagoon in New Georgia Island extends from Munda to Kalena Bay near Viru Harbour. The lagoon is protected by a series of offshore, raised coral islands that developed during the Pleistocene from sea-level changes and accretion of coral limestone, organic debris and volcanic detritus (Stanton and Bell 1969). The outer lagoon shoreline is characterised by rugged and notched limestone with numerous inlets, bays, carbonate-sand beaches and moats (Stoddart 1969), while in the inner lagoon there are small islets, coral reefs and intertidal reef flats. The Vonavona Lagoon, adjacent to Roviana, lies northwest of New Georgia between Kohinggo and Parara Islands and has a similar topography to Roviana (Fig. 2), although the movement of large masses of water has favoured the development of more coral reefs in southern Vonavona.

The Roviana and Vonavona region is home to about 15,000 people who share a common ancestry and history and are mostly Roviana speakers. The Roviana Lagoon is divided into the political districts of Saikile and Kalikoqu to the east, each a collection of villages that was ruled until recently by a paramount chief. To the west are the hamlets of Nusa Roviana, Dunde, Kekehe, Lodu Maho and Kindu in the Munda area which either have chiefs or council of elders who independently control each hamlet. Vonavona is similarly divided into small and large chieftainships. Community leaders exercise control over the use of and access to natural resources within their particular customary land and sea territories, although changing demographic and consumption patterns coupled with large-scale resource extraction ventures are increasingly eroding these indigenous management systems.

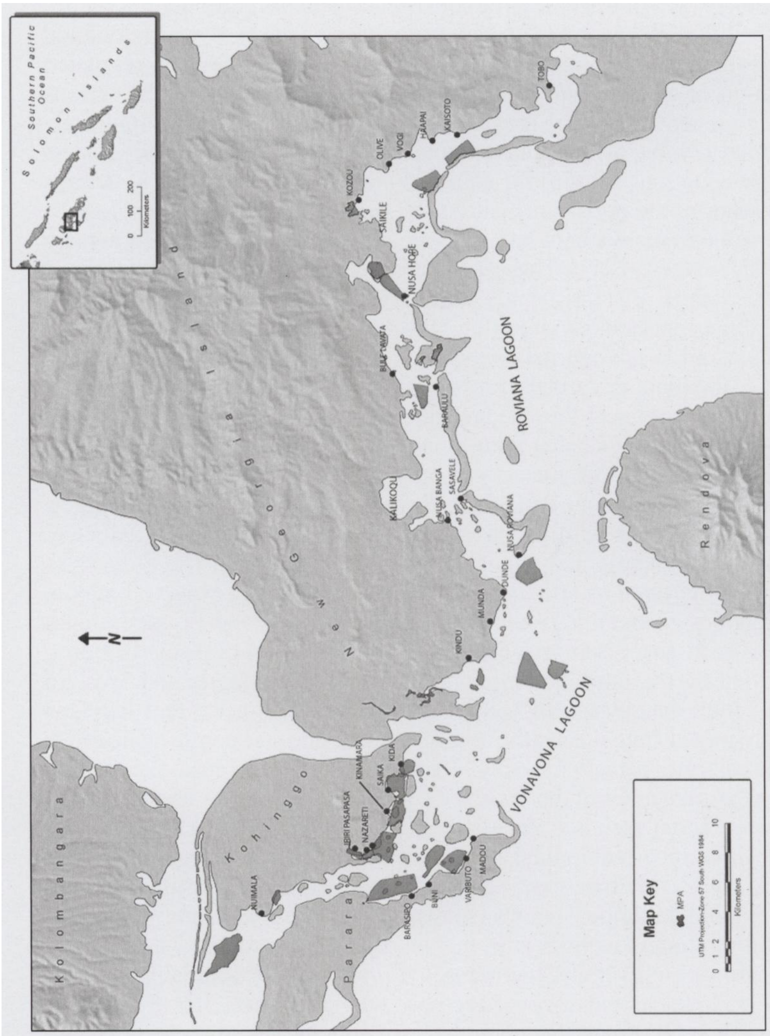

Figure 2. The Roviana and Vonavona Lagoons, New Georgia, Solomon Islands (MPA sites established under our research and conservation programme in collaboration with local communities shown in dark grey).

While people make money by shell diving, marketing of local produce, the selling of handicrafts, copra production and the operation of small stores, among other types of activities, the subsistence economy still plays a central role in the life of Roviana and Vonavona dwellers. Today, several livelihood activities threaten coral reefs. These include the small-scale, non-regulated exploitation of commercial species like holothurians, trochus and various shell species; increasing pressures on the subsistence fishery from small-scale commercial netting of fish, night diving for scarids and for rock lobsters for the growing tourist industry; collection of corals for building structures such as wharfs; the aquarium fish collection trade; and most importantly, sedimentation from poor land-based practices which impact on lagoon nursery areas (Halpern *et al.*, 2013). These, coupled with environmental effects related to climate change, are increasingly degrading coral reefs and their future role in providing ecosystem services (e.g., local food sources).

Roviana and Vonavona fishers have a deep awareness of the biological rhythms of their lagoons and the creatures that inhabit the numerous habitats. They possess ecological knowledge rooted in the maritime experiences of the ancestral coastal peoples who inhabited these lagoons (Vuragare and Koloi tribes), knowledge that is not only an intergenerational transfer of information, but is also one that is transformed within the context of people's practical engagement with, experience of and performance of productive activities in a dynamic and changing marine environment (Ingold 1993). Even so, as suggested by Hviding (1996) for neighbouring Marovo Lagoon, the indigenous epistemology is being challenged as islanders increasingly entangle with the outside world. Indigenous ethnobiology is being transformed by the introduction of new fishing technologies and Western environmental categories. In fact, recent research suggests that Roviana people are increasingly losing the ability to make fine taxonomic distinctions of various marine species (Aswani n.d.). For all this change, local fishers still: (i) have cognitive maps of the seascape and marine organisms therein, which translate into actual resource classification, use and allocation geographically; (ii) recognise local ecological processes and changes, including habitat structure (habitat delineation), species composition and distribution, and spatio-temporal biological events (spawning aggregations) and (iii) possess proxy information to identify sites that incorporate the ecological processes which support biodiversity, including the presence of exploitable species, vulnerable life stages and inter-connectivity among habitats (Olds *et al.* 2014).

Since 1999 my research team and I have collaborated with local people to establish a series of conservation measures, including temporary and permanent closures to manage coral reefs across many sites in the Western Solomon Islands (32 MPAs) (Fig. 2). The management sites were selected through a combination of locally-driven assessments and the socio-ecological research of local habitats and associated management needs (as detailed in this paper). Temporal and permanent closures were selected following a perceived decrease in the size distribution and abundance of fish and invertebrates thought to be driven by fishing pressures, site preferences and village proximities. Some temporal closures, and their seasonal harvesting in particular, were established to conform to local social (e.g., death and feasting) and economic (e.g., need for cash for school fees) realities of Solomon Islands communities. As of 2014, various permanent and temporal closures were still operational (approximately seven or eight MPAs including Nusa Hope, Buni and Kozou among others), but a number of projects had been disbanded as a result of an ongoing religious conflict between various local communities.

METHODS

For over two decades, my team and I have collected multiple data sets using a combination of ecological, geospatial, and anthropological methods to analyse: (i) people's environmental perceptions and the dominant characteristics of coral reef habitats in the region, (ii) the prevalent climatic and environmental phenomena associated with reefs, (iii) the productive practices exerted in these habitats by the Roviana and Vonavona people, (iv) local perceptions and effects of environmental and climatic change on reefs and (v) the socio-cultural meaning of reefs for inhabitants from the standpoint of local ecological knowledge.

Documenting Coral Reef Ethnobiology

Indigenous ecological knowledge (IEK) of coral reefs was documented through extensive participation in fishing expeditions and interviews with fishers. Open-ended, semi-structured and structured interviews with several hundred young, middle-aged and elderly men and women from the region were conducted between 1992 and 2014 to elicit IEK. *Emic* (local perspective) categories for coral reefs and associated species (as well as those of other habitats [see Aswani and Vaccaro 2008]) were documented by inquiring about: (i) the name and ecological composition of recognised reef types, (ii) the associated species of fish, molluscs and crustaceans found in each reef category, (iii) seasonal variations in the availability of different taxa found within each reef type, (iv) the existence of particular seasonal events such as spawning aggregations, (v) varying weather, tidal and lunar conditions and their impacts on coral reef types and fauna and (vi) local uses for each coral reef type and its associated species. Emic environmental categories were matched with corresponding Western ones to designate habitat composition and biotic taxonomies. The Latin binomial nomenclatures for identifying corals follow Vernon (1993); for shells, Cernohorsky (1978) and Hinton (1972); for fish, Masuda *et al.* (1984), Munro (1967) and Randall, Allen, and Steene (1990); for echinoderms and algae, Morton and Challis (1969); and for sea grasses, Waycott *et al.* (2004). All organisms were identified through photographs and specimen collections (particularly shells).

Mapping Coral Reefs

To map the seascape, we first digitised 91 black-and-white aerial photos using a high-resolution scanner and then georectified the images so that they could be used as base maps. These digitised aerial photos were brought into the GIS and merged to create a mosaic of the lagoons. These large maps were used as visual tools to conduct participatory image interpretation exercises in each of the villages across the lagoons to identify coral reefs and other marine habitat types (Aswani and Lauer 2006a). During these focus-group exercises, fishers were instructed to identify and discriminate particular marine areas (e.g., coral reef types) to establish the spatial foundation for the ensuing analysis. Next, we worked with local fishers to delineate the seascape with GPS receivers and map indigenously defined biophysical areas, fishing grounds and spots, and associated coral reefs and other marine habitats. Local fishermen from each community guided a researcher in a small boat around the perimeter of each named area. During each trip, the locations of spawning, nursery, burrowing and aggregating sites for particular species within each recognised area were recorded and pinpointed with the GPS. The spatial extent of the area (represented as either lines or polygons) and the location of particular biological characteristics (represented usually as points) collected with the GPS receivers were consolidated into a large file and imported into our GIS database as a layer. Eventually, this information was ground-truthed (verified) via *in situ* habitat mapping and underwater visual census (UVC) surveys (see Aswani and Lauer 2006a for further details).

