Contributed Paper

Implications of Urbanization for Artisanal Parrotfish Fisheries in the Western Solomon Islands

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Abstract: *Increasing migration into urbanized centers in the Solomon Islands poses a great threat to adjacent coral reef fisheries because of negative effects on the fisheries and because it further erodes customary management systems. Parrotfish fisheries are of particular importance because the feeding habits of parrotfish (scrape and excavate coral) are thought to be critical to the resilience of coral reefs and to maintaining coral reef health within marine protected areas. We investigated the ecological impact of localized subsistence and artisanal fishing pressure on parrotfish fisheries in Gizo Town, Western Solomon Islands, by analyzing the density and size distribution of parrotfish with an underwater visual census (UVC), recall diary (i.e., interviews with fishers), and creel surveys to independently assess changes in abundance and catch-per-unit-effort (CPUE) over 2 years. We then compared parrotfish data from Gizo Town with equivalent data from sites open to and closed to fishing in Kida and Nusa Hope villages, which have different customary management regimes. Results indicated a gradient of customary management effectiveness. Parrotfish abundance was greater in customary management areas closed to fishing, especially with regard to larger fish sizes, than in areas open to fishing. The decline in parrotfish abundance from 2004 to 2005 in Gizo was roughly the same magnitude as the difference in abundance decline between inside and outside customary management marine reserves. Our results highlight how weak forms of customary management can result in the rapid decline of vulnerable fisheries around urbanized regions, and we present examples in which working customary management systems (Kinda and Nusa Hope) can positively affect the conservation of parrotfish—and reef fisheries in general—in the highly biodiverse Coral Triangle region.*

Keywords: artisanal fisheries, conservation, customary management, parrotfish, Solomon Islands, urbanization

Implicaciones de la Urbanización para las Pesquerías Artesanales de Peces Loro en las Islas Salomón Occidentales

Resumen: *El incremento de la migración hacia centros urbanos en las Islas Salomón es una gran amenaza para las pesquerías en los arrecifes de coral adyacentes debido a los efectos negativos sobre las pesquerías y porque erosiona los sistemas de manejo tradicionales. Las pesquerías de pez loro son de particular importancia debido a que se piensa que los hábitos alimentarios de los peces loro (raspar y excavar coral) son críticos para la resiliencia de los arrecifes de coral y para el mantenimiento de la salud de los arrecifes dentro de áreas marinas protegidas. Investigamos el impacto ecológico de la presión de pesquerías de subsistencia y artesanal sobre las pesquerías de pez loro en Gizo Town, Islas Salomón Occidentales, mediante el análisis de la densidad y distribución de tallas de pez loro con un censo visual submarino, la memoria diaria (i.e., entrevistas con los pescadores) y muestreos de las cestas de pescadores para una evaluación independiente de los cambios en abundancia y en captura por unidad de esfuerzo a lo largo de dos años. Posteriormente comparamos los datos de peces loro de Gizo Town con datos equivalentes de sitios abiertos y cerrados a la pesca en los poblados de Kida y Nusa Hope, que tienen regímenes de manejo tradicional diferentes. Los resultados indicaron un gradiente en la efectividad del manejo tradicional. La abundancia de peces loro fue mayor en las áreas de*

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manejo tradicional cerradas a la pesca, especialmente en relación con tallas más grandes, que en las áreas abiertas a la pesca. La declinación en la abundancia de peces loro de 2004 a 2005 en Gizo básicamente tuvo la misma magnitud que la diferencia en la declinación de la abundancia entre sitios dentro y fuera de reservas marinas con manejo tradicional. Nuestros resultados resaltan la manera en que las formas débiles de manejo tradicional pueden resultar en una rápida declinación de pesquerías vulnerables alrededor de áreas urbanizadas, y presentamos ejemplos de cómo los sistemas de manejo tradicional (Kinda y Nusa Hope) pueden afectar positivamente a la conservación de peces loro – y las pesquerías en arrecifes en general – en la región altamente biodiversa del Triángulo de Coral.

