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Integrating indigenous ecological knowledge and customary sea tenure with marine and social science for conservation of bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Solomon Islands

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SUMMARY

Indigenous ecological knowledge and customary sea tenure may be integrated with marine and social science to conserve the bumphead parrotfish (*Bolbometopon muricatum*) in the Roviana Lagoon, Western Solomon Islands. Three aspects of indigenous ecological knowledge in Roviana were identified as most relevant for the management and conservation of bumphead parrotfish, and studied through a combination of marine science and anthropological methods. These were (1) local claims that fishing pressure has had a significant impact on bumphead parrotfish populations in the Roviana Lagoon; (2) the claim that only small bumphead parrotfish were ever seen or captured in the inner lagoon and that very small fish were restricted to specific shallow inner-lagoon nursery regions; and (3) assertions made by local divers that bumphead parrotfish predominantly aggregated at night around the new moon period and that catches were highest at that time. The research supported claims (1) and (2), but did not support proposition (3). Although the people of the Roviana Lagoon had similar conceptions about their entitlement rights to sea space, there were marked differences among regional villages in their opinions regarding governance and actual operational rules of management in the Lagoon. Contemporary differences in management strategies resulted from people's historical and spatial patterns of settlement across the landscape and adjoining seascapes, and the attendant impact of these patterns on property relations. This was crucial in distinguishing between those villages that held secure tenure over their contiguous sea estates from those that did not. Indigenous ecological knowledge served to (1) verify that the bumphead parrotfish was a species in urgent need of protection; (2) explain how different habitats structured the size distribution of bumphead parrotfish; (3) identify sensitive locations and habitats in need of protection; and (4) explain the effect of lunar periodicity on bumphead parrotfish behaviour and catch rates. Secure customary sea tenure identified locations best suited to bumphead parrotfish management programmes, with a greater likelihood for local participation and programme success. The information was used to establish two marine protected areas in the region for bumphead parrotfish conservation.

Keywords: bumphead parrotfish, conservation, customary sea tenure, indigenous ecological knowledge, marine science, marine protected areas, social science, Solomon Islands

INTRODUCTION

In recent years, a burgeoning literature has called for the incorporation of indigenous ecological knowledge and customary sea-tenure institutions into inshore fisheries management (see Acheson & Wilson 1996; Mahon 1997; Zann 1999; Johannes *et al.* 2000; Thomas 2001). This reiterates earlier efforts to include local communities and their institutions in decentralized participatory fisheries management (see Johannes 1978; Chapman 1985; Ruddle 1988). Johannes (1998), among others, proposed the use of data-less precautionary management in the tropical Indo-Pacific region, where fisheries biologists have failed to predict inshore fishery dynamics with any certitude. One way to manage inshore tropical fisheries is to incorporate local knowledge and sea-tenure institutions, where they are still operational, and then devolve some managerial responsibilities to local communities. Local fishers have first-hand experience and knowledge of the environment that they exploit, including knowledge about the direct assessment of local marine stocks and how they change over time, which is an expertise marine biologists rarely have. Further, because in some areas local communities still retain customary control over their waters, or what is known as sea tenure, they can enact gear restriction initiatives, protect breeding aggregations, establish temporal or permanent marine reserves, and impose minimum size limits (Johannes 1998). Studies of indigenous ecological knowledge and sea tenure can serve as a basis from which to extrapolate management strategies to be applied elsewhere in the region. This approach may prevent further resource degradation while also serving as a cost-effective way to manage resources in the absence of substantial information.

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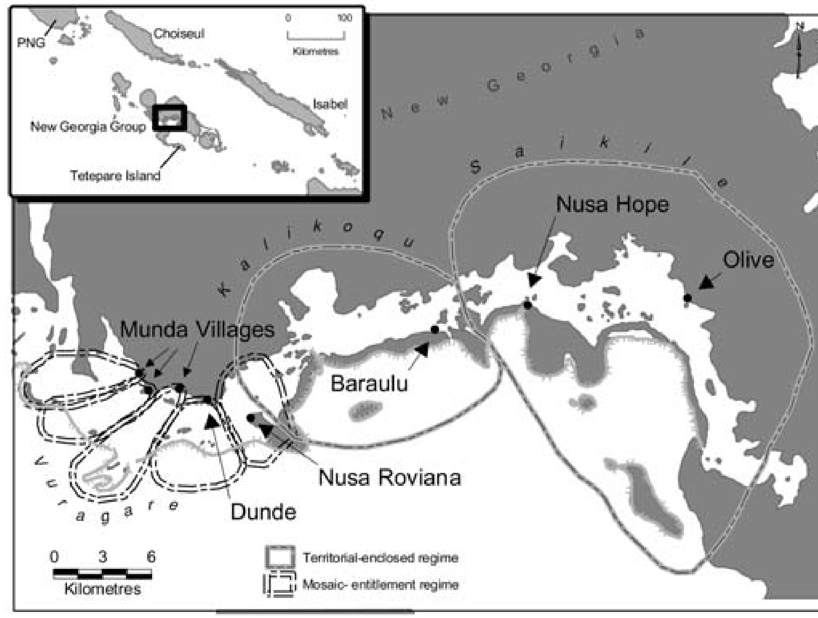

Figure 1 The Western Solomons and the Roviana Lagoon. Note that the sea-tenure lines are only conceptual boundaries and not definitive.

We investigated how indigenous ecological knowledge and customary sea tenure have been integrated into the co-management of bumphead parrotfish (*Bolbometopon muricatum*) conservation in the Roviana Lagoon in the Solomon Islands (Fig. 1). Given the global concern for this pivotal coral reef fish (see Pennisi 2002; Bellwood *et al.* 2003), we studied the status of the bumphead parrotfish fishery in the area, with a view towards designing preventive management strategies for its conservation. In doing so, we confined ourselves to two key questions. First, is Roviana's indigenous ecological knowledge about the bumphead parrotfish scientifically reliable? Second, is the customary sea tenure that covers the bumphead parrotfish habitats a viable institutional framework upon which to base conservation initiatives? The more general aim of our study was to show how to integrate natural and social systems in resource management planning and execution.

The bumphead parrotfish has a broad Indo-Pacific range and is an excavating, herbivorous fish that feeds on corals (Bellwood & Choat 1990). This species is considered to be a keystone species in coral reef processes, as it is largely responsible for bioerosion on outer shelf reef habitats (Bellwood *et al.* 2003). It is also extremely vulnerable to overfishing (Lieske & Myers 1994; Dalzell *et al.* 1996), and local overfishing is believed to have severely reduced the population size of the species in Guam (Hensley & Sherwood 1993) and in the Lau Group in Fiji (N.K. Dulvy & N.V.C. Polunin, unpublished data 2001). The fish is a highly prized food fish in the Indo-Pacific region, and this represents a cultural preference that is reflected in elaborate ecological knowledge bases and detailed folk taxonomies (see Johannes 1981). In the Solomon Islands, the increasing subsistence and commercial exploitation of this species is threatening the fishery's viability. Anecdotal evidence suggests that fishing pressure has had a significant impact on bumphead parrotfish populations in the Roviana and Vonavona Lagoons. Yet here, unlike other areas of the Indo-Pacific region (Hensley & Sherwood 1993), the bumphead parrotfish fishery has not yet collapsed.