Recording Foraging and Productive Practices in Coral Reefs

Productive practices were recorded by extensive participation in fishing expeditions. Participant observation consisted of focal follows, which involved keeping *in situ* time-motion records of over a hundred fishers' behaviours and measuring their catches. In addition, various fishers kept self-reporting foraging (fishing and gleaning) diaries to supplement this data set. This information was used to understand seasonal movements of fishers, to forecast the decisions that fishers make in the types and abundance of fish that they prey on, the use frequency of different coral reefs, and to understand the fluctuating intensification of fishing efforts as fishers respond to environmental transformations related to climate change (see Aswani 1998).

Tracking Coral Reefs, Climate and Environmental Change

Indigenous ecological knowledge of environmental change was recorded through two methods: interviewing and participatory image interpretation. For the interviews we used semi-structured interviews and free-listing exercises. Respondents were asked to describe and list the changes they had observed in various coral reef habitats, as well as across other domains (open sea, inner lagoon, land ecology, agriculture and weather) (n = 266). The responses were "free-listed" allowing each respondent to list as many responses as they wanted. The assumption was made that the first response was the most important change recognised by the informant and so forth. For each change, respondents were asked to free-list the causes of change and concurrently they also were asked to explain how they "adapted" to the change. Finally, respondents were asked when they first noticed the change. Changes and causes were each coded into a common set of responses and were reduced to the codes that elicited 95 percent of the responses. The remainders were given the code of "other". Data were examined to determine the most common changes observed for each system. The scores for each change were summed across all data (first listed change = 4, second listed change = 3, third listed change = 2, fourth listed change = 1) (Aswani and Abernethy n.d).

Participatory image interpretation was conducted in two villages (Nusa Hope and Olive) to analyse local perceptions of change in coral reefs over the past 25 years (1986-2011). Knowledgeable informants were selected through a snowball sample to interpret remotely sensed data (identify reef types) and delineate changes in coral reefs (e.g., bleaching) on large-format image printouts. Groups convened upon arrival in each community and meetings were held in each village's town hall. The group was informed that the objective of the exercise was to map collectively observed changes in coral reefs (and other habitats too) across the lagoons. They did this by drawing points, lines and polygons on the satellite images, colour-coded according to the nature of the impact. Afterwards, I photographed the marked-up images with a digital camera for digitising. To enable further analysis, Esri's ArcGIS software was used to digitise the participants' drawings and associated written descriptions. The photographs of each marked-up satellite image were geo-referenced, and each drawing was digitised as a unique point, line or polygon feature representing the location of an impact on coral reefs. The digital features were assigned attributes corresponding to the ancillary written data collected during the mapping exercise. These attributes describe: (i) the village of the participants who created the drawing; (ii) the domain (e.g., coral reef types) associated with the drawing and (iii) a description of the noticed impact (e.g., bleaching, anchor damage, disease, etc.).

Identifying Cultural Meaning of Coral Reefs/Seascapes

To understand the cultural meaning of coral reefs for Roviana and Vonavona people, I studied customary management systems and their historical context using open and semi-structured interviews with household heads. These interviews explored kinship systems, tribal history, marine territoriality, and people's current perceptions of resource use and access rules. Key informants (mostly elders) were also interviewed about regional oral history and customary practices as they relate to fishing and coral reefs.

RESULTS

Coral Reef Ethnobiology

Western Solomon Islanders do not conceptually divide terrestrial and marine areas into separate domains. Rather they see their inclusive ancestral property estate, or *pepeso* for Roviana and Vonavona people, as including all terrestrial and marine habitats stretching from the interior of the New Georgia mainland all the way through to the open sea mid-way between the channel which separates New Georgia and other neighbouring islands (Fig. 3). Each *pepeso* is demarcated by a boundary (*voloso*) which divides the land and reefs of each respective estate. Boundaries generally follow major rivers flowing from the mountainous interior into the lagoon. At the barrier islands, territorial dissections are usually marked by the passages. In the Vonavona Lagoon area, where there are no major rivers, particularly on Parara Island, boundaries are marked by traditional shrines placed in inner lagoon islands and by certain topographic features. Within each major boundary, hundreds of smaller subdivisions separate individual land holdings, gardens, communal plantations, villages, and even households. A *pepeso* is divided into four major sections: The mainland (*tutupeka*), the lagoon (*poana* or *koqu*), the outer barrier islands (*toba*) and the adjacent sea-facing habitats (*vuragarena*), and the open sea (*lamana*). The *tutupeka* includes the interior forests, swamplands, rivers and bordering mangroves. The *poana* encompasses internal waters, inner lagoon islands, and from the mid-section to the interior shores of the barrier islands. The *vuragarena* comprises the mid-section of the barrier island (*toba*) to the outer shore, the adjacent reef drop, and the adjacent open ocean waters. Finally, the open-ocean where fishermen troll for bonito and tuna is considered the *lamana*. These domains, in turn, are highly diverse mosaic environments consisting of numerous habitat types.

Within each marine section, inhabitants divide each of the mentioned marine areas into named locations (the name usually preceded by the term *sagauru* 'reef') which are viewed as marine resource exploitation areas, geographical features that permit or restrict people from navigating, and cultural and historical markers that represent territorial boundaries and/or cultural sites

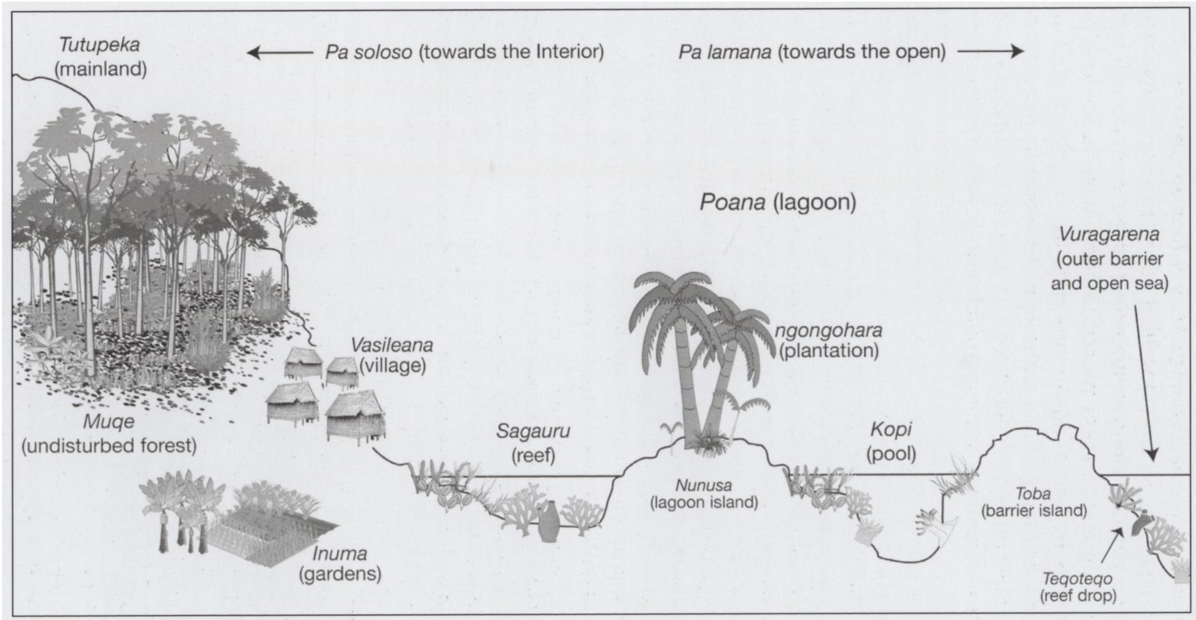

Figure 3. Roviana zoning of land and sea domains or *pepeso* (Aswani and Vaccaro 2008).

of importance. Next, fishers classify fishing grounds (*habuhabuana*) that are found within the locally named and delimited geographical areas (Aswani and Vaccaro 2008). Fishing grounds tend to be clearly definable habitats such as isolated reefs (or reefs surrounded by deep water), channels, bays, grassbeds, inland pools, coastal pools, mud flats, and sections of the outer reefs (reef slopes). Fishing grounds are recognised by native informants as productive depending on daily, lunar and seasonal variation. In areas where there are no human settlements, fishing grounds are identified as productive at all times, and other areas are only recognised as productive when certain migratory species pass through them. Fishing grounds themselves are composed of one or more areas or floating spots (*alealeana*), in which people drop their lines or nets to target particular species or assemblages of species. Underlying this cognitive construction of the seascape (Fig. 4), lagoon dwellers recognise a number of biological events of significance, such as spawning aggregations sites, as well as major and minor ecological assemblages of abiotic and biotic features (Figs 4 and 5). In what follows, I show the ethnobiological or emic conceptualisation of *major* and *minor* reef habitats and associated biotopes. Specifically, I review their correspondence with scientific habitat mapping, the activities that occur across these habitats, how people perceive changes in the marine environment and associated resources, and the place of spiritual beliefs in shaping cultural activities across the seascape.

Inner Lagoon Shallow Reefs (Major). The word *sagauru* is generic for 'reef', but it is usually employed locally in reference to inner lagoon shallow reefs ranging between one and four metres in depth. Shallow reefs or *sagaru masa*, are characterised by dead and live *Porites, Acropora, Millepora*, Faviidae,

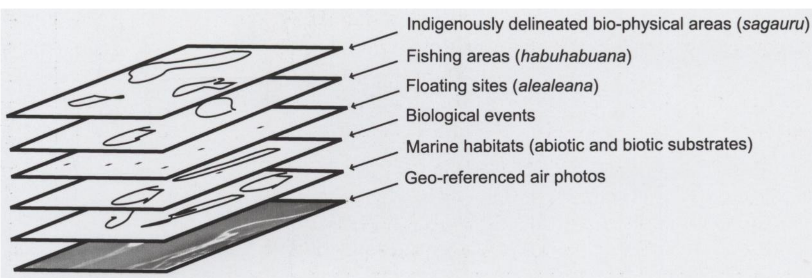

Figure 4. Roviana perception of the seascape as represented by layers (or themes) in the GIS (Aswani and Lauer 2006a).