Palabras Clave: conservación, Islas Salomón, manejo tradicional, pesquerías artesanales, pez loro, urbanización

Introduction

Fishing pressure is one of the biggest threats facing coral reefs today (McManus 1997; Pandolfi et al. 2003). Archaeological data from many Pacific Islands suggest that fishing pressure on reef and pelagic fishes has been significant (Kirch & Yen 1982; Aswani & Allen 2009), but in recent decades overharvesting and habitat degradation have intensified across the region. At the same time, notwithstanding that millions of people directly and indirectly depend on coral reef fisheries for their social and economic well-being, subsistence and artisanal fisheries have been given inadequate attention, funding, and research effort compared with global industrialized fisheries (Sadovy 2005). A majority of these people live in developing countries, which will continue to see sharp increases in their populations in the coming decades. The movement of people looking for employment will invariably lead to the concentration and expansion of urbanized centers (Dalzell et al. 1996), and localized fishery declines have been noted as a serious and emerging threat in urban and emerging urban centers (Gillett & Moy 2006; Cinner & McClanahan 2006). Fishery declines will be further aggravated by increasing tourism and the globalization of the reef fish trade.

Of particular interest are parrotfish (Labridae), which play a crucial functional role as grazers and bioeroders in the reef ecosystem (Hughes 1994; Hawkins & Roberts 2004), and thus their abundance can be used as an indicator of coral reef health (Hughes et al. 2005). Increasing migration into urbanized centers in Oceania, and particularly in the Solomon Islands and Papua New Guinea, poses a great threat to parrotfish and coral reefs fisheries in general because immigrants overexploit the adjacent fishery through increased demand in local markets and tourism. Fishing intensity in these areas also increases because immigrants do not have traditional custodial rights to adjacent reefs.

Centralized and science-driven coastal fisheries programs in the region have, in general, failed. Thus, there is a growing interest in the relationship between remnant customary governance systems and management of marine resources. Customary governance and management systems are cultural and historical practices designed to regulate the use of, access to, and transfer of resources locally, and they are informed by indigenous ecological knowledge and embedded in customary land- and sea-tenure institutions (Cinner & Aswani 2007). Current interdisciplinary studies are examining the effects of changing socioeconomic factors on customary management systems (Aswani 2002), and other studies have explored the relationship between customary management and the status of artisanal fisheries (Cinner et al. 2006; Aswani et al. 2007; Turner et al. 2007; McClanahan & Cinner 2008). More research is needed to provide an understanding of the ecological and socioeconomic effects of changes to customary management practices that result from urban migration, monetization, and cultural change. In particular, more information is needed on the relationship between changing fishing intensity and management systems and the abundance of species that play a critical role in the resilience and vulnerability of coral reef ecosystems; on changes over time in the size distribution and abundance of parrotfish; and on changes in the catch-per-unit-effort (CPUE) of fisher folk under transforming customary management systems. Gauging the human processes that drive local population dynamics of coral reef fishes is central to effective management of fisheries.

We investigated the ecological impact of localized subsistence and artisanal fishing pressure on parrotfish fisheries in Gizo Town, Western Solomon Islands (Fig. 1), and used this information to conduct a comparative assessment of parrotfish abundance in customary open-access and customary closed-access coral reefs in the Western Solomon Islands. We highlight the role of the erosion of customary management in the rapid decline of vulnerable fisheries around urbanized regions and present an example in which functioning customary management systems can positively affect the conservation of parrotfish and reef fisheries.

Study Site and Sociocultural Context

The New Georgia Group in the Western Solomon Islands consists of volcanic islands that stretch from the northwest to the southeast and elevated reef limestone islands in the northwest (Fig. 1). The marine ecosystem