In the past, the Roviana method of choice for capturing bumphead parrotfish (known locally as *topa*) was night time spearfishing, using wooden spears (*dumi* and *hopere*) thrown from canoes or from the edge of the intertidal zone, with illumination provided by hand-held burning coconut fronds. Typically, only a couple of large fish were captured with such traditional methods, and local fishers suggest that such strategies maintained harvest limits on bumphead parrotfish. In Roviana, night diving for the parrotfish began in the mid-1970s with the introduction of underwater flashlights and a growing availability of dive goggles, spear guns, and rubber-propelled wire spears. With this new technology, fishers could take over 50 bumphead parrotfish in a single night, or five times the maximum number of fish that reportedly could be captured using traditional methods. As a result, the number and size of bumphead parrotfish has dropped sufficiently that Roviana divers are making distant fishing trips to the less-exploited grounds of Tetepare Island. Fishers report that the average size and number of bumphead parrotfish harvested in Tetepare are equal to those captured in Roviana several decades ago (Hamilton 2003*a*). The current bumphead parrotfish fishery is biased toward the capture of large individuals. When divers locate a school of resting bumphead parrotfish, they selectively target the largest individuals, causing the remaining fish to flee.

A number of researchers have suggested that, where it is possible and cost-effective, knowledge obtained from local fishers needs to be evaluated and subsequently combined with Western scientific knowledge (see Johannes 1981;

Christie & White 1997; Poizat & Baran 1997; DeWalt 1999). This is especially important with regard to knowledge that can enhance biodiversity conservation, protect particular species, or improve stock abundance. Our previous research in the Roviana Lagoon has shown that fishers possess a wealth of indigenous ecological knowledge about bumphead parrotfish (Aswani 1997; Hamilton 1999). In this study, three main aspects of Roviana indigenous ecological knowledge were identified as being most relevant for the management and conservation of bumphead parrotfish and requiring study through a combination of marine science and anthropological methods.

First, in the Roviana Lagoon, fishers stated that catch rates of bumphead parrotfish have markedly declined over the past 20 years and that there has been a very noticeable decline in the abundance of larger specimens (*topa kakara*). The larger fish are reported to have dominated outer-reef and passage catches in the past. Second, local fishers asserted that only small bumphead parrotfish (*kitakita*) were ever seen or captured in the inner lagoon and that very small fish (*lendeke*) were restricted to specific shallow inner-lagoon nursery regions of only several metres in depth. Local fishers also suggested that the largest specimens were more abundant in the passage habitat. Finally, local divers proposed that bumphead parrotfish predominantly aggregate at night around the new moon period and that catches were thus highest then. Most Roviana people know that bumphead parrotfish enter a deep slumber and are easily approached when there is no moonlight, but awaken and swim slowly around the reef once the moon is up. During this time, they are wary and easily disturbed. The bumphead parrotfish, therefore, is captured exclusively at night during periods when the moon has set. During the period from the new moon to the full moon, fishing trips begin progressively later at night (starting once the moon has set), a strategy that is reversed after the full moon.

In establishing any system of participatory management, it is not only imperative to study aspects of indigenous ecological knowledge, but also to examine the institutional reliability of local forms of sea tenure where they are still operational. If this is not done, it is impossible to predict the capability of local people to institute and enforce the proposed regulatory mechanisms. We considered two main aspects of Roviana sea tenure most relevant for the management and conservation of bumphead parrotfish: (1) the spatial distribution of stakeholders in relation to their marine holdings and their corresponding cultural attitudes with regard to 'interloping' by neighbouring villages, and (2) the role of traditional versus state governance in fisheries management.

Ethnographic studies of customary sea tenure in Roviana have found that all entitlement holders recognize similar hereditary property rights to their respective sea territories, a circumstance that makes differences in governance between regimes indistinguishable on the surface (Aswani 1999, 2002). Upon closer examination, however, there are marked differences in cultural attitudes regarding governance and operational rules of management among regional hamlets. Some traditional leaders of sea territories are more capable of managing their resources than others. Past research suggests that contemporary differences in management strategies are, in essence, the result of people's historical and spatial patterns of settlement across the landscape and adjoining seascapes, and the attendant impacts of these patterns on property relations. Different historical settlement processes have determined whether holders of entitlements to indigenous sea estates live in areas adjoining or away from those estates (see Aswani 2000*a*; Aswani & Sheppard 2003). To better grasp this situation, it is necessary to understand the Roviana kinship system.

In Roviana, descent is cognatic and cumulative, which means that people trace their descent through maternal and paternal ancestors and can amass entitlement rights to the estates of either parent. This potentially permits people residing in one village to fish in neighbouring territories. Overlapping rights to sea estates are common in communities across Oceania and do not necessarily result in jurisdictional and managerial problems. However, when the spatial distribution of individuals with overlapping rights to one or more sea estates is asymmetric, giving rise to a situation in which members of one village can conduct forays into their neighbours' waters but not vice versa, then possibilities for dissension and abuse increase. Members of villages with dual access rights may simultaneously interlope into their neighbours' waters while denying their neighbours access to their own resources, particularly if the latter are deemed economically valuable. Thus, members without overlapping rights to their neighbours' estates are not only left without access to those waters, but are also powerless to stop their neighbours from interloping. Aswani (1999) showed that, as a result of various settlement processes, Kalikoqu and Saikile inhabitants had exclusive rights over their respective estates while concurrently having powerful rights over those of Nusa Roviana and Munda area villages (Fig. 1). On the other hand, the latter had no control or access rights to the territories of the former. To examine this more closely, we measured the distribution of stakeholders across the land and adjoining seascapes and then analysed their corresponding cultural attitudes regarding interloping and governance.

Overall, we do not claim that indigenous ecological knowledge or customary sea tenure are designed for the purpose of conserving marine resources. Indigenous ecological knowledge and customary sea tenure have emerged from the need to increase fishing success and to appropriate the highest possible share of existing marine resources (Polunin 1984; Aswani 1998). We contend, nonetheless, that these are useful and culturally appropriate frameworks within which to work in the absence of any binding and enforceable legislative or regulatory apparatus. Such *de facto* conditions are found in many Pacific island states, and this lack of enforceability demands appraisal of local ecological knowledge and sea-tenure institutions and their potential role in co-management.

METHODS

Study site

The research reported in this study was conducted in the Roviana Lagoon and on Tetepare Island, Western Solomon Islands. The Roviana Lagoon in New Georgia extends from Munda to Kalena Bay near Viru Harbour (Fig. 1). The lagoon is protected by a series of raised offshore coral islands that developed during the Pleistocene period from sea-level changes and accretion of coral limestone, organic debris and volcanic detritus (Stanton & Bell 1969). The outer lagoon shoreline is characterized by rugged, notched limestone with numerous inlets, bays, carbonate sand beaches and moats (Stoddart 1969), while the inner lagoon contains small islets, coral reefs and intertidal reef flats. The lagoons encompass a variety of habitats that include grass beds, mangroves, freshwater swamps, shallow reefs, outer reef-drops and river estuaries. Roughly twelve thousand people inhabit the Roviana and Vonavona region (National Census 1999). In the east, the Roviana Lagoon is divided into the political districts of Saikile and Kalikoqu, each being a collection of villages ruled by a paramount chief. The independent hamlets of Nusa Roviana, Dunde, Kekehe, Lodu Maho and Kindu in the Munda area to the west (Fig. 1) are each controlled by a chief and/or council of elders. Each community's leaders exercise control over use of and access to natural resources within their respective customary land and sea estates. In recent years, growing populations and changing consumption patterns have threatened the viability of indigenous social institutions and have increasingly threatened the region's ecology. Multinational fishing and timber corporations are also degrading Roviana marine and terrestrial habitats.