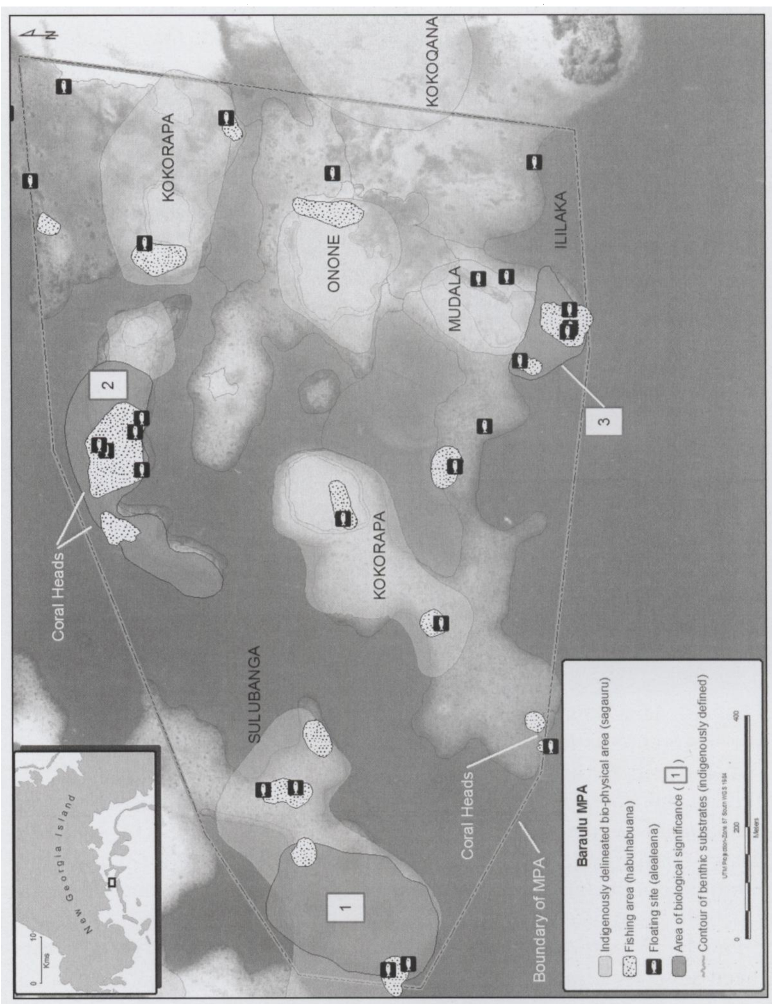

Figure 5. Local demarcation of predominant reefs and fishing sites of the Baraulu MPA (Aswani and Lauer 2006b).

Agariciidae and *Pocillopora* coral colonies, as well as scattered *Fungia* corals. Other organisms such as branchial crowns (e.g., *Spirobranchus giganteus*) and sabellids (e.g., *Sabellastarte sanctijosephi*) inhabit the crevices of *Porites* coral heads (Womersley and Bailey 1969). Various species of Hydrocharitaceae sea grass (e.g., *Thalassia hemprichii* and *Halophila ovalis*) and *Halimeda* spp. macroalgae are spread over the dominant sand and coral rubble substrate (*zalekoro*). Shallow reefs are heavily exploited by everyone for fishing and collecting crustaceans and shells, particularly during the day low-tide/night high-tide season from May to September (*masa rane/odu bongi*). This habitat is good for fishing during early mornings and evenings but can also be good at noon on particular reefs. Fishers say that the best time for fishing in this habitat is during low and ebbing tides when reef and pelagic species concentrate in these areas. The best lunar phases are the new moon, first quarter and full moon. Fishing methods employed in shallow reefs include angling, trolling, netting, diving, spearing, and the use of piscicide leaves. The practice of each fishing method varies according to the tidal seasons or time of day. Some of the most important income-generating shells are gathered from these areas, such as cardita clams (*Beguina semiorbiculata*) and nassarius shells (*Nassarius camelus*), which are collected by men and women during the day low-tide season. Shells taken for subsistence purposes in shallow reefs include venus (*Gafrarium tumidum*) and ark shells (*Anadara* spp.). With the shift in tidal seasons in September, nocturnal low-tide permits divers to access multiple reefs where various species of sea cucumbers (*bêche-de-mer*) are found. Although sea cucumbers are harvested throughout the year, during this period the *bêche-de-mer* fishery intensifies. Once processed, *bêche-de-mer* is sold to Asian traders in Roviana and Honiara for export.

Inner Lagoon Mid-Depth Reefs (Major). Mid-depth reefs or *sagauru lamana* are inner lagoon reefs found at depths between five and 15 m. Like shallow reefs, mid-depth reefs include *Porites, Acropora, Millepora*, Faviidae, Agariciidae and *Pocillopora* coral colonies. Sea grasses and macroalgae are not as abundant as in shallow reefs because of water depth. The substrate is a mix of coral rubble and fine silt combined with sand. Mid-depth reefs occur throughout the lagoons and are prevalent in lagoon pools and channels. Local people recognise these areas as commonly colonised by large coral formations locally called *huquru* (*Porites cylindrica*), which in recent years have been severely affected by disease and bleaching. These coral colonies are good fishing spots because various species of fish, such as paddle-tail (*Lutjanus gibbus*), hussar (*Lutjanus adetii*) and yellow-margined (*Lutjanus fulvus*) snappers, aggregate in them during the full moon. While mid-depth reefs are considered good fishing grounds, they are not visited as commonly as shallow reefs. Men do most of the fishing here, as women and children prefer shallower waters. Line fishing is favoured during low-tide as larger fish concentrate in this habitat away from very shallow reefs, grassbeds and sand banks. Mid-depth reefs are visited throughout the year according to the lunar cycle and species targeted, and the preferred fishing times are as with shallow reefs. The most common fishing methods used in this habitat are drop-line, angling, trolling and diving. Diving in mid-depth reefs is more common in the Munda and Vonavona areas, since the waters are clearer than the more turbid Roviana ones.

Cape Reefs (Major). Cape reefs (*miho sagauru*) are reefs that are differentiated locally from other reef types because they form around capes or peninsulas that extend out from inner lagoon islands or mainland promontories, and present diverse prospects for fishing. These reefs are usually shallow and have similar characteristics to shallow inner lagoon reefs. However, colonies of soft corals such as *Sarcophytum* and *Sinularia* and some gorgonians are common in the sloping edges of these reefs. Common fishing techniques used by locals include trolling, angling, day and night spear throwing and spearfishing, netting and diving and gleaning for invertebrates. Various pelagic species, such as great barracudas (*Sphyraena barracuda*) and bluefin trevally (*Caranx melampygus*), aggregate in cape reefs, and experienced fishers know that fish forage up and down the fringing drops and wait for them to aggregate at the reef's edge. In the mornings and evenings between September and December, and during the last quarter of the lunar cycle, fishers angle and drop-line in cape reefs for yellowmargin (*Pseudobalistes flavimarginatus*) and titan (*Balistoides viridescens*) triggerfishes, scribbled snapper (*Lutjanus rivulatus*), and speckled-fin rock cod (*Epinephelus ongus*), as these species concentrate in the deeper edges of these areas.

Reef Drops (Major). The word *teqoteqo* refers to reef drops either in the inner or outer lagoon (smaller drops are known as *barapatu*). Those found in the inner lagoon extend from three to 40 m in depth and are located at the edge of lagoon channels, pools and passages. They are generally comprised of coral rubble and rocky substrates spotted with *Porites, Acropora, Pachyseris* and *Merulina* colonies, among other hermatypic coral families. In larger passages, colonies of soft corals such as S*arcophytum, Sinularia* and gorgonians are common. Fishing here is good and fishers prefer early morning and late evening, low-tide, and the new and full moons. Drops bordering passages are good for fishing scribbled snapper, triggerfishes, speckled-fin rock cod, and flowery cod (*Epinephelus fuscoguttatus*) during the last quarter and 'no moon' (*koroqana*) lunar phases.

Outer lagoon reef drops, on the other hand, range between three and 200 m in depth and are more diverse than inner lagoon reefs because waters are clearer, thus affecting the distribution and density of coral reef species. Outer lagoon corals can cover up to 100 percent of the limestone substrate and include *Pocillopora, Montipora, Acropora, Favia, Porites, Goniopora, Pavona, Echinophyllia, Lobophyllia, Seriatopora* and *Stylophora*, among many others. Fishing in this habitat is good and less influenced by tidal variation of than along the inner lagoon reef drops, though weather conditions govern their ease of access. Currents are also an important consideration when fishing in the outer drops; Roviana fishers say that the best fishing occurs when bait "scent" follows the direction of the current towards the known fish location. For instance, if a fisher is fishing at the edge of a drop and the current is flowing outward to sea, the fisher should position away from the drop in the shallow shelf and cast the line towards the reef drop. Fishing methods in the inner and outer reef drops are similar, the most common being angling, trolling, bottom-lining, spearing and diving. Inner reef drops are used throughout the year, while outer drops are mostly used from August through December when large schools of barracuda (e.g., *Sphyraena jello, S. putnamiae* and *S. barracuda*) congregate in specific areas.