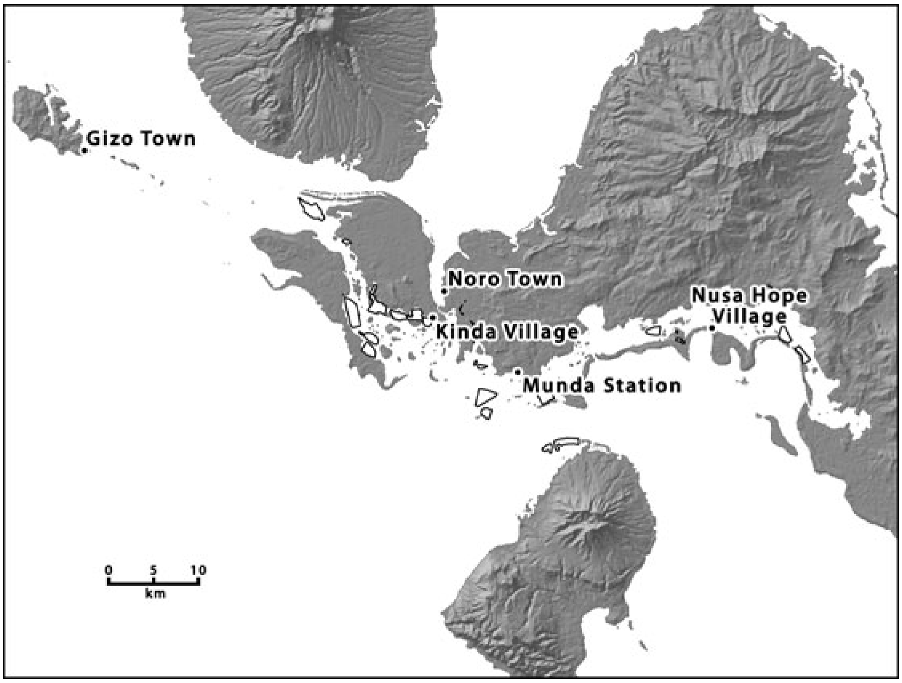

Figure 1. The New Georgia Group, Western Solomon Islands. The community-based marine protected area (CBMPA) sites in our conservation program are the outlined areas offshore.

is diverse, including coastal and coral atoll lagoons, barrier reefs, grassbeds, mangrove forests, river mouths, and mudflats, among other habitats. The Western Solomons is an area rich in biodiversity within the Coral Triangle region (Allen 2008), a marine ecoregion that encompasses the nations of the Philippines, Malaysia, Indonesia, East Timor, Papua New Guinea, and the Solomon Islands, and interest in conserving its marine ecosystems is growing. Traditionally, inhabitants have customary land and sea tenure, which in principle allows inclusive members right of access and use of marine and terrestrial resources and bars those without tenurial entitlements. Such rights are contingent upon a member's birthright, spousal affiliation, and location of residence, and chiefs and elders control each district and exercise control over tribal territories. Today, a majority of coastal inhabitants still rely on fishing and horticulture as their means of subsistence, despite extensive social and cultural change over the past two centuries. Subsistence fishing dominates village life, and marine resources provide the bulk of the protein in people's diets. Nevertheless, urbanization in towns like Noro and Gizo, and in the Munda Station (Fig. 1) have greatly reduced subsistence activities and increased reliance on cash to buy food.

Gizo Town on Ghizo Island, the capital of the Western Solomon Islands (Fig. 1), is the second largest urban center in the Solomons, with a population of approximately 8000 individuals. Gizo inhabitants are a mixture of groups from around the Western and Eastern Solomons and immigrants from the Gilbert Islands (Micronesia) brought by the British Government between the 1950s and 1970s. The island was depopulated in the 1840s when local inhabitants fled to neighboring islands to escape headhunting raids (Bennett 1987). Subsequently, the British Colonial Administration settled Gizo Town and seized the land and surrounding reefs from the few remaining traditional owners. The present descendants are trying to reclaim the land and surrounding reefs in a push to restore customary ownership titles, but the island's history, along with high population densities, cultural heterogeneity of the various migrant groups, and increasing urbanization has rendered the customary sea tenure over the surrounding reef moribund.

Kida village is a small settlement on the Island of Kohinggo in the Vonavona Lagoon area with a population of around 150 people (Fig. 1). Most households in Kida and other Vonavona hamlets produce copra as the major economic activity, followed by wage labor. Increasing pressure from a growing population in the Vonavona Lagoon area, whose inhabitants now number several thousands and forage on the same reefs for subsistence and commercial fishing alongside interlopers from Noro Town and Munda Town fisher folk, is threatening the ecology and social viability of existing systems of customary management. The Kida community, with our assistance, responded to this threat in 2003 by establishing a community-based marine protected area (CBMPA) to protect and manage marine resources (particularly bumphead parrotfish [*Bolbometopon muricatum*] and other scarids), but its sea-tenure system remains vulnerable.

Nusa Hope is one of the largest villages in the Roviana Lagoon area, with a population of approximately 1000 people (Fig. 1). The majority of households rely on subsistence agriculture and fishing for the bulk of their nutrient intake, and cash is generated, among other activities, by diving for marine products or selling fish and vegetables. Nusa Hope is surrounded by biodiverse habitats, including extensive forests on the New Georgia mainland, expansive coral reefs and estuaries, and sustained fertile gardens on the barrier islands. Nevertheless, logging, overexploitation of marine resources, and growing local and neighboring populations have degraded marine and terrestrial ecosystems to some extent. In response, local authorities, with our technical and financial support, have established a very effective CBMPA to manage marine resources (particularly grouper [Serranidae] spawning aggregations and bumphead parrotfish) (Aswani & Hamilton 2004). This conservation initiative has been socially and ecologically successful because Nusa Hope has a robust customary sea–tenure system.