Tetepare lies south-east of Rendova Island, and is approximately 27 km long and 7 km wide (Fig. 1). The island is unique because it is the largest uninhabited island in the South Pacific. Although various tribal groups inhabited the island in the 18th and 19th centuries, they eventually abandoned it because of warfare, disease and internal disputes, settling finally in villages across the New Georgia Group (see Aswani 2000*a*). Today, Tetepare descendants have collectively inherited the island and have access rights to its rich forest and marine resources. The Island's abundance and diversity of resources have made it a reliable harvesting ground for obtaining large quantities of food for major feasts or celebrations.

Data collection

Initially, we documented indigenous ecological knowledge on bumphead parrotfish to see if it corresponded with data from previous studies (Aswani 1997; Hamilton 1999). This knowledge was documented through our participation in 50 night-diving expeditions and interviews with 21 divers during 2000 and 2001. In our purposive sample, we selected fishers for interviews based on their recognized status as experts within their respective villages. We sought out older spearfishing experts who had lived in Roviana for long periods and who had remained active in night-time spearfishing. Older fishers were able to provide detailed information on the changes that have occurred in the bumphead parrotfish fishery over the last 30 years. The open-ended and structured interviews covered the following: (1) indigenous size classifications, (2) past and present status, (3) spatial distribution of size classes and (4) the effects of lunar periodicity on the species. This indigenous ecological knowledge base allowed for the formulation of a number of working hypotheses.

First, we conducted and compared creel surveys of artisanal night-time spearfishing in the heavily exploited Kalikoqu region and the lightly fished Tetepare Island in order to investigate the local claims that the catch rates and mean size of the parrotfish captured in outer-reef and passage habitats have markedly decreased in the Kalikoqu region over the last 20 years. A survey was conducted in both places to establish the importance of bumphead parrotfish in spearfishing catches.

We measured catches from very similar sites to control for the possible effect of habitat structure on the size distribution and abundance of bumphead parrotfish. The Kalikoqu fishing grounds in which catches were measured refer to the Honiavasa Passage habitat and the outer-reef 90° wall drops adjacent to the west and east of the Honiavasa passage. The Tetepare fishing grounds were located at the south-western extremity of the island, and encompassed a passage habitat and an outer-reef 90° wall drop adjacent to the passage. The topography of the outer-reef sites at each location was virtually identical, and the topography of the passage environments was very similar, except that the Tetepare passage, at 20-m depth, is only a third of the depth of the Honiavasa Passage.

Thirty night-time spearfishing trips were documented in the Kalikoqu passage and outer-reef-drop habitats from September 2000 through July 2001, representing 236 hours of fishing effort, and four spearfishing trips were documented in the Tetepare Island passage and outer-reef-drop habitats from April through June 2001, representing 47 hours of fishing effort. Off the uninhabited island of Tetepare, we were able to record only four diving trips because access was difficult and because foraging there by diverse Western Solomon cultural groups is sporadic. Bumphead parrotfish catch-per-unit-of-effort (CPUE) was calculated by dividing the total weight of fish captured on a fishing trip by the amount of time spent fishing. The captured bumphead parrotfish on all fishing trips were weighed, and the length of each individual was recorded. Data obtained from these two creel surveys enabled us to compare catch rates and size frequency distribution of fish between Kalikoqu and Tetepare.

To test the claim that the size distribution of bumphead parrotfish is structured by different lagoon habitats, we examined the size-frequency distribution of fish captured and recorded in inner-lagoon, passage and outer-lagoon habitats. In addition, we conducted an underwater visual census (UVC) survey to independently assess the effect of lagoon habitat on structuring the size distribution of the bumphead parrotfish

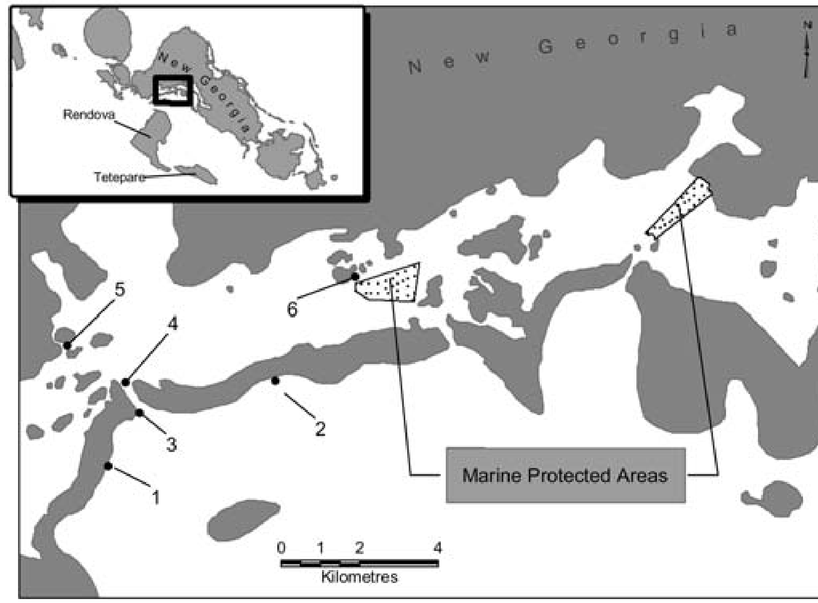

Figure 2 UVC sites in the Roviana Lagoon (site 7 in Tetepare Island is not illustrated). Patterned lines indicate the illustrated marine protected areas (MPAs).

populations in six sites located in representative habitats (Fig. 2). Between the months of October 2000 and June 2001, we surveyed the following habitats: outer-reef drops (sites 1 and 2), lagoon passages (sites 3 and 4), and inner-lagoon reefs (sites 5 and 6). Site 5 was a deep-water inner-lagoon passage, and site 6 was a shallow inner-lagoon site. A UVC survey was also conducted in Tetepare Island at a passage area (site 7, not shown in Fig. 2) between April and June of 2001, and this allowed us to compare potential differences in the mean size of the parrotfish in passage habitats between Roviana and Tetepare. Note that in designing the UVC research we considered indigenous ecological knowledge regarding the spatial distribution of different size classes of bumphead parrotfish. The position of all sites was recorded using GPS receivers.

The outer-reef sites 1 and 2 were 90° walls descending well below 100-m depth. Sites 3 and 4 in the Honiavasa passage were also coral wall habitats that descended initially at 90° and then sloped more gently to a muddy and sandy bottom at around 50–60-m depth. The inner-lagoon site 5 was situated in a small passage of 5–20 m in depth that connected to Honiavasa. The remaining inner-lagoon site 6 was very shallow (maximum depth 4 m). There were no drops, and the substrate was predominantly made up of sand and dead coral clumps that were generally covered in encrusting and fleshy algae. Site 7 in Tetepare was located in a passage environment that intersected the fringing reef. The passage wall initially sloped at approximately 70°, ending on a sandy bottom 20 m from the surface. Rocky outcrops were patchily distributed on the bottom of the passage.

A total of 18 UVC samples were completed at each site in Roviana. Nine dives were conducted during the full moon and nine dives during the new moon. Two UVC surveys were conducted in the passage habitat of Tetepare in 2001. All UVC surveys were conducted using scuba at fixed sites of 500 m in length, with bumphead parrotfish being recorded when sighted within 10 m either side of the diver, which constituted a reef sampling area of 10 000 m^2 per transect. The exception to this method was at sites 5 and 6, in which poor visibility often reduced the total area sampled to less than 10 000 m^2. Since all outer and passage sites were 90° drops, count procedures in these environments involved descending to a 10-m depth and then swimming along and recording all bumphead parrotfish sighted on the wall between the surface and a depth of 20 m. The size of all fish sighted was estimated, and the time when they were sighted and their approximate depth were recorded. At the inner-lagoon site 6, the transect profile followed the lagoon floor, with bumphead parrotfish being observed on either side of the transect being recorded. The precise timing of daily dives and the order in which sites were visited depended upon sea conditions and logistics. Dives in the inner lagoon were normally conducted on ebbing tides, when visibility was at its best, and outer sites were surveyed when sea conditions were relatively calm.