Outer Lagoon Deep Water Reefs (Major). Sagauru ruata are deep water reefs found in the outer lagoon that are usually not visible from the surface. The depth of these reefs ranges from 15 to over 100 m and dense coral formations including various *Acropora, Montipora, Echinophyllia, Leptoseris, Pavona, Sinularia* and gorgonians species dominate the rocky substrate (Morton and Challis 1969). Some *ruata* reefs are near the outer lagoon intertidal zone, while others are hundreds of metres away from the shoreline. *Ruata* reefs are used by men and are only accessible at specific times because southeast trade and westerly winds prevent access to these sites. *Ruata* are considered good fishing spots and, unlike inner reefs, they are productive throughout the lunar cycle. Midday and nights are the favoured times to fish here and fishing is optimal on full moon nights as currents are not too strong and certain species like paddletail snappers, big-eye bream (*Monotaxis grandoculis*) and red bass (*Lutjanus bohar*) aggregate in these reefs. Traditionally, a local fishing method named *kura habili*, involving the use of traps to capture humphead Maori wrasse (*Cheilinus undulatus*), was practiced during the last quarter of the lunar phase from September to December of every year in the shallower areas of this habitat. Today, the most common fishing methods used in *ruata* reefs are drop-lining, vertical-trolling, and regular trolling if schools of fish are spotted on the surface.

Pede Coral Colony (Minor). Pede is used as a generic term to refer to coral colonies of the *Turbinaria, Pavona* and *Acropora* families, which are found in mid-depth and shallow areas of the inner lagoon. These infrequent colonies tend to stand apart in sandy bottoms away from coral reefs and, while visited throughout the year, these are more intensively exploited during the day low-tide season. The most commonreef fishing methods used here are angling and diving. All sorts of coral fish species are caught here, the most prevalent being paddletail snappers, various groupers (e.g., *Cephalopholis microprion*, *C. boenak*, and *C. cyanostigma*) and brown-headed emperor (*Lethrinus hypselopterus*). In recent years anthropogenic processes have led to the demise of many of these coral formations.

Huquru Coral Colony (Minor). Huquru or *Porites cylindrica* coral colonies, can be found in shallow reefs around islands inside the lagoons and are considered good fishing spots. Local divers note that they are good places to catch smaller green and hawksbill turtles, which often are found resting under these coral formations. Frequent reef fish include hussar snappers, various species of groupers, black-banded seaperch (*Lutjanus semicinctus*), yellow-margined seaperch, and sweetlips (*Plectorhinchus chaetodonoides*, *P. goldmanni*, and *P. obscurum*). Also, *hikama koqu* 'painted rock lobsters' (*Panulirus versicolor*) are found here. The prominent fishing methods practiced in *huquru* are angling and diving with locally-made spear throwers known as *bugiri*. Like *pede*, these formations have been decimated in recent years.

Patu Voa Coral Head (Minor). Patu voa "stones" are *Porites* corals formations (e.g., *P. lobata, P. australiensis* and *P. lutea*) that are the most widespread hermatypic corals in the Roviana and Vonavona lagoons. They are found everywhere, including in mangroves and near river mouths. These corals can be massive and thrive in the sediment-rich water of the lagoons (Vernon 1993). Colonies found in mangroves and grassbeds are small and many are dead, which are then classified locally as *patupatu.* Most reef fish species targeted by humans can be caught near these coral heads, the most prominent being several species of groupers (*Epinephelus ongus*, *Plectropomus areolatus* and *P. laevis*), titan triggerfish and sabre squirrelfish (*Sargocentron spiniferum*). Groups of surgeonfish and sweetlips aggregate in these coral heads at specific times. The most common fishing activities carried out in these formations include angling, diving and the use of traditional piscicides. Diving for cardita clams (*Beguina semiorbiculata*), which are found embedded in these corals, is also an important activity.

Patu Kakarapihi Coral Head (Minor). Favites and *Goniastrea* corals are locally referred to as *patu kakarapihi* and are recognised as being structurally similar to *patu voa* but much softer and less widespread. *Patu kakarapihi* are found in well-developed coral reefs near reef slopes and outer lagoon reefs; few are found in the inner shallow reefs of the lagoon. Common reef fish found here include paddletail snappers, yellow-margined seaperch, groupers and angelfish (*Pomacanthus* spp.). During the day low-tidal season these coral heads are visited by divers looking for fish and for cardita shells.

Coral Reef Maps

The local categories were compared with scientific habitat mapping and there was a close correspondence between these forms of habitat categorisation. The geospatial analysis of coral reef ethnobiology revealed that out of the 615 indigenously defined foraging areas, more than 400 areas were locally classified as "coral reefs" of some sort, particularly inner and outer lagoon coral reefs (Fig. 6). Notably, this emic map of the coral reef seascape corresponds with scientific habitat mapping conducted by our team (Albert, Grinham, Bythell *et al.* 2011), and an in-depth analysis of particular sites revealed high correspondence rates between indigenous classifications of coral reefs and scientific surveys. For instance, a point-to-point comparison between quadrat dive field survey results and indigenous aerial photo interpretation of dominant benthic substrates in the Baraulu MPA (Roviana Lagoon) (Fig.7) showed that equivalence rates for a moderately detailed classification scheme of the benthos were on average between 75 percent and 85 percent. For hard corals agreement ranged between 55 percent and 89 percent, depending of the mix of hard corals with other abiotic substrates (e.g., sand, rubble or rock) (Aswani and Lauer 2006a). The habitat mapping exercise, in tandem with the foraging analysis (next section), showed that inner shallow lagoon and outer drop reefs are among the most important habitat types in the lagoons and a large percentage of the total marine resources acquired come from these habitats.

Productive Practices in Coral Reefs

Roviana and Vonavona people have a close relationship with the illustrated coral reefs and a large proportion of marine protein for sustaining lagoon dwellers comes from these habitats. Lagoon peoples distinguish over 50 major fishing methods with numerous local variants that are adapted to particular environmental conditions and designed to target specific or general species clusters. There are four major interdependent physical forces that structure the times and places where fishers use these methods: (i) daily and seasonal tidal fluctuations, (ii) lunar phase periodicity, (iii) wind patterns and (iv) lagoon

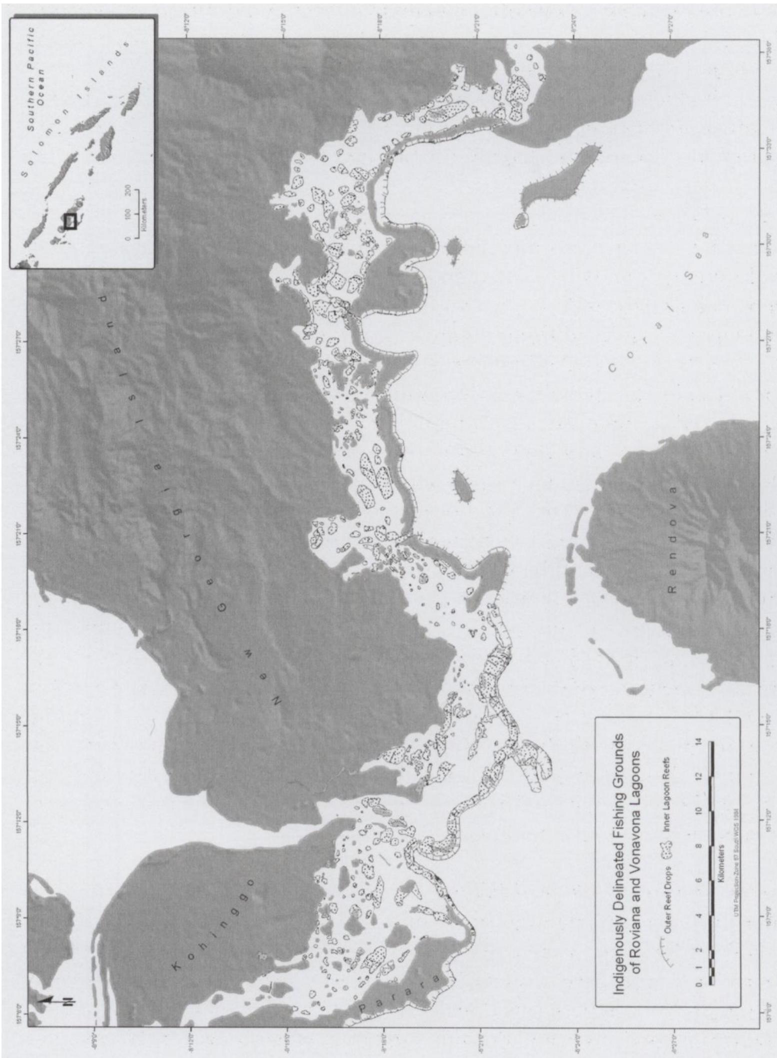

Figure 6. Locally delineated marine habitats with predominance of inner-lagoon and outer-lagoon reefs (Aswani and Lauer 2006b).

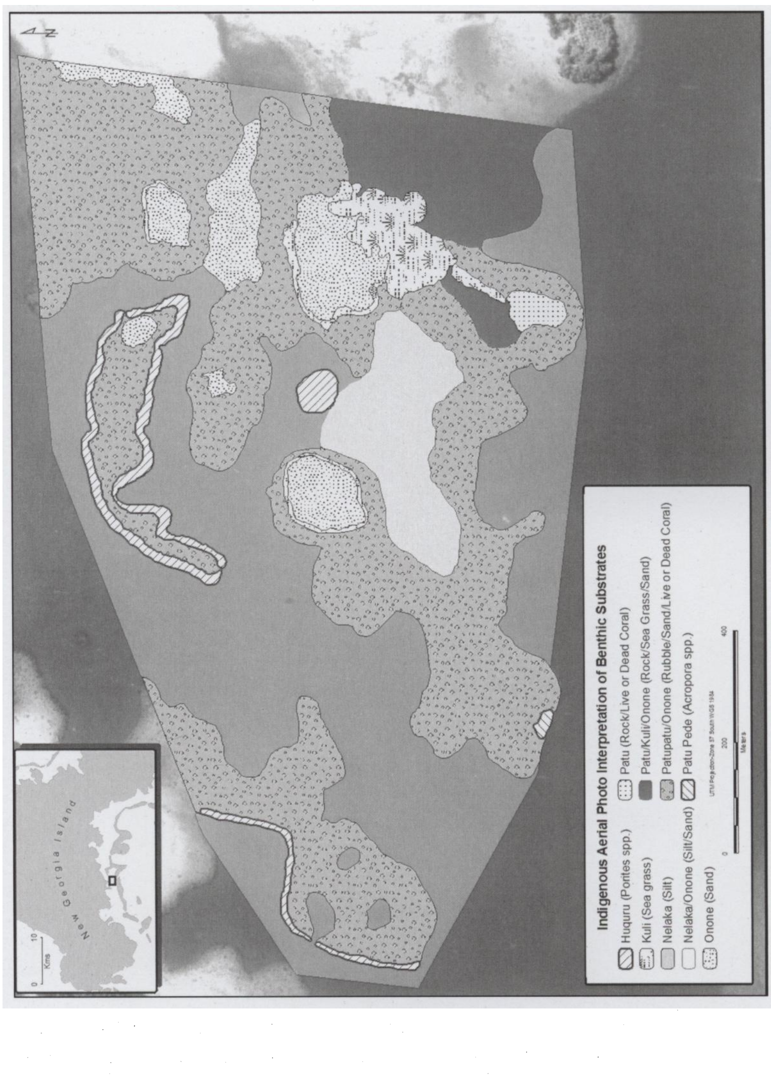

Figure 7. Local demarcation of predominant abiotic and biotic substrates of the Baraulu MPA, Roviana.