Parrotfish are one of the most important groups of herbivorous fishes found on coral reefs, with about 90 known species (Streelman et al. 2002). Parrotfish are recognized as a subfamily (clade) within Labridae (tribe Cheilini; Westneat & Alfaro 2005). With their beak-like fused jaws, they graze continually over reef surfaces, either scraping up algae and detritus or excavating the reef surface itself. This prevents overgrowth of algae and Scleractinian corals and redistributes as sediments large amounts of calcareous material (Bellwood 1995; Crossman et al. 2001; Choat et al. 2002).

Archaeological evidence suggests parrotfish have been heavily fished across the Pacific Islands for millennia (Kirch & Yen 1982). Today, increasing human populations across Oceania, the decline of other commercial reef fisheries, and more effective fishing techniques have contributed to increased fishing pressure on parrotfish. Their localized decline has now been linked to overfishing in American Samoa (Page 1998) and Guam (Hensley & Sherwood 1993), and to ecosystem changes in Tuvalu (Gillett & Moy 2006). In the Solomon Islands, certain species of parrotfish have long been prized for food and are harvested regularly by local fishers (Aswani & Hamilton 2004). Fishing grounds targeted by artisanal and subsistence fisher folk neighbored Gizo Town 30 years ago (Eginton & James 1979), but today expanding local markets are pushing fisher folk to other areas in the Western Province (Sabetian & Foale 2006). Gizo residents, because of the declining local abundance of marine resources, are now expanding beyond the town and fishing in reefs where they have no customary rights.

Methods

The density and size distributions of parrotfish in Gizo were measured over 2 years (2004 and 2005) with underwater visual censuses (UVC) to determine whether artisanal fishing pressure resulted in localized shifts in parrotfish sizes and abundance over time. Recall diary (interviews with fishers) and creel survey data were collected for the same period of time to independently assess CPUE and the ecological impact of localized subsistence and artisanal fishing pressure on parrotfish populations. For recall diary and creel survey data, CPUE was calculated by dividing the grams of fish weight by the number of hours of fishing. We directly compared density and size distributions of parrotfish between years in Gizo (2004 and 2005). We then gathered equivalent unpublished and published UVC data on the abundance and size distribution of parrotfishes in open-to-fishing (control) and closed-to-fishing (experimental) customary management sites in Kinda and Nusa Hope to compare with the data we collected for Gizo. Finally, data for all the sites open to fishing were compared with sites closed to fishing in Kinda and Nusa Hope villages to determine the local effects of moribund (Gizo), vulnerable (Kida), and robust (Nusa Hope) customary fishery management systems. We focused on parrotfish because of the critical functional role of parrotfish herbivory on the health of shallow-water coral-reef ecosystems (Hughes 1994; Hawkins & Roberts 2004) and their role in maintaining coral reef health within marine protected areas (MPAs) (Mumby et al. 2006), and because they are a main target of fishers across the Solomon Islands (Aswani & Hamilton 2004).

Underwater Visual Census (UVC)

Scarids are ideal for sampling because they are not cryptic and are ecologically tied to coral reefs (Choat & Bellwood 1991). We used a strip-transect underwater visual census (UVC) technique to measure the abundance and size–frequency of parrotfish. Three scraping (*Scarus ghobban, Hipposcarus longiceps,* and *Scarus rubroviolaceus*) and three excavating (*Bolbometopon muricatum, Chlorurus microrhinos,* and *Chlorurus bicolor*) parrotfish were selected for sampling in Gizo, although other parrotfish species were also tallied when they were easy to identify. We sampled in Aghana Islet, which is one of the many small, raised, uninhabited coralline islands of the Ghizo group that are commonly used by local fishers under a de facto open-access regime (although customary claims to this area do exist). The extensive adjacent fringing-reef morphology appeared to be similar on both the protected (eastern) and seaward (western) sides, with hermatypic corals descending down to about 40 m across the entire area.

Nevertheless, rugosity, as an indication of structural complexity over a smaller spatial scale (Wilson et al. 2008), appeared to be higher on the open side, where the slope was steeper and descended more sharply after 10 m. For logistical reasons, only the sheltered side of Aghana was monitored. Forty-one 100×10 m^2 belt transects were delineated on the reefs of Aghana at a 15-m depth and were surveyed between July and August 2004 and between May and June 2005. A test of power (Cohen 1988, 1992) revealed that for an effect size of 0.80 at a threshold of $p < 0.05$, significant differences would be detected 70% of the time (power = 0.70) with as few as 16 transects per village year.