Potential differences in the mean size of the parrotfish between study sites were examined by carrying out a Welch's General Linear ANOVA test, which is recommended when sites displaying uneven variance are being analysed (Day & Quinn 1989). A Studentized Maximum Modulus (GT2) multiple comparison *post hoc* test was performed, with the alpha level set at the 0.05 confidence interval level, in order to determine which sites differed significantly from each other. For the purpose of examining the single size variable between sites, the following variables were ignored in this analysis: potential effect of lunar stage, area, visibility, time and pseudo-replication. To test the final proposition that bumphead parrotfish catches are higher during the new moon period, we compared the hourly catch rates of bumphead parrotfish taken on spearfishing trips conducted across each lunar stage. Data necessary for this analysis were obtained from 81 CPUE surveys of night-time spearfishing trips documented in Roviana between 2000 and 2001.

Customary sea tenure and its institutional robustness or vulnerability could be better understood by distinguishing between those villages that hold secure tenure over their contiguous sea estates from those that do not and by discerning the ratio of members within each village with overlapping rights to neighbouring estates. The research population was established through a population census conducted in 2001. Close to 100% of all households within the 14 major villages in Roviana and Vonavona were sampled. We used two approaches in identifying the spatial distribution of entitlement holders: (1) a qualitative review of historical settlement patterns, and (2) a quantitative measure of the geographical distribution of households having members with tribal affiliations to the major sea estates of Roviana. To understand settlement patterns, we used information from open-ended and structured interviews elicited during previous research (1994–1995; Aswani 1997). A chi-square test was employed to test the association between households in major contemporary Roviana villages and central tribal affiliations to sea estates.

To gain an understanding of people's cultural attitudes in each village, we conducted structured interviews in 2001. Between 15% and 20% of all adult inhabitants (aged 18 and older) in each hamlet were randomly selected for these interviews. We enquired about recognized tenure regimes, the identification of each estate's major stakeholders, social rules determining membership, use and access rules, boundary delineations, local mechanisms for enforcing management decisions, monitoring capacities, issues of governance, and mechanisms of traditional and legislative conflict resolution. A Z-test statistic ($\alpha = 0.05$) was employed to determine whether there were significant differences between selected villages in terms of particular response proportions. Next, a chi-square goodness-of-fit test ($\alpha = 0.05$) was employed to determine whether the observed frequencies of responses regarding governance among selected villages departed significantly from the frequencies proposed by the null hypothesis (i.e. that there were no differences in response frequencies among respondents).

RESULTS

Indigenous ecological knowledge

Catch weight and fishing effort between Kalikoqu and Tetepare differed significantly (Table 1). Bumphead parrotfish made up 59.6% of the total catch in Kalikoqu and 86% in Tetepare. The mean catch rates per hour (kg h^{-1}) of bumphead parrotfish around the Kalikoqu and Tetepare passages and outer-reef drops (2.89 kg h^{-1} [SD 2.18] and

Table 1 Mass and composition of total catch of different families caught in Kalikoqu and Tetepare passage and outer-reef habitats.

Family of species	*Kalikoqu*		*Tetepare*	
	Mass (kg)	*Composition (%)*	*Mass (kg)*	*Composition (%)*
Acanthuridae	66.6	6.25	32	2.79
Balistidae	4.4	0.41	–	–
Caesionidae	3.95	0.37	–	–
Carangidae	1.6	0.15	0.4	0.03
Cheloniidae	27.2	2.56	49.5	4.31
Haemulidae	34.15	3.21	1	0.09
Holocentridae	1.15	0.11	0.4	0.03
Kyphosidae	2.5	0.23	0.6	0.05
Labridae	73.3	6.88	20.8	1.81
Lethrinidae	41.15	3.86	11.3	0.99
Lutjanidae	15.8	1.47	1	0.09
Mullidae	5.55	0.52	2.5	0.22
Muraenidae	4.4	0.41	–	–
Pomacanthidae	2.85	0.27	–	–
Ostraciidae	6.7	0.63	3.5	0.31
Palinuridae	33.4	3.13	3.5	0.31
Scaridae				
Bolbometopon muricatum	634.6	59.58	985.8	85.95
Other *Scarus* sp.	42.05	3.95	28.6	2.49
Sepiidae	4.1	0.38	–	–
Serranidae	46.3	4.35	3.9	0.34
Siganidae	4.55	0.43	1.35	0.12
Sphyraenidae	8.9	0.84	–	–
Total (catches)	1065.2	100	1146.95	100

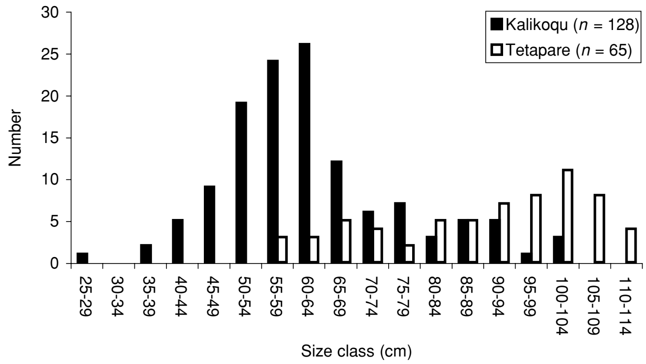

Figure 3 Size frequency distribution of bumphead parrotfish speared in Kalikoqu and Tetapare passage and outer-reef habitats.

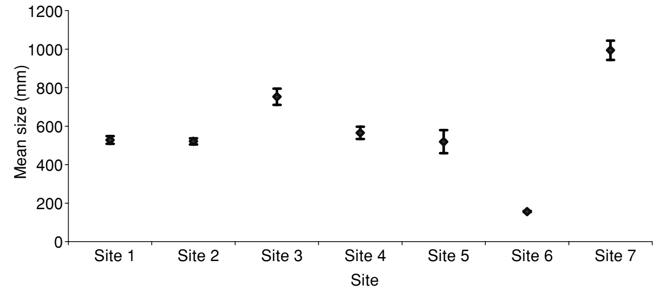

Figure 5 Mean size of bumphead parrotfish sighted at each site ± two standard errors (site 1, $n = 308$; site 2, $n = 196$; site 3, $n = 86$; site 4, $n = 111$; site 5, $n = 31$; site 6, $n = 36$; and site 7, $n = 43$; total $n = 813$).

22.32 kg h^{-1} [SD 10.20], respectively) differed significantly (ANOVA, $p < 0.0001$). At Kalikoqu, bumphead parrotfish were 28.5–102.0 cm in length, while at Tetepare the range was 59.0–111.5 cm (Fig. 3), and the mean lengths (62.7 cm [SD 14.0] and 89.5 cm [SD 15.8], respectively) were significantly different (ANOVA, $p < 0.0001$).