hydrology (see Aswani and Vaccaro 2008 for an in-depth discussion). Today, customary fishing methods have either been transformed by the introduction of new technologies or have been abandoned all together. Following the Second World War, less conventional methods such as damming rivers (*tukutuku leana*), or fishing with bow and arrow (*bokala*), were abandoned in favour of nylon fishing lines and iron hooks. Currently, the predominant methods are hook and line fishing, netting, diving, spearing and gleaning. Less frequent techniques include fish drives, piscicides, fish trapping, hand-fishing and dynamite fishing, but since the late 1990s these methods have been gradually abandoned. The use of each method is conditioned by seasonal tidal fluctuations, making some methods appropriate only under specific circumstances. For example, the *kuarao* fish drive method is only conducted from mid-May to the beginning of July when morning ebbing tides are at their optimum level for the successful performance of this method in the expansive Munda area reefs.

Fish in these lagoons, as in most Pacific Island coastal societies, constitutes the most basic form of protein intake, or what is referred to as *baso* by Islanders. Rarely will a meal take place without some kind of *baso*, whether seafood, canned food, or an occasional ration of fresh animal meat. Food consumption patterns vary regionally according to each hamlet's participation in the cash economy. However, the burgeoning influence of the market is eroding the traditional subsistence base of rural Roviana and Vonavona communities. In regional centres like Munda, for example, *baso* is increasingly coming from canned foods. Notwithstanding these changes, local seafood still constitutes a major source of food in the region, and catches are particularly high in the various types of coral reefs discussed in the previous sections (Table 1).

Roviana people can name hundreds of marine species and have an intimate knowledge of the behavioural ecology of the organisms with which they interact regularly. A series of related "species clusters" harvested across many habitats, including coral reefs, have emerged from two decades of measuring fishing excursions (Table 2). The annual variability of species' spatio-temporal distributions offers fishers opportunities to harvest numerous organisms at different times, and seasonal variation in species availability through lunar and tidal cycles. Monthly lunar spawning aggregations, such as those of orange-striped emperor on new moons, and yellow-margined seaperch and paddletail snapper during full moons are spatio-temporally predictable phenomena that potentially increase a fisher's harvestable stock throughout the year. Numerous other species, while not forming aggregations, respond to lunar changes by increasing feeding activities, hence becoming more vulnerable to human predation. Species characterised by spawning periodicity only increase in frequency during certain periods. According to local knowledge, the most

Table 1. Annual average catch rates expressed as a net mean return rate for lagoon habitats (major areas of coral reefs in bold).

Habitat	Annual net mean return rate (kcal per hour)
Outer lagoon islands	3776
Open ocean	3624
Grassbeds	3091
Sand banks	2622
Outer reef drops	2232
Passages	2070
Shallow inner reefs	1896
Outer shallow reefs	1689
Deep lagoon	1650
River mouths	1650
Mangroves	1272
Intertidal zones	732

significant aggregations occur between September and December, decreasing in intensity thereafter. Spawning peaks occur during the last quarter and new moon lunar phases (but see Hamilton *et al.* 2012). Species forming spawning aggregations that are targeted by fishers include barracuda, triggerfish, grouper and rock cod, and several snapper species. Figure 8 summarises the major prey species, particularly those occurring in or near coral reefs, and their lunar and seasonal occurrences (using indigenous names).

Seasonal and daily tidal variations have a great impact on how intensively some habitats and species are exploited. During the day high/night low-tidal season from September through late December and early January (*odu rane/masa bongi*) fishers prefer to fish in the passages and nearby reef drops because many fish aggregations occur in these habitats. This is a period when fishers turn into specialists by targeting a limited number of species. In contrast, during the day low/night high-tidal season (*masa rane/odu bongi*) fishers become *generalists* by reverting to inner lagoon habitats and exploiting all species in shallow reefs, grassbeds and mangrove areas. In-between tidal seasons, such as *vekoa kolo* 'staying water' (which runs from February to mid-April), fishers again switch between different habitats and species clusters, and move between inner reefs and the lagoon passages. This switching behaviour has a probable impact on the lagoon fishery by periodically alleviating pressure on some species and habitats. Aswani and

Table 2. Roviana and Vonavona prey species clusters.

Species cluster	English names	Latin binomial names	Roviana names	Major habitats
Estuarine/ mangrove cluster	Trevallies	Varied Carangidae	*mara*	Everywhere
	Mullet	*Valamugil seheli*	*lipa*	Estuarine
	Great barracuda	*Sphyraena barracuda*	*gohi*	Everywhere
	Mangrove jack	*Lutjanus argentimaculatus*	*kakaha*	Everywhere
	Biddies	*Nematalosa* spp.	*suliri*	Estuarine
	Rabbitfish	*Siganus* spp.	*tetego*	Estuarine
	Mud crab	*Scylla serrata*	*kapehe*	Mangroves
	Ark shells	*Anadara granosa*	*riki kosiri*	Mangroves
	Mud shells	*Geloina* spp.	*deo*	Mangroves
	Mangrove oysters	Ostreidae spp.	*roza*	Mangroves
Inner lagoon reef cluster	Paddletail snappers	*Lutjanus gibbus/L. adetii*	*heheoku*	Inner-outer reefs
	Thumbprint emperor	*Lethrinus harak*	*osaŋa*	Shallow reefs, grassbeds
	Orange-striped emperor	*Lethrinus obsoletus*	*ramusi*	Shallow reefs, grassbeds
	Yellow-mar. seaperch	*Lutjanus fulvus*	*odoŋo*	Shallow reefs
	Speckled-fin grouper	*Epinephelus ongus*	*pazara kalula*	Shallow reefs
	Emperor	*Lethrinus hypselopterus*	*karapata*	Shallow reefs, reef drops
	Yellowmargin triggerfish	*Pseudobalistes flavimarginatus*	*makoto lio*	Shallow reefs, sandbanks
	Titan triggerfish	*Balistoides viridescens*	*makoto noa*	Shallow reefs
	Anchor tuskfish	*Choerodon anchorago*	*pakopako*	Shallow reefs, estuarine
	Monocle bream	*Scolopsis monogramma*	*pepata*	Shallow reefs
	Butterfish	*Pentapodus* spp.	*doŋopusi*	Shallow reefs
	Sabre squirrelfish	*Sargocentron spiniferum*	*hori*	Shallow reefs, reef drops

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Species cluster	English names	Latin binomial names	Roviana names	Major habitats
Inner lagoon reef cluster – *continued*	Grouper	Varied Epinephelinae	*pazara*	Shallow reefs, reef drops
	Ark shell	*Anadara antiquata.*	*riki repi ŋohara*	Sandbanks, grassbeds
	Cardita clam	*Beguina semiorbiculata*	*belaŋavi*	Shallow reef
Outer reef flat cluster	Striped surgeonfish	*Acanthurus lineatus*	*berabera*	Barrier reef, reef drops
	Blackstreak surgeonfish	*Acanthurus nigricauda*	*valiri*	Barrier reef, reef drops
	Convict surgeonfish	*Acanthurus* spp.	*tarasi* (generic)	Barrier reef, reef drops
	Unicornfish	*Naso* spp.	*isu/ino*	Barrier reef, reef drops
	Parrotfishes	*Scarus* spp.	*sinoku* (generic)	Barrier reef, reef drops
	Steephead parrotfish	*Scarus microrhinos*	*vele*	Barrier reef, reef drops
	Bumphead parrotfish	*Bolbometopon muricatum*	*topa*	Barrier reef, reef drops
	Humphead Maori wrasse	*Cheilinus undulatus*	*habili*	Barrier reef, reef drops
	Long-faced emperor	*Lethrinus elongatus*	*mihu*	Barrier reef, sandbanks
	Yellowlip emperor	*Lethrinus xanthochilus*	*suru*	Barrier reef, sandbanks
	Trochus shells	*Trochus niloticus*	*bikoho*	Barrier reef, reef drops
	Borrowing giant clam	*Tridacna crocea*	*gulumu*	Barrier, shallow reefs
	Horsehoof giant clam	*Hippopus hippopus*	*hohobulu*	Barrier, shallow reefs
	Spider shells	*Lambis* spp.	*riqasa*	Coral rubble
	Stromb shells	*Strombus* spp.	*ununusu*	Coral rubble, sandbanks
Outer reef drop-passage cluster	Barracudas	Varied *Sphyraena* spp.	*pipo*	Reef drops, passages
	Spanish mackerel	*Scomberomorus commerson*	*taŋiri*	Reef drops, passages
	Bigeye trevally	*Caranx sexfasciatus*	*moturu*	Reef drops, passages
	Giant trevally	*Caranx ignobilis*	*batubatu*	Everywhere