Transects were worked by a single diver to reduce the potential for interobserver bias in the recorded parameters of species, frequency, total length (TL), and color phase. The sampled areas were marked with a global positioning system (GPS) to ensure that transects did not overlap. Similar to Gizo but at 20 m depth, parrotfish abundance and size distribution was quantified along independent 100×10 m^2 belt transects inside ($n = 18$) and outside ($n = 18$) the Nusa Hope CBMPA and inside ($n = 26$) and outside ($n = 26$) the Kida CBMPA (Aswani et al. 2007).

Recall Diaries

We collected recall diary data at Gizo with the collaboration of local fishers. The participating spear fishers used a recall diary method to identify fish species captured and fishing methods used and to answer other fishing-related questions. They were also asked to group all fish into families and to weigh them. To minimize recording effort, no species-specific compositions were recorded beyond the six selected species of parrotfish, although participants were asked to record specific species if they were prominent in the total catch (e.g., *Scarus oviceps*). The 12 expeditions between July and September 2004 represented 110 fishing hours. The six expeditions between May and June 2005 represented 94 fishing hours. The collected data represent CPUE rates solely on the basis of nighttime spearfishing expeditions.

Creel Surveys of Scarids

We conducted creel surveys of scarids to gauge the productivity of Gizo Town fishers and to independently assess the recall diary data. Over 2 years, we sampled the catches of fishers who spearfished for parrotfish at night in the Ghizo reefs. In 2004 five expeditions, representing 64 hours of fishing, were conducted between June and August to compare with the six expeditions, representing 70 hours of fishing, conducted between September and October 2005. Species color and metamorphosis phase (initial or terminal) were identified (when possible), and catches were weighed to the nearest kilogram for CPUE calculation. Because of logistical and time constraints and because these data were collected for triangulation with the other data sets, we conducted only a few creel surveys.

Statistical Analysis

We analyzed Gizo UVC abundance and size distribution data with multiple analysis of variance (MANOVA). Abundances in fish-size ranges were the dependent variables and the year the reef was sampled was the independent variable (hereafter Gizo 2004 and Gizo 2005). We contrasted Gizo 2004 with Gizo 2005 in counts of all scarids and six other surveyed species. To foster interpretation of findings, fish were categorized into size classes: 15–24 cm, 25–34 cm, 35–44 cm, and over 45 cm. We conducted log and square-root transformations to foster the assumptions of (M)ANOVA, but no transformation satisfactorily reduced the heterogeneity of variance across village years, so raw, untransformed frequencies are reported. Differences were considered statistically significant at a threshold of $p < 0.05$, but the reported p values reflect Greenhouse-Geisser corrections for sphericity when appropriate (Keppel 1991; Howell 1997). No nesting or weighting of transects within years was necessary because no inference was made per transect, each transect was treated identically, and each transect contributed equally weighted values per year.

We used paired t tests to contrast CPUE from recall diary and creel surveys in Gizo 2004 and Gizo 2005. We calculated CPUE as grams caught per person per hour of fishing effort. Using MANOVA with pairwise comparisons to localize significant differences, we compared size distribution and abundance of the six sampled species of parrotfish for Gizo 2004 and Gizo 2005 with data from outside and inside the community-based MPAs of Nusa Hope and Kida. To supplement findings from ANOVA, effect sizes were expressed as Cohen's D because the difference between means in units of standard deviation provides an unbiased estimate (Cohen 1988, 1992). We categorized effect sizes as small ($D = 0.20$), medium ($D = 0.50$), or large ($D = 0.80$) using the objective criteria of Cohen (1992).

Results

Underwater Visual Census (UVC)

Total scarids declined 45% from 2004 to 2005 in Gizo ($F_{1,86} = 12.9$, $p < 0.0001$, $D = 0.83$). The largest decline (62%) was evident in the largest fish (Table 1). Scraping parrotfish *S. ghobban* (44%), *H. longiceps* (36%), and S. *rubroviolaceus* (63%) declined significantly ($p < 0.005$). For each scraping parrotfish species, the largest reduction occurred in the largest size category. Excavating parrotfish declined significantly from 2004 to 2005 in Gizo, with the largest declines measured for *B. muricatum* (60%, $p < 0.005$, $D = 0.60$) and *C. bicolor* (56%, $p < 0.05$, $D = 0.41$). *C. microrhinos* declined 33%, but this small effect ($D = 0.16$) was not statistically significant ($p = 0.45$) (Table 1).