The second proposition was that only small bumphead parrotfish are ever seen or captured in the inner lagoon and that very small ones are restricted to specific shallow inner-lagoon nursery regions. Bumphead parrotfish sampled from the inner lagoon ranged in length from 30.5–64.0 cm, with a mean length of 52.2 cm (SD 8.9); those taken from the passages ranged in length from 48.5–100.0 cm, with a mean length of 74.1 cm (SD 15.3); and those sampled from the outer lagoon ranged in length from 28.5–102.0 cm, with a mean length of 58.2 cm (SD 12.9) (Fig. 4). The mean lengths of bumphead parrotfish sampled in the inner lagoon were significantly lower than those sampled in the passage (ANOVA, $p < 0.0001$) and outer-reef ($p < 0.01$) habitats. The mean length of specimens sampled in the outer reef was also significantly smaller than that of those sampled in the passage habitat ($p < 0.0001$). During the UVC conducted in Roviana (sites 1–6), 770 bumphead parrotfish were sighted over the span of 108 surveys. Forty-three were sighted on two surveys at Tetepare Island. Significant differences are shown by an adjusted Welch's ANOVA test ($F = 4.9218$, $df = 806$, $p = 0.0001$) in mean sizes between sites (Fig. 5).

The mean sizes of bumphead parrotfish at sites 3, 6, and 7 were significantly different from all other sites (Table 2). Bumphead parrotfish observed at site 3 in the Honiavasa passage (Fig. 2) were larger on average than those seen at all the other sites in the Roviana Lagoon, and the mean size of the fish sighted in the shallow inner-lagoon site 6 was significantly smaller than at all of the other sites. The mean size of the fish observed in Tetepare's passage (site 7) was significantly larger than for all Roviana sites.

Finally, the hypothesis that bumphead parrotfish predominantly aggregate at night around the new moon period and that catch rates are far greater during the new moon was not supported by our results (Fig. 6). The catch rates for the lunar stages did not differ significantly (ANOVA, $F = 0.68$, $df = 80$, $p = 0.57$).

Customary sea tenure

There was a significantly non-random ($\chi^2 = 94.03$, $df = 18$, $p < 0.001$) association between households in major contemporary Roviana villages and central tribal affiliations

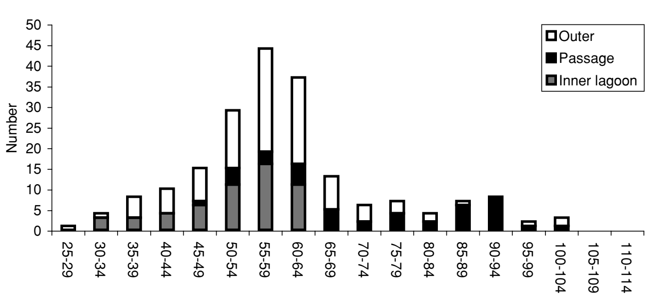

Figure 4 Size distribution of all bumphead parrotfish sampled from inner-lagoon, passage, and outer-reef drop habitats in Kalikoqu ($n = 200$).

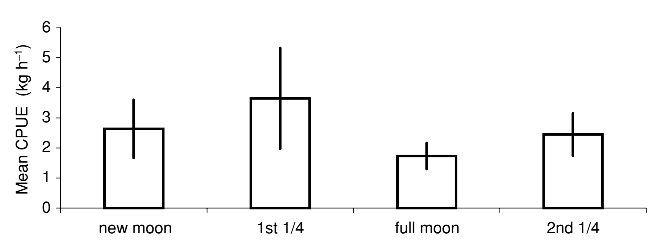

Figure 6 Mean catch rates of bumphead parrotfish (kg h^{-1}) in Roviana during each lunar stage ± one standard error (new moon, $n = 16$; first quarter, $n = 12$; full moon, $n = 23$; and second quarter, $n = 30$; total $n = 81$).

Table 2 Results of GT2 test of *Bolbometopon muricatum* size differences between sites in Kalikoqu and Tetepare. *Indicates comparisons significant at the 0.05 level.

Site comparison	*Lower confidence limit*	*Difference between means*	*Upper confidence limit*	*Significance*
1–2	−34.55	6.77	48.09	
1–3	−280.50	−225.35	−170.19	*
1–4	−87.09	−37.03	13.04	
1–5	−76.62	8.60	93.81	
1–6	294.51	372.27	450.02	*
1–7	−539.67	−466.05	−392.42	*
2–1	−48.09	−6.77	34.55	
2–3	−290.61	−232.12	−173.62	*
2–4	−97.52	−43.80	9.92	
2–5	−85.59	1.83	89.24	
2–6	285.33	356.49	445.66	*
2–7	−548.97	−472.82	−396.66	*
3–1	170.19	225.35	280.50	*
3–2	173.62	232.12	290.61	*
3–4	123.35	188.32	253.29	*
3–5	139.20	233.95	328.69	*
3–6	509.52	597.61	685.71	*
3–7	−325.16	−240.70	−156.23	*
4–1	−13.04	37.03	87.09	
4–2	−9.92	43.80	97.52	
4–3	−253.29	−188.32	−123.35	*
4–5	−46.24	45.63	137.50	
4–6	324.29	409.29	494.29	*
4–7	−510.25	−429.02	−347.78	*
5–1	−93.81	−8.60	76.62	
5–2	−89.24	−1.83	85.59	
5–3	−328.69	−233.95	−139.20	*
5–4	−137.50	−45.63	46.24	
5–6	254.21	363.67	473.12	*
5–7	−581.20	−474.64	−368.09	*
6–1	−450.02	−372.27	−294.51	*
6–2	−445.66	−365.49	−285.33	*
6–3	−685.71	−597.61	−509.52	*
6–4	−494.29	−409.29	−324.29	*
6–5	−473.12	−363.67	−254.21	*
6–7	−939.00	−838.31	−737.62	*
7–1	392.42	466.05	539.67	*
7–2	396.66	472.82	548.97	*
7–3	156.23	240.70	325.16	*
7–4	347.78	429.02	510.25	*
7–5	368.09	474.64	581.20	*
7–6	737.62	838.31	939.00	*

(Table 3). Members of the Kalikoqu and Saikile villages had a high ratio of affiliations with their own estates while simultaneously holding a substantial proportion of entitlements to the sea territories of the Dunde and Nusa Roviana villages. Indeed, they claimed entitlement to the estates of all other villages in the Munda and Vonavona areas. By contrast, inhabitants of Dunde and Nusa Roviana had a strong affiliation only with the Kazukuru tribe, which owns land and some reefs near Munda, and only half of the households had rights to the estates of the Vuragare tribe, which holds all the reefs bordering the Munda area and beyond. This was true also for other Munda area hamlets. Only low proportions of households in Dunde and Nusa Roviana had entitlements to the property of the Kalikoqu and Saikile (Table 3). Therefore, Kalikoqu and Saikile inhabitants have exclusive rights over their respective estates while concurrently having powerful rights to the Vuragare and Kazukuru estates. These entitlement asymmetries allow members of Kalikoqu and Saikile villages to claim rights over the waters of Nusa Roviana and Dunde, while simultaneously

Table 3 Proportion of households in principal villages with at least one member (either spouse) with affiliation to the major tribal groups in Roviana (villages from west to east). *Each of these is an amalgam of various tribes. Modified from Aswani (2002).

Major tribes	*Dunde (Munda) area) (n = 35)*	*Nusa-Roviana (Munda area) (n = 22)*	*Sasavele (Kalikoqu) (n = 22)*	*Baraulu (Kalikoqu/ Saikile) (n = 38)*	*Nusa Hope (Saikile) (n = 49)*	*Olive (Saikile) (n = 15)*	*Ha'apai (Saikile) (n = 14)*
Kazukuru	100	95	73	76	39	33	83
Vuragare	46	50	77	95	71	53	83
Kalikoqu tribe*	14	32	100	100	43	13	14
Saikile tribe*	23	23	14	84	98	100	79

keeping their own territories free from interlopers. Nusa Roviana and Dunde inhabitants, on the other hand, lack sufficient kin ties to Kalikoqu and Saikile estates to claim rights there, and so they must protect their own territories from Kalikoqu and Saikile territorial demands, particularly as prospects for future commercial fishing and tourism development increase in the Munda area.