Species cluster	English names	Latin binomial names	Roviana names	Major habitats
Outer reef drop-passage cluster – *continued*	Bluefin trevally	*Caranx melampygus*	*mara balibaligutu*	Everywhere
	Maori seaperch	*Lutjanus rivulatus*	*sina*	Reef drops, passages
	Red bass	*Lutjanus bohar*	*riŋo*	Reef drops, passages
	Yellow-spotted emperor	*Lethrinus erythracanthus*	*kaburubaŋa*	Reef drops, passages
	Flowery cod	*Epinephelus fuscoguttatus*	*pazara veata*	Reef drops, passages
	Big-eye bream	*Monotaxis grandoculis*	*matalava*	Everywhere
	Chitons	*Acanthozostera gemmata*	*tatadu*	Barrier intertidal zone
	Turban shells	*Turbinidae* spp.	*popu*	Barrier intertidal zone
	Nerites shells	*Nerites* spp.	*sise*	Barrier intertidal zone
Open sea cluster	Skipjack tuna	*Katsuwonus pelamis*	*makasi*	Open Sea
	Island bonito	*Rastrelliger kanagurta*	*reka*	Open Sea
	Yellowfin tuna	*Thunnus albacares*	*tataliŋi*	Open Sea
	Big eye tuna	*Thunnus obesus*	*gomo*	Open Sea

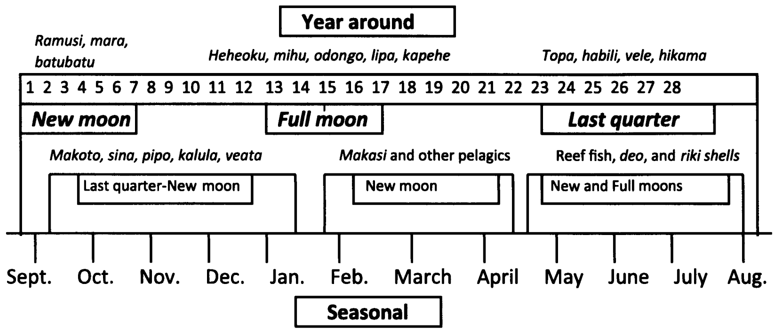

Figure 8. Lunar and seasonal periodicity of important prey species (emperor fish: *ramusi* and *mihu*) (snappers: *sina*, *heheoku* and *odongo*), (trevallies: *mara* and *batubatu*), (parrotfish: *topa* and *vele*), (wrasses: *habili*), (groupers: *kalula* and *veata*), (mullet: *lipa*), (triggerfish: *makoto*), (barracuda: *pipo*), (tuna: *makasi*), (crustaceans: *hikama* and *kapehe*), (molluscs: *riki* and *deo*). Also see Table 2.

Vaccaro (2008) provide an in-depth review of these environmental processes, major fishing methods practiced, fishing seasonality and species targeted.

In terms of division of labour and fishing it is commonly held by government fishery officers that artisanal fisheries are distinctly divided into two labour groups "man the fisher" and "woman the gleaner". Undoubtedly there is some truth to this generalisation in the Solomons as men are responsible for big game fishing, while women conduct most collecting activities. Upon a closer look, however, a distinct picture emerges from the activities of each gender (Table 3). In the lagoons of New Georgia, women are among the most avid anglers and are reputed for their fishing skills, so much so that many men blame women for the ongoing decline of inner lagoon reef fish, maintaining that women's use of small hooks affects the subsistence fishery by targeting immature fish. Jokingly, experienced fishermen refer to women's fishing as *habu malivi* 'fishing of the giant', because according to folk stories, when a race of giant men living in the interior of New Georgia descended into the lagoons they trampled over all coral reefs and living things. While the maritime activities of both sexes merge at the inner lagoon, angling fishery, they diverge when conducted in either the barrier islands/ outer lagoon (*vuragarena*) reefs and in the mainland mangrove forests (*petupetuana*). The former is the domain of men, where big game fishing is carried out, while the latter is where the most significant women's gleaning activities take place. Note that these are only generalisations as women

Table 3. Division of labour in fishing and gleaning.

	Men	Women	Both	Children
Fishing activities	Spearing Spear diving Bottom-lining Open sea trolling Vertical-trolling Turtle hunting Dugong hunting *Kura* trapping Netting	Seaweed diving Collecting *deo* clams Collecting *riki* shells Barrier reef gleaning	Angling Sink-line Trolling Collecting crabs Crab diving Shell diving Net drives Fish drives Piscicides	Angling Trolling Gleaning shells Collecting crabs Fish drives Netting

Table 4. Number of weekly hours allocated to fishing and gleaning according to age and sex across different areas (1994-1995).

Area/Village	7-16 years		17-26 years		27-45 years		46-75 years	
	Males	Females	Males	Females	Males	Females	Males	Females
Baraulu	5.2	4.8	6.9	6.6	12.8	6.6	13.5	7.5
Nusa Hope	4.5	5.6	7.1	6.1	8.7	8.9	11.7	9.8
Olive	6.0	4.3	3.8	8.2	11.6	9.5	14.5	8.1
Ha'apai	5.2	3.9	3.1	–	10.9	8.9	–	–
Sasavele	4.7	4.7	3.5	4.9	9.9	7.5	8.6	6.2
Nusa Roviana	5.4	4.3	3.8	4.5	8.4	5.2	7.9	6.9
Munda area	4.5	4.2	3.6	2.9	7.6	5.8	6.4	5.8
Vonavona area	3.7	5.3	5.8	2.8	10.8	5.2	7.1	7.0
Mean hours	4.9	4.6	4.7	5.1	10.1	7.2	9.9	7.3

frequent barrier intertidal zones for gleaning and angling and men visit mainland mangrove habitats for spearing, netting and line fishing.

In terms of livelihood significance, Western Solomon Islands rural communities depend on marine resources for the bulk of their animal protein intake. National per capita consumption of seafood is among the highest in the world with an average of 33 kg/person/year (Bell *et al.* 2009). In New Georgia, rural communities are highly dependent on marine resources for subsistence and commercial purposes. Fishing and gleaning for shells and crabs are ordinarily carried out by everyone. Weekly mean time allocation to fishing and gleaning grouped by age and sex suggest that people are more active fishers after the age of around 30 (mostly married) and that men, notably mature men, allocate more per-capita time to marine foraging activities than women do (Table 4). The reasons for this are multiple, ranging from the absence of young women, who prefer working in town or at the Noro cannery, to seasonal preferences in foraging. Women tend to concentrate their gleaning and fishing efforts during the *masa rane* tidal season from May to September, while men tend to fish year-round. Weekly fishing and gleaning activities are partially structured around the church's recommended activity schedule, particularly in Christian Fellowship Church villages. Mondays and Fridays are assigned to working on gardens, while Saturdays are designated for fishing for meals after Sunday Mass. The remaining days are reserved for community work and for personal affairs. During the week, fishers tend to go out in the early mornings and/or evenings after working in their gardens, while on Saturdays they go on day-long gleaning and fishing excursions. Sunday is considered the Sabbath and no fishing, gardening or community work is conducted, albeit these patterns may vary from village to village.

Coral Reefs, Climate and Environmental Change

The analysis of local perceptions of environmental and climate-related change revealed that people are relatively aware of ongoing changes in coral reefs. Respondents were able to identify changes in the lagoon reefs as well as those in the outer lagoon. For the inner lagoon reefs, informants identified and ranked a number of changes (Fig. 9), the three most important being in order of importance as: (i) no change, (ii) turbid/dirty water and (iii) less fish. For the outer lagoon reefs, respondents also recognised and ranked a number of changes (Fig. 10), including the top three as: (i) no change, (ii) less fish and (iii) coral reef damage (Fig. 10). The identified causes for change in coral reefs were various, but the three most important (in order of importance) were: (i) logging operations and siltation, (ii) the effects of the 2007 earthquake/ tsunami and (iii) sea changes/don't know were equal in ranking importance (Fig. 11). The vast majority of informants saw these changes as affecting their livelihoods negatively, particularly the notions of "less fish" and "coral

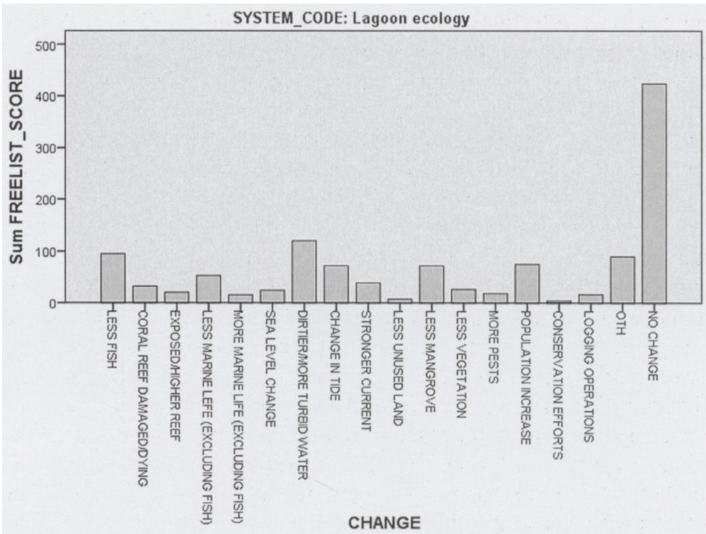

Figure 9. Changes identified for inner lagoon marine environments (predominantly shallow coral reefs).

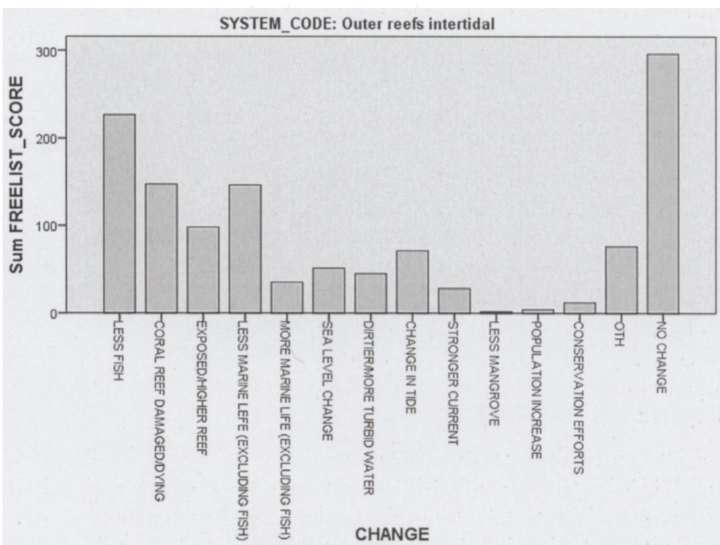

Figure 10. Changes identified for outer lagoon coral reefs.