Recall Diaries and Creel Surveys

Herbivorous fish (scarids, Labridae, and Acanthuridae in particular) were the most prominent catch in both

Table 1. Underwater visual census of scraping and excavating parrotfish at Gizo in 2004 and 2005.[a]

Species and size (cm)	Gizo 2004		Gizo 2005		Change (%)	Cohen's D
	mean	SD	mean[b]	SD		
Scraping parrotfish						
S. rubroviolaceus						
15–24	1.1	1.6	0.5*	0.9	55	0.40
25–34	1.5	1.6	0.4**	1.0	73	0.72
35–44	0.1	0.3	0.1	0.3	0	0.16
45+	0	na	0	na	na	na
total	2.7	2.7	1.0***	1.4	63	0.72
S. ghobbans						
15–24	1.6	1.8	1.1	1.5	31	0.26
25–34	1.1	1.3	0.6[b]	0.9	45	0.42
35–44	0.6	0.7	0.0***	0.2	100	0.82
45+	0	na	0	na	na	na
total	3.2	2.5	1.8**	1.6	44	0.63
H. longiceps						
15–24	4.2	3.8	3.3	2.3	21	0.27
25–34	2.6	2.1	1.3***	1.5	50	0.69
35–44	0.9	1.8	0.3	1.3	67	0.34
45+	0	na	0	na	na	na
total	7.7	4.2	4.9***	3.2	36	0.69
Excavating parrotfish						
C. microrhinos						
15–24	0	na	0	na	na	na
25–34	0.3	0.7	0.1	0.3	67	0.35
35–44	0.4	0.9	0.5	1.0	−25	−0.07
45+	0.1	1.0	0.0	0.2	100	0.13
total	0.9	1.7	0.6	1.1	33	0.16
C. bicolor						
15–24	<0.1	0.2	0	na	na	na
25–34	0.5	0.8	0.2	0.5	60	0.39
35–44	0.3	0.7	0.2	0.4	33	0.22
45+	<0.1	0.1	<0.1	0.2	na	na
total	0.9	1.2	0.4	0.8	56	0.41
B. muricatum						
15–24	0	na	0	na	na	na
25–34	0	na	0	na	na	na
35–44	1.2	1.6	0.5**	0.9	58	0.54
45+	0.8	1.4	0.3*	0.6	63	0.44
total	2.0	2.4	0.8**	1.3	60	0.60
Total scarids						
15–24	6.9	5.5	5.0**	3.1	27	0.41
25–34	6.0	4.1	2.7***	2.7	55	0.86
35–44	3.4	3.3	1.5**	2.0	55	0.66
45+	1.0	1.7	0.4**	0.8	62	0.43
total	17.3	10.1	9.6***	6.2	45	0.83

[a]*Mean values express fish per transect.*
[b]*Significance:* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$ *compared with 2004.*

Gizo 2004 and Gizo 2005 recall diaries (Table 2). The CPUE decreased 30% from 2004 and Gizo 2005, an average of 144 g· person^{-1}·h^{-1}·species^{-1}, ($t_{12} = 2.4$, $p < 0.05$). Large decreases occurred in *H. longiceps* (23%) and *S. ghobban* (65%), the two most abundant species by weight caught in 2004. Creel-survey catch per species declined 6% from 2004 to 2005, but this difference of 13 g·person^{-1}·h^{-1}·species^{-1} was not statistically significant ($t_{19} = 0.3$, $p = 0.75$). The creel survey also revealed decreases from 2004 to 2005 in the larger parrotfish, S. *ghobban*, S. *rubroviolaceus*, and B. *muricatum* (Table 3).

Intervillage UVC Comparisons

The significant interaction between fish size and village management system in abundance ($F_{15,\ 492} = 25.8$, $p < 0.0001$) demonstrated a compelling pattern. Parrotfish abundance was greater inside than outside the customary CBMPAs across all settlements and sampling years (Fig. 2). Localizing pairwise comparisons revealed that the Nusa Hope CBMPA (effective MPA) had significantly greater parrotfish abundance than the Kida CBMPA (moderately effective MPA) ($p < 0.001$, $D = 0.87$), which in turn had significantly greater abundance than outside the Nusa

Table 2. Catch per unit effort from fisher recall diaries at Gizo for 2004 and 2005.*