It is important to understand how these differences between sea-tenure regimes translate into people's cultural attitudes and their actual social behaviour. For instance, residents of Olive, in the Saikile chiefly district, would like all neighbouring communities with or without overlapping rights to ask chiefly permission before they use their resources for commercial purposes. This demand is effective because they have secure tenure over their territory and because chiefly authority is more binding here than in Munda-area villages. Nusa Roviana residents near the Munda area, on the other hand, can only require outsiders who have no overlapping rights whatsoever to ask permission to exploit commercial resources, which they rarely do. These differences occur even though both communities rely heavily on marine resources for household income (Aswani 2002). Table 4 shows that the two villages differ significantly ($\alpha = 0.05$) in their cultural attitudes toward the fishing activities of neighbouring hamlets. While residents of the two villages have analogous views regarding the fishing activities of outsiders (non-Roviana residents), they have an opposite attitude toward the commercial fishing activities of neighbouring groups. Note that Kalikoqu residents rarely foray into Nusa Roviana waters. However, groups from neighbouring Dunde and Rendova Island, who also have overlapping rights, frequently exploit resources in Nusa Roviana. Nusa Roviana leaders simply lack the authority to forbid neighbouring stakeholders from gaining access to their marine resources. Chiefly authority in this village has been eroded by sustained contests over natural resources. In fact, there was a significant difference ($\alpha = 0.05$) between the villages with regard to people's confidence in their traditional leaders. Olive residents had more confidence in their traditional leader's ability to manage marine resource (88%) than in Nusa Roviana, where only slightly over half (55%) of the inhabitants trusted their leader's management abilities. Members of both villages also significantly differed in their attitudes regarding issues of marine resource governance (Table 5). The chi-square goodness-of-fit test showed that the value of the test statistic $\chi^2 = 12.18$ was larger than the critical value of $\chi^2 = 7.81$ at a significance level of $\alpha = 0.05$. The observed frequencies of responses of Olive and Nusa Roviana inhabitants, therefore, differed significantly from those predicted by the null hypothesis (i.e. that frequencies did not differ).

Table 4 Cultural attitudes of Olive ($n = 84$) and Nusa Roviana ($n = 89$) adults (aged 18 and older) regarding interloping activities of neighbours.

Area	*Neighbours for income*		*Other Solomon islanders for income*	
	Yes	*No*	*Yes*	*No*
Olive (Saikile)	10	74	6	78
Nusa Roviana (Munda area)	81	8	9	80

DISCUSSION

Integrating indigenous ecological knowledge and marine science

Our findings show that in areas around Roviana Lagoon, where ecological changes have occurred within the lifespan of local fishers, knowledge regarding ecological transformation can be detailed and useful. Local beliefs that catch rates of bumphead parrotfish have declined markedly following the advent of market-driven spearfishing and that large fish are rare today are supported by results that showed that bumphead parrotfish catch rates and sizes between the lightly exploited island of Tetepare and more heavily exploited Kalikoqu differ significantly. Fisheries-independent UVC results concurred with these findings. In light of these results and ecological knowledge on recent changes in the Kalikoqu fishery, we argue that the differences in catches between Kalikoqu and Tetepare predominantly reflect different levels of historical fishing pressure on bumphead parrotfish stocks in the two regions. We propose that selective fishing of large parrotfish has eliminated the large individuals from the Roviana Lagoon.

Table 5 Cultural attitudes of Olive ($n = 85$) and Nusa Roviana ($n = 86$) adults (aged 18 and older) concerning best ways for local marine resource management.

	Credence in chiefly control		*No credence in chiefly control*	
	Olive	*Nusa Roviana*	*Olive*	*Nusa Roviana*
Credence in provincial government control	59 (69%)	34 (40%)	4 (5%)	19 (22%)
No credence in provincial government control	16 (19%)	13(15%)	6 (7%)	20 (23%)

An alternative explanation is that significant environmental differences between the two study sites explain differences in abundance and size distribution of bumphead parrotfish. Varying levels of fish abundance and biomass between separated regions have been attributed to variability in food availability, recruitment, migration, growth, temperature and genetics (Rijnsdorp & Ibelings 1989; Campana *et al.* 1995; Clifton 1995; Craig *et al.* 1997; St John *et al.* 2001; Gust *et al.* 2002). In our spatial comparison, however, we considered similar habitats that were only 50 km apart. Considering the close proximity of the locations and the nature of dispersive larval stages of coral reef fishes (Sale 1980), it is unlikely that localized genetic adaptations exist (Warner 1991) or that temperature is a factor of any importance on such a small geographical scale.

Indeed, Tetepare does not support the extensive lagoon systems that Roviana does. Thus, the high abundance of small bumphead parrotfish sighted and captured in outer-reef and passage habitats in Kalikoqu is likely to be, in part, a consequence of the close proximity of these habitats to inner-lagoon nursery areas. This may explain some of the very large differences in mean sizes and catch rates observed between the two regions. Yet, it does not detract from the finding that large bumphead parrotfish were very rarely captured (or sighted) in the Kalikoqu passage and outer-reef habitats. In the absence of historical quantitative baseline data for the Kalikoqu region, it is impossible to verify reductions in mean sizes and abundances of bumphead parrotfish scientifically.

The reported catches of bumphead parrotfish in Tetepare were not exceptionally high for lightly exploited regions in the Solomons (Hamilton 2003*b*). The recent commercialization of the bumphead parrotfish fishery in Kia, Isabel Island, provides a good example. In August 2001, the Bahana Fisheries Centre in Kia began to purchase bumphead parrotfish for the first time in the centre's 10-year history. In 16 months, the centre purchased over 31 000 kg wet-weight of bumphead parrotfish, with recorded catches of over 500 kg being regularly landed by a single diving party in a night. We consider Tetepare a lightly fished area because the island is uninhabited and is only visited sporadically by a number of groups across the Western Solomons. The cost in terms of petrol and effort in getting to Tetepare is prohibitive. We are aware that Gilbertese fishers from Ghizo Island continue to poach in these waters, but given their numbers and the size of Tetepare, it is reasonable to conclude that Tetepare is still a lightly fished area. Unfortunately, this situation is rapidly changing as the Solomon Island economy continues to crumble.

The indigenous anecdotal evidence, and the creel survey and UVC comparison data enable us to grasp the magnitude of recent changes. This information has allowed us to hypothesize about the possible underlying causes and rates of ecological change, while also providing us with a measure of achievable goals for the restoration and preventive management of bumphead parrotfish. This could not have been accomplished based solely on the limited perspective of recent ecological observations (Hamilton & Walter 1999; Pitcher 2001). In essence, we argue that in a 'data-less' context, such as the Solomons, it is vital to draw on indigenous ecological knowledge to gain an historical perspective on recent changes in and the current status of a fishery (Johannes *et al.* 2000).

Indigenous ecological knowledge has been instrumental in designing other aspects of our fisheries research. It has contributed to the development of hypotheses regarding the effects of habitat in structuring the size distributions of bumphead parrotfish in this area. Local conclusions that very small individuals are restricted to the shallow inner lagoon and that only small fish are captured in the inner lagoon have been shown to be very accurate. Research results of reproductive studies (R.J. Hamilton & S. Adams, unpublished data 2003) have shown that bumphead parrotfish achieve 100% female maturity at 650 mm standard length, which means that virtually all specimens taken from the inner lagoon are juveniles. Closing inner lagoon areas to night divers would greatly reduce the number of juveniles taken, with long-term benefits for the fishery. Indigenous ecological knowledge regarding the size structure of bumphead parrotfish in the passage habitat has also proved to be correct, with the largest fish on average being sighted and captured there. In female bumphead parrotfish, gonad weight increases exponentially with increasing length (Hamilton 2003*a*), indicating that large females contribute overwhelmingly to the egg production that renews fish populations (Pauly *et al.* 2002; Sadovy 1996). Prohibiting spearfishing within passage habitats would provide a measure of protection to what may be the last remaining significant spawning stocks of bumphead parrotfish in this region.