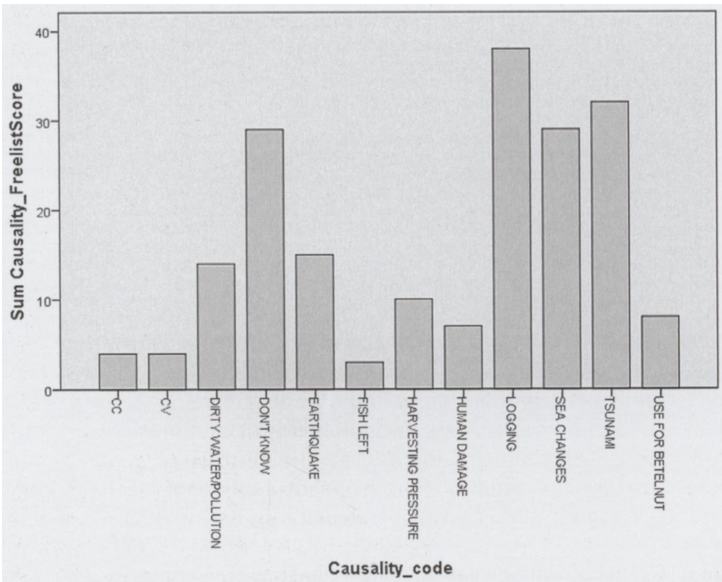

Figure 11. Causes of coral reef damage.

damage". In terms of when these changes began, most respondents agreed that while many changes started in the 1980s, the worst symptoms were noticed in the late 1990s and even more acutely after the 2007 earthquake/tsunami. In fact, results for the mapping exercise revealed that informants recognised changes in areas of coral damage via bleaching and disease (which cannot be differentiated locally) over the last two decades. They also acknowledged that since 1986 there has been an increase in dead coral in the outer lagoon reefs (Fig. 12) rather than in the inner lagoon ones. These results correspond with a recent scientific survey which found that bleaching and diseases (white syndrome [WS]) induced coral mortality, mainly affecting *Acropora* and *Pocillopora* species, was higher in offshore drop-off areas than the inner lagoon (Albert *et al.* 2011) in the Olive and Nusa Hope areas and the lagoons more generally.

Cultural Meanings of Coral Reef/Seascapes

Fishing decisions are not only influenced by the flow of information between fishers and the physical environment, but also by that between fishers and a cultural land- and seascape. The seascape conveys multiple cultural meanings, such as the presence of benevolent or evil ancestral spirits, which can influence who may access an area, the fishing methods conducted there

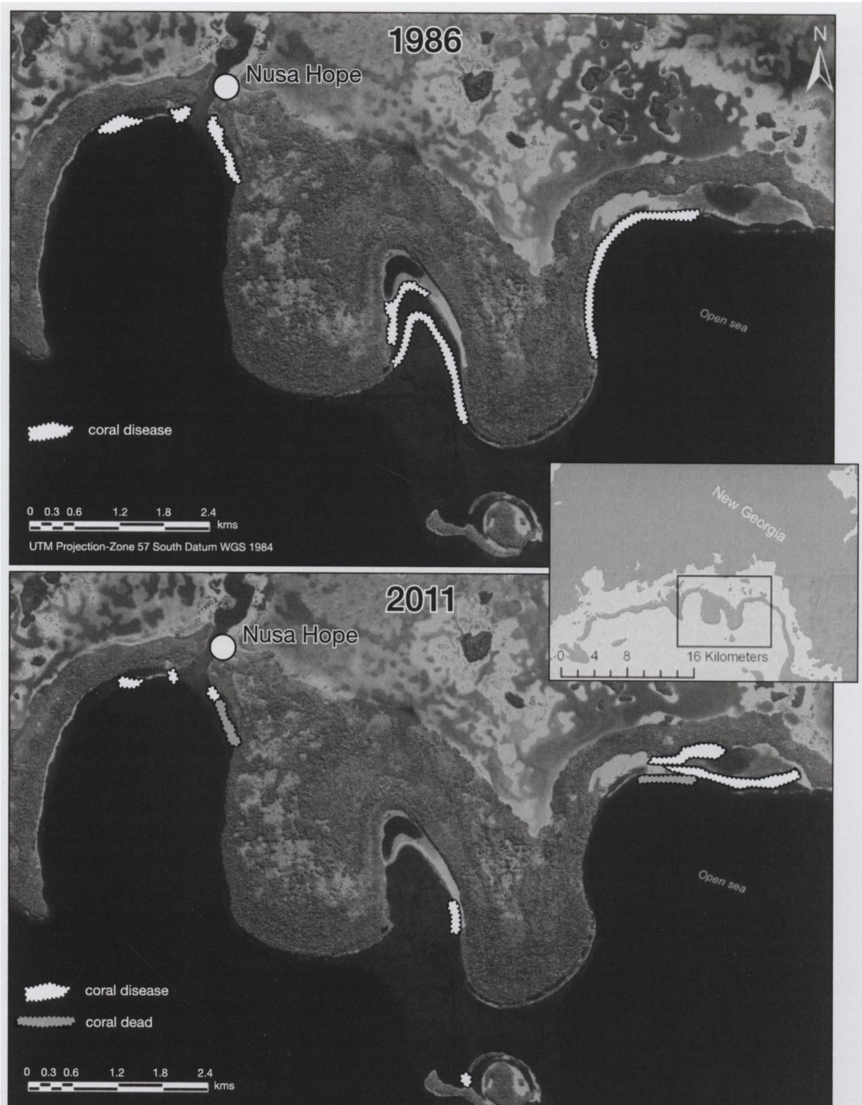

Figure 12. Locally recognised distribution of coral reef damage (disease and bleaching) prevalence in the Olive and Nusa Hope areas, comparing 1986 and 2011.

and the species collected. Even today, when the discourse of Christianity, modernisation and economic development pervades throughout the Solomon Islands, ancestral customary beliefs firmly persist, particularly those regarding physical space. New Georgia Islanders believe that magical powers to control natural phenomena emanate either from an individual's innate disposition or through acquired means. Those individuals conferred with powers flowing from their ancestral links can unilaterally employ magic to improve their fishing efforts or those of others. Conversely, they also can bestow 'unluckiness in fishing' (*dula-ia sa tie*) through the use of particular charms. Fishers are not defenseless against attempts to blemish their reputation or fishing capacity, and can use the essence of certain customary leaves, such as *zipolo* (species of *Cordyine* and *Dracaena*), to shield themselves against assailing spells. Prowess or failure in fishing also can originate from one's social behaviour and that of one's relatives, particularly female kin. Fortune in fishing is not so much attributed to one's good behaviour, as to misfortune from wrongdoing. The following account summarises the ripple effect of a woman's "mischievous" action on the daily activities of fishers:

> When a Baraulu man was bitten by a crocodile in March of 1995, fishing activities at Baraulu were significantly reduced. During a canoe trip to bring rice and other goods to Beulah Secondary School, the man and his wife were attacked by a crocodile. The man's leg was severely bitten, but fortunately, he was able to save it. Apparently the man, whose family totem is the crocodile, told the animal that it had no reason to bite him and so the animal released him. In Roviana nothing happens by accident. If a man is attacked by a shark or a crocodile, it is because he or someone in his lineage, usually a female, has committed some kind of misdeed. That same day it was known that the man's second cousin had been impregnated out of wedlock by the married nephew of an important religious personality. In New Georgia, as in the rest of the Solomon Islands, this is a serious customary breach that can only be solved by appeasement of ancestral spirits, or as it is done today, through the culprit's confession in church and compensation payment. After the man was bitten, the large crocodile was seen frequenting the village and trying to kill pigs. These events made people at Baraulu, especially women, very apprehensive and in consequence, very few women dared to go fishing for a whole month (Pastor Buka pers. comm. December 1994).

The cultural meaning of reefs and the seascape more generally also emanates from the spiritual significance of place. As mentioned, coral reefs are not only resource extraction areas but are also physical features that permit or hinder people from navigating, signs that define property rights of the seascape in relation to other coastal and terrestrial habitats, and cultural and historical features that embody tribal identity and ideology. For instance, the Rereghana Passage in Baraulu Village, Roviana Lagoon, a passage with shallow and sloping reefs, is of extreme economic and spiritual significance to the people of Baraulu. At the subsistence level, the passage is referred to as *mami epata* 'our food basket', as this area is a major fishing area for Baraulu people. Custodian rights to the passage have been passed to these people by their Koloi coastal ancestor who dwelt on the barrier islands of Roviana. On a spiritual plane, the passage is affectionately referred to as *Kaleqe Rereghana* 'old women from Rereghana', because many large manta rays, or incarnated ancestors, seasonally pass through it.

The passage is also guarded by the Tetepare Island customary sharks *Bugotu* and *Bilosi* which, in the past, were seasonally fed by *hiama* 'priests', with the first fruits of *Canarium* trees. Because of its spiritual significance, many customary restrictions exist in the area. For instance, women were barred from fishing here in pre-Christian times and even today, when no such customary restrictions are institutionalised, only women with direct kin relations to the original owners of the passage come here to fish. A contemporary interdiction forbids selling fish from Rereghana Passage, as this area was given in trust to Baraulu people for their subsistence needs. Villagers believe that ancestral spirits punish those who sell fish from the passage by lessening their catches. If fishers break this taboo, which they often do, they pay compensation (*here*) to their ancestral spirits by tossing a coin into the passage in the hope of regaining their fishing fortune. The flow of cultural and ecological information conditions and constrains the daily decisions made by fishers in their interaction with the marine ecosystem and, therefore, play an integral role in the use of coral reefs.