	Gizo 2004		*Gizo 2005*		
Families	*kg*	*g·person^{-1}·h^{-1}*	*kg*	*g·person^{-1}·h^{-1}*	*Change*
Acanthuridae	87	791	61	555	−236
Balistidae	41	373	10	91	−282
Carangidae	33	300	34	309	9
Haemulidae	15	136	27	245	109
Holocentridae	24	218	28	255	36
Labridae	87	791	13	118	−673
Lethrinidae	17	155	18	164	9
Lutjanidae	52	468	13	118	−350
Mullidae	17	155	7	64	−91
Scarids (clade of Labridae)	184	1673	150	1364	−309
Serranidae	59	536	43	391	−145
Siganidae	20	182	15	136	−45
Others	41	373	51	464	91
Average per species	52	473	36	329	−144
Total	677	6150	470	5000	−150

**The 2004 data were based on 110 person hours, and 2005 data were based on 94 person hours.*

Hope CBMPA and outside the Kida CBMPA ($p < 0.0001$, $D = 1.30$). Gizo 2004 parrotfish abundance was essentially identical to abundance outside the Nusa Hope and Kida CBMPAs, and abundance for Gizo 2005 was significantly lower than for Gizo 2004 and villages with CBMPAs ($p < 0.0001$, $D = 1.07$). Abundance dropped by almost half between 2004 and 2005 in Gizo, a decline of roughly the same magnitude as the difference between outside and inside the Nusa Hope and Kida CBMPAs.

Total parrotfish abundance differed significantly across village years ($F_{5,170} = 32.0$, $p < 0.0001$). Localizing pairwise comparisons revealed that Nusa Hope outside sites were significantly ($p < 0.001$) lower than inside Nusa Hope CBMPA in scarid abundance in each size category (Fig. 3a). Similarly, Kida outside sites were significantly lower than inside Kida CBMPA (Fig. 3b), and Gizo 2005 was significantly lower than Gizo 2004 in each size category (Fig. 3c). Large effects (Cohen's $D = 0.80$ or greater) between inside and outside CBMPAs were evident in each size category. Combined, these findings reinforce the stark difference in abundance across fish-size categories between inside and outside the CBMPAs

Table 3. Creel survey of scarids at Gizo in 2004 and 2005.*

		Gizo 2004		*Gizo 2005*		
Scarid species	*Phase*	*kg*	*g·person^{-1}·h^{-1}*	*kg*	*g·person^{-1}·h^{-1}*	*Change*
B. muricatum		10	156	0	0	−156
C. bicolor	Initial	14	219	3	43	−176
C. bicolor	Terminal	13	203	6	86	−117
C. bleekeri	Initial	7	109	28	400	291
C. bleekeri	Terminal	13	203	21	300	97
C. microrhinos		17	266	6	86	−180
H. longiceps		44	688	37	529	−159
S. bicolor	Terminal	0	0	3	43	43
S. dimidiatus	Initial	2	31	1	14	−17
S. dimidiatus	Terminal	11	172	22	314	142
S. ghobban	Initial	28	438	11	157	−280
S. ghobban	Terminal	21	328	8	114	−214
S. globiceps		9	141	21	300	159
S. oviceps	Initial	7	109	7	100	−9
S. oviceps	Terminal	27	422	58	829	407
S. quoyi		8	125	12	171	46
S. rubroviolaceus	Initial	12	188	0	0	−188
S. rubroviolaceus	Terminal	18	281	16	229	−53
S. schlegeli		6	94	17	243	149
Assorted		28	438	27	386	−52
Average per species		14.75	230	15.2	217	−13
Total		295		304		+9

**The 2004 data were based on 64 person hours, and 2005 data were based on 70 person hours.*

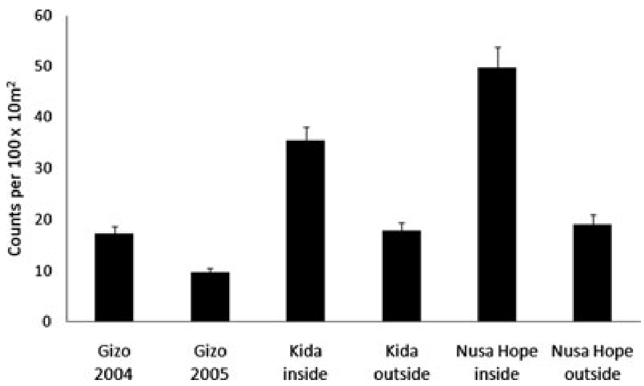

Figure 2. Total parrotfish abundance across all settlements, years of sampling, and management systems in Gizo, Kida, and Nusa Hope sites (error bars, SE).