Not all indigenous ecological knowledge was supported by our quantitative studies. Specifically, local estimations that catch rates of bumphead parrotfish are greater during the new moon were not supported. From a management perspective, this finding is also interesting, because we initially assumed that local notions about higher catches around the new moon might reflect fishing of spawning aggregations during this period and that a ban on fishing during the new moon would afford some protection to spawning stocks. Contrary to our initial expectations, histological studies suggest that spawning in bumphead parrotfish occurs late in the full moon quarter (spawning could well occur during the full moon, but no samples from this period were recorded, as catching bumphead parrotfish is very difficult when the moon is up; R.J. Hamilton & S. Adams, unpublished data 2003) and that any lunar ban on spearfishing should focus on this period.

Customary sea tenure and institutional dependability

We suggest that (1) if a large proportion of entitlement holders to a sea estate live adjacent to their marine holdings, they, along with those people residing away from their property, are more likely to manage and protect that corporate sea estate (for example Olive); and, conversely, (2) if a large proportion of entitlement holders to a sea estate are scattered and live away from their marine holdings, they, along with those still residing within their property, are less likely to manage and protect that corporate sea estate (for example Nusa Roviana). Members of Olive continued to have faith in their traditional leaders, while in Nusa Roviana this confidence in leaders has continued to erode. These results are consistent with cultural attitudes collected in 1994 and 1995 (see Aswani 2002). The cultural attitudes obtained from islanders regarding the interloping activities of neighbouring villages and the role of the government in fisheries management (Tables 4 and 5) can be used as a proxy for actual resource-access control and enforcement. In Roviana, 'enforcement of access' is achieved through direct territorial behaviour and through the force of public opinion. The latter is the primary means of enforcing territoriality and serves as an effective 'social boundary defence' mechanism (Cashdan 1983) that keeps potential interlopers out. This system is particularly effective when regional populations recognize the territorial boundaries of a group, such as those of Kalikoqu and Saikile inhabitants. They are less effective when there are contests over the control of territorial waters, as in Nusa Roviana and Dunde. Olive's cultural attitudes (as those of most people in Saikile and Kalikoqu) toward the role of traditional authorities' control over traditional waters reveal a stronger confidence in the ability of traditional authority to enforce regulatory measures.

It is theoretically plausible that if sea co-owners live in close spatial proximity they are likely to share beliefs and preferences, thus lowering transaction costs and leading them to compete less for the same resource. Cultural homogeneity, therefore, facilitates the regulation of resource exploitation by traditional authorities. Conversely, if sea co-owners reside apart, they are likely to have diverging beliefs and preferences, which could increase transaction costs and competition for the same resources. The probability of failure to regulate resources under these circumstances increases because entitlement owners hold less-certain authority over their territories. In other words, they are more likely to allow interlopers to overexploit the ocean for subsistence and for cash in the short term because they are less likely to benefit in the long term from sustainable resource management practices. Cultural heterogeneity, therefore, hinders the role of traditional authorities in regulating resource exploitation (Aswani 2002). Cooke *et al.* (2000) reached a similar conclusion based on their work in Fiji, where management strategies varied among members belonging to different sea-tenure regimes.

In summary, when considering the establishment of participatory regulatory measures to protect marine species in Roviana, it is crucial that we distinguish between local sea-tenure regimes in terms of people's capacity to institute regulatory mechanisms. Such divergences are products of different historical trajectories: in one, systems of governance can potentially translate into systems of management; in the other, they are harder to implement. Our results indicate that resource-management initiatives in Roviana will be seriously handicapped unless an institutional context is selected in which there is minimal public contest over natural resources. A successful tenure regime requires that boundaries be well defined, that they be recognized regionally, that there is little or no poaching by neighbouring groups, that there is a capacity to monitor and enforce rules, and that most of the inclusive stakeholders will endorse a management initiative. Aswani (1999) called this situation the territorially enclosed entitlement regime, as is found in Kalikoqu and Saikile. Simply put, it is meaningless to implement a management regime in an area, no matter how rich in marine biodiversity, if exclusion of non-members and harvest restriction rules cannot be enforced. The knowledge gained from ethnographic research is essential to the establishment of successful participatory and precautionary co-management regimes.

Bumphead parrotfish management: theory into practice

Studying indigenous ecological knowledge and sea tenure concurrently in this project has facilitated the selection of a key species and its associated habitats that most urgently need management, and the institutional contexts that are most amenable to precautionary management programmes. More specifically, investigating indigenous ecological knowledge has served to (1) verify that the bumphead parrotfish is a species in urgent need of protection; (2) aid in understanding how different habitats structure the size distribution of bumphead parrotfish; (3) help in identifying sensitive locations and habitats that need protection, including shallow inner-lagoon sites that serve as nursery areas; and (4) help us comprehend how lunar periodicity affects bumphead parrotfish behaviour and catch rates. Studying customary sea tenure, on the other hand, has allowed us to identify locations that are best suited to accommodating bumphead parrotfish management programmes with a greater likelihood for local participation and for programme success.

Sites selected for management have been chosen by a combination of locally driven assessments and by the

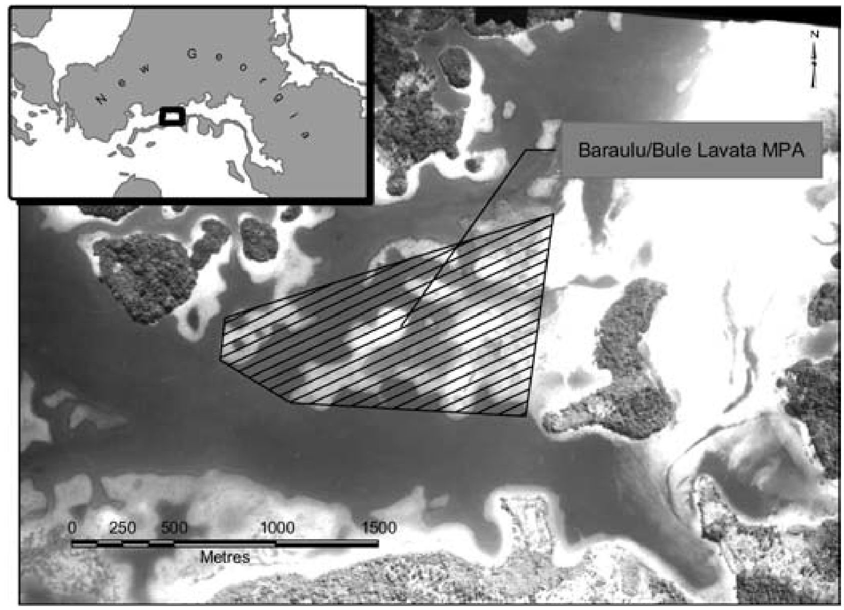

Figure 7 Baraulu Village MPA. Patterned area shows 'no take' zone. Light areas in the picture indicate inner-lagoon reefs (these being a composite of coral gravel, sand, predominantly *Porites* coral colonies and grass beds) and dark areas are deep inner-lagoon passages.