Do New Georgia fishers have an environmental ethic for managing and conserving their marine resources and coral reefs? The "original" indigenous views of nature and resource conservation have, after more than 100 years of colonial and postcolonial history, been entirely transformed. Keeping this in mind, a description of local environmental beliefs has to encompass the differentiated ancestral views of coastal and bush peoples, Christian doctrine, capitalist principles and, in recent years, Western environmental discourse. This ideological puzzle makes elusive any attempt to discern an autochthonous conservation ethic, and ecological research in the region suggests that such a view as understood by Westerners is not present (Aswani 1998). Roviana and Vonavona peoples' understanding of ecological processes and the environmental impact of human action vary, from those who believe that God will regenerate all human ravages inflected on nature to those who foresee the cataclysmic ruin of the local ecological systems. For some individuals, particularly those with higher education, the need to establish guidelines for sustainable resource use and conservation are paramount. Many educated Islanders have been exposed to Western anti-logging environmental campaigns, notably from New Zealand and Australia, which encourage

Islanders to resist the assault of Asian logging companies. People are not oblivious to the steady decline of many marine species. For instance, recent surveys suggest that 68 percent of Roviana respondents feel that marine resources are susceptible to over-exploitation, while 24 percent think that marine resources cannot be depleted. In relation to exogenous development pressures, 74 percent of all respondents acknowledge that present logging activities are endangering the Roviana Lagoon (Aswani, n.d.).

New Georgians, as with Melanesian societies, do not customarily dichotomise nature from nurture as some Westerners do; humans are an integral part of a holistic environment. Roviana and Vonavona people have a deep sense of their interconnectedness with all things and are physically and spiritually bonded to their land and reefs. Hviding (1996: 28) suggests that Marovo people's interaction with the environment transcends a mere linear relation between consumers and natural resource exploitation, and includes material and spiritual "affordances" provided by nature. He defines the concept of *kino* in Marovo, with its equivalent *kinopu* in Roviana, as 'guardianship' and maintains that it is the basic tenet for an indigenous "holistic view of sustainability", or equivalent to a conservation ethic (1996: 366). In Roviana and Vonavona, the *kinopu* concept denotes "control of" and "stewardship of" traditional estates, but it does not explicitly suggest sustainable use of resources. In fact, chiefs and prominent men responsible for the "stewardship" of land and sea estates have monopolised or, rather, capitalised on their role as "guardians" by allowing Asian logging companies and Japanese bait-fishers to exploit their natural resources. Perhaps the concept of *kinopu* has been affected by the influences of economic development or maybe, instead of an autochthonous view of sustainability, *kinopu* embodies political contest and subsequent control of land and sea estates. In sum, there are numerous indigenous concepts, such as *kinopu*, that can be identified as approximating a conservation ethic, while there are others, such as the notion of *habu malivi* 'fishing of the giants', which denote the contrary. In a general sense, however, lagoon dwellers' relation to their environment is based on an intimate sense of place which potentially precludes Islanders from desecrating their land, albeit this sentiment is rapidly eroding as a result of modernisation forces.

* * *

This article has described people's ecological and social relationships with coral reefs in two extensive lagoon ecosystems in the Western Solomon Islands using a combination of ecological, geospatial and ethnographic data. Ethnobiological knowledge informs Roviana and Vonavona inhabitants on how to exploit their environment most efficiently. Annual fluctuations in species' spatial and temporal distributions allow fishers to harvest numerous organisms at different times and places—this variability being determined by lunar and tidal phases. Recurrent lunar aggregations are spatio-temporally predictable occurrences that can increase a fisher's catches across various periods of the year. Sometimes fishers become specialists by targeting a limited number of species, while at others times they act as generalists and exploit a wide range of species in various marine habitats. Roviana and Vonavona fishers, therefore, do not fall into the simple specialist versus generalist dichotomy, but rather move between these two types of strategies in response to environmental variability and thus ostensibly increase their resilience to stochastic resource variability. Understanding these knowledge systems and behavioral processes is crucial. As discussed below, this involves: (i) considering how ethnobiological understandings can affect a people's livelihood resilience or vulnerability, (ii) understanding the cultural and socio-economic importance of reefs to people and (iii) using this information to design comprehensive and participatory fishery management plans.

First, ethnobiological knowledge (biological, ichthyologic, climatic, etc.) of reefs not only aids people in understanding and taking advantage of a complex and variable marine environment, but also in understanding its transformation and adapting to such changes over time. Ethnobiological knowledge is not only the generational transfer of knowledge but also observations and ideas that are generated within the context of people's practical engagement with a dynamic and changing local marine environment (Ingold 1993). It also can be useful for mapping changes in the environment. This is particularly relevant because the ongoing transformation of marine and terrestrial habitats and associated biological communities as a result of anthropogenically-driven forces, such as climate change, is making coastal people more vulnerable nutritionally and economically. People's observation and perception of environmental changes, or lack thereof, plays a fundamental role in how they perceive the risks associated with change. In fact, anticipatory and autonomous adaptation to environmental change at the community level is shaped by the perceived changes and causes of change by people locally (Aswani *et al.* under review.) Thus, building resilience in coastal socio-ecological systems (traditional or otherwise) requires enabling coastal communities to learn quickly and enhance their adaptive responses and capacity to increasingly swift ecological transformations. As individuals detect and respond to change (or not), the acquired information feeds back into the socio-ecological system, which in turn affects people's livelihoods and their managerial responses to new environmental circumstances. Alternatively, people's incapacity to detect, comprehend and/or respond to ecological changes undermines resilience and exacerbates vulnerability. Current trends in the Solomons indicate that there is gradual abandonment of diversity of traditional capture technologies, as well as people's recognition of taxonomic distinctions of marine organisms over time. Processes of this kind are likely to make people's livelihoods more vulnerable to environmental variability and generalised environmental degradation in the near future (Albert *et al.* n.d.).

Second, this paper also has shown that reefs are not just resource exploitation areas, but also are signifiers of sea tenure property rights, and sites of deep cultural and historical significance, embodying tribal distinctiveness and an indigenous world view. Property rights over reefs and associated ethnobiological knowledge and beliefs encompass a cultural bundle or "customary management" (CM) system (Cinner and Aswani 2007). Beyond the basic design principles of authority, rights, rules, monitoring and enforcement, CM systems function to manage coastal communities, not just natural ecosystems, and also to ensure community harmony and continuity, which commonly emphasises the importance of ancestors, identity and place. Because "place" is so fundamental to people's subsistence and identity, any form of local alteration of a community's territory (e.g., through the introduction of development enterprises) can result in widespread local conflict and confrontations (Aswani and Ruddle 2013). This presents a considerable challenge for development in the region. Customary tenure and management over land and sea is at the core of Roviana and Vonavona socio-economic, political, and cultural life yet today, it is also at the roots of local conflicts and disputes, particularly in the context of capital extraction enterprises such as the logging of lowland rainforests. Further, as tourism development increases in the region, local disputes over reefs and associated habitats by multiple customary groups and their associated leaders (big men) are likely to increase. Thus, understanding the cultural and social meanings of the seascape is paramount.

Finally, ethnobiological knowledge can be utilised for managing and conserving marine resources. Results show that there is considerable congruence in local understandings of ecology and habitat with those of science which, in turn, can aid conservation efforts. In the Roviana and Vonavona case, our study of coral reef ethnobiology has allowed us to analyse the relationship between ecological complexities, indigenous knowledge and the ways in which this knowledge is used for productive purposes, as well as to understand rapid and protracted ecological change. By more fully understanding the characteristics of human-marine interactions, our programme has been able to design and implement management regimes (MPAs and watershed management) that move towards ecosystem-based resource management. A systematic articulation of local cultural knowledge and ecological values through anthropology and marine science can better promote local participation in the design and developments of community-based marine protected areas and produce a more inclusive approach to conservation. The documentation of coral reef and marine ethnobiology, in fact, has set the stage for the development of hybrid marine and terrestrial conservation plans. Integrated hybrid management schemes that combine local perceptions and beliefs with modern management systems are likely to be more successful than government driven top-down management plans.This is because hybrid approaches consider the social, political, economic and cultural contexts of Oceanic communities and can, to some extent, address fundamental concerns of local peoples, including coastal degradation, climate change, sea level rise, weak governance, corruption, increasing poverty, and limited resources and staff to manage and monitor marine resources, among others. The rapid degradation of coral reefs calls for urgent solutions. The research approaches outlined in this paper, in tandem with the work of other researchers (e.g., Cinner *et al.* 2005, Johannes 2002, Kittinger 2013, Ruddle 1993), provide examples of how to study reef ethnobiology and move towards more inclusive management regimes. This is key given the lack of resources for monitoring and policing in most of the tropics. There really are no other viable alternatives for holistic and successful management of watershed and marine ecosystems, which are needed to sustain the resilience of local livelihoods into the future.

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ABSTRACT

Coral reefs are of great socio-economic and cultural importance for many coastal communities across the tropics, yet little is known about people's local classifications and their social and ecological relationships with these habitats. In the case of island peoples, coral reefs are more than just resource exploitation areas; they are also geomorphologic features that allow or bar people from navigating, markers that define property rights of the seascape in relation to other coastal and terrestrial habitats, and cultural and historical features that embody tribal identity and ideology. Building upon over two decades of research, this paper uses published and unpublished data to describe people's ecological and socio-economic relationships with coral reefs in two extensive lagoon ecosystems in the Western Solomon Islands. It combines ecological, geospatial and ethnographic data to analyse the dominant characteristics of coral reef habitats in the region, the prevalent environmental phenomena associated with reefs and their transformation, the productive practices exerted in these habitats by the local inhabitants, and the socio-cultural meaning of coral reefs for lagoon peoples from the standpoint of local ecological knowledge. Understanding people's classification and socio-economic and cultural use of coral reefs is not just a descriptive effort. Rather, it is an essential step toward understanding human-environmental relationships theoretically and creating comprehensive base resource maps for planning marine and terrestrial conservation, including marine protected areas (MPAs) and ecosystems-based management (EBM) plans that potentially can enhance people's livelihood resilience.

Keywords: Coral reefs, ethnobiology, conservation, livelihoods, marine fisheries, resilience, Solomon Islands

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