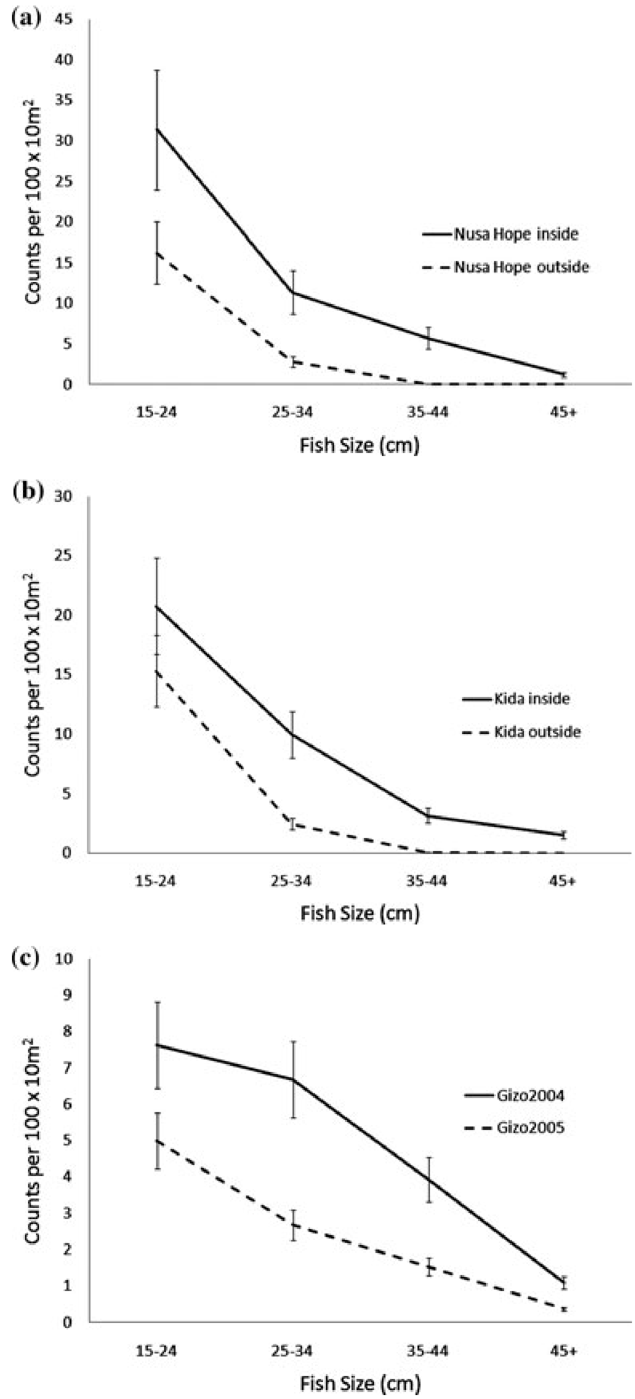

Figure 3. Parrotfish size and abundance per village by year in (a) Nusa Hope, (b) Kida, and (c) Gizo sites (bars, SE).

of villages with customary management and an urbanized center.

Discussion

These results suggest that the erosion of customary governance and associated management is fostering the rapid decline of already vulnerable fisheries around urbanized regions of the Western Solomon Islands. The recall diary, creel survey, and UVC results each independently document the stark decline in abundance of parrotfish in Gizo from 2004 to 2005. Abundance dropped to half in Gizo from 2004 to 2005, which is reflected in scarid counts for all surveyed species except *C. microrhinos,* which did not demonstrate a large, statistically significant drop. Generally, the decline was most evident in the medium and large size categories. In turn, data from areas open to fishing outside CBMPAs in Kida and Nusa Hope showed that average size and abundance were essentially identical to Gizo 2004, but that by 2005 Gizo yields were significantly lower than they were outside the Nusa Hope and Kida CBMPAs. Average size and abundance were higher inside CBMPAs than in adjacent open-to-fishing sites, with the effect being most evident in medium and larger size categories. These findings suggest that the decline in scarids in Gizo from 2004 to 2005 was approximately the same magnitude as the large, statistically significant differences seen between transects inside and outside the CBMPAs.

Changes in Gizo parrotfish abundance could have been caused by stochastic or seasonal environmental events. Our 2-year study, however, was a sufficient period over which to judge human-driven fishery changes in parrotfish abundance and size distribution. Prior research on grouper and parrotfish fishery dynamics in Gizo suggests that the fishery changes reported here are typical for a 2-year period and that there are no significant seasonal differences in density estimates that could confound our overall conclusions (Sabetian 2002; WWF, unpublished data). Sites away from Gizo, which have similar environments (or even less-desirable