information gained from this research. Kalikoqu and Saikile district people have voiced their concern regarding the growing depletion of their marine resources. We have assisted local people in establishing marine protected areas (MPAs) to protect their marine species and habitats (Aswani 2000*b*). More specifically, Kalikoqu and Saikile stakeholders have agreed to establish two MPAs. One has been established in the areas of the Mudala, Ilaka, and Onone reefs adjoining Baraulu Village (Fig. 7) to protect bumphead parrotfish and other lagoon species. This MPA serves to (1) preserve representative lagoon shallow-reef habitats in which bumphead parrotfish are commonly found, (2) provide a safe heaven for bumphead parrotfish as well as other species, and, principally, (3) preserve bumphead parrotfish nursery areas. Similarly, Saikile authorities have agreed to establish an MPA in the Heloro reef complex bordering Nusa Hope Village (Fig. 8). This MPA serves to (1) preserve spawning areas for triggerfish and several Serranidae species, (2) protect nocturnal aggregations of the bumphead parrotfish, and (3) safeguard bumphead parrotfish nursery areas. Both no-take MPAs were formally established in September of 2002 and are expected to continue for an indefinite period. The biological (for example spill-over) and

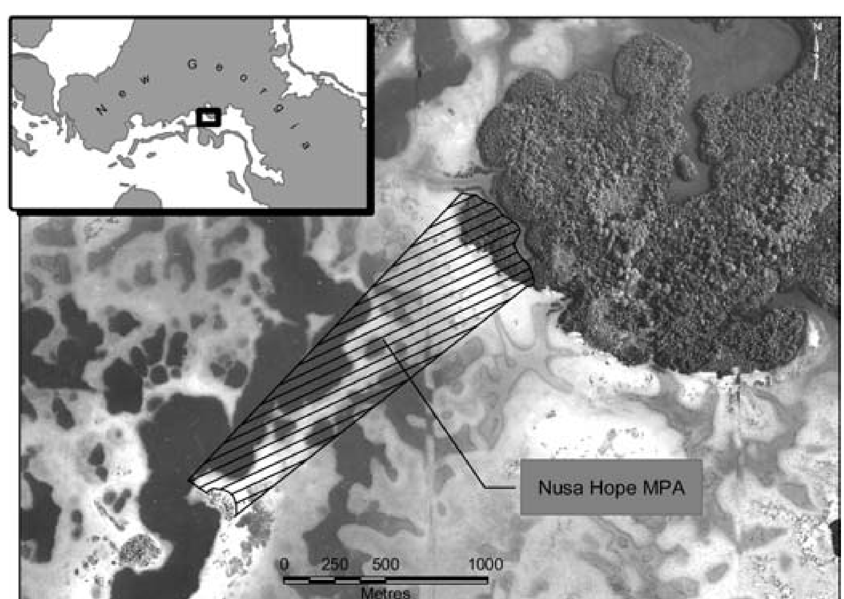

Figure 8 Nusa Hope Village MPA. Patterned area shows 'no take' zone. Light areas in the picture indicate inner-lagoon reefs (these being a composite of coral gravel, sand, predominantly *Porites* coral colonies and grass beds) and dark areas are deep inner-lagoon passages.

social (for example food security) effects of these MPAs are yet to be determined.

Along with the establishment of these and other MPAs, additional protective measures are being studied in consultation with local authorities. These include a ban on bumphead parrotfish spearfishing in all Kalikoqu and Saikile inner-lagoon habitats, in order to give juveniles a chance to mature and join the adult fishery before being subjected to fishing pressure, and a ban on taking large bumphead parrotfish from the passage habitat. Protecting some of the highly fecund large females would enhance the sustainability of the Roviana fishery. Such bans on fishing in highly contested waters, such as those of Dunde or Nusa Roviana, would be almost impossible to monitor and enforce. It is conceivable, however, that future management success in Kalikoqu and Saikile will encourage villagers in other areas (such as Nusa Roviana and Dunde) that are more vulnerable to resource contests and overexploitation to negotiate with neighbouring groups to define and implement natural resource management practices. In fact, this process has already begun with the establishment of a spatio-temporal 'no take' zone in Nusa Roviana in 2003.

Co-management in the region is being designed with the participation of officials at the local, provincial, and national levels. We are also conducting a series of workshops to encourage local participation in and awareness of the planned management initiatives (Aswani & Weiant 2003). The workshops promote the value of species such as bumphead parrotfish, as well as resource management, the sharing of information, the involvement of government officials at various levels, the discussion of issues of local enforcement and monitoring, and the importance of having all parties understand both the project objectives and the expected results. Enduring legislative enforcement of management initiatives to protect bumphead parrotfish and other species will be achieved through the Western Province 'Customary Land Resource Management Orders' statute. The order can be requested by a community to protect their forest and marine resources in a particular area of customary land. Meanwhile, Baraulu and Nusa Hope authorities have both set up a 'Resource Management Committee' (RMC), formed by various village constituencies, to supervise the marine protected areas and to mediate between stakeholders if any disputes arise. Another significant step in ensuring the long-term sustainability of the conservation initiatives has been the recent sanction of our project by the head of the Christian Fellowship Church, the members of which have customary control over huge areas of New Georgia Island.

These efforts illustrate how anthropologists and marine scientists can integrate their empirical research for the purpose of precautionary and participatory fisheries co-management. The lessons being learned are that fishery biologists will rarely achieve ecological sustainability and the protection of marine biodiversity unless they seriously consider the social, economic, and political behaviours of the actors whose ecosystems they seek to conserve. Fisheries scientists increasingly are recognizing the importance of these parameters (see Adams 1996; Bunce *et al.* 1999). In turn, social scientists involved in conservation projects have to understand the major ecological processes that pattern their study sites if they are successfully to formulate policies that will safeguard the ecological and social interests of those whom they seek to assist. As succinctly put by Johannes (1993, p. 37) in reference to methods for studying indigenous ecological knowledge, '. . . neither natural scientists nor social scientists can do the job well without the expertise of the other.' The results presented in this paper illustrate how interdisciplinary efforts integrate natural and social systems in resource management planning and execution, thus narrowing the gap between the natural and social sciences while at the same time enhancing the possibilities for successful resource management.

CONCLUSIONS

Our research sought to evaluate the commensurability of indigenous ecological knowledge with marine science and the institutional reliability of sea-tenure institutions prior to their incorporation into plans to protect tropical species, in this case the bumphead parrotfish. Existing variations of indigenous ecological knowledge and sea tenure must be acknowledged, and the historical, socioeconomic, political, and environmental conditions that pattern and transform these frameworks, which have emerged from different historical trajectories, must be studied. They are diverse, wide-ranging and dynamic. This approach will be crucial to identifying conditions that can make or break a management system. We do not suggest that Western forms of knowledge or practice are superior in any measure, but rather we seek to find ways to work in partnership with local communities and to combine the strengths of indigenous ecological knowledge, customary sea tenure, marine science and anthropology for the successful management of marine resources in the Pacific region.

By simultaneously studying the ecology of a pivotal marine species and identifying institutional differences, we have achieved two complementary results. First, by integrating local knowledge and current marine science knowledge, we have identified a species and associated habitats that most urgently need management. Second, through anthropological fieldwork, we have distinguished those institutional contexts that are best suited to accommodating precautionary management programmes, i.e. locations where there is greater likelihood of local participation and successful outcomes. In summary, we hope that our findings may be applicable to other regions of the Indo-Pacific region with operational sea tenure and indigenous ecological knowledge regimes, thus making the formulation of community-based marine protected areas across the region more effective.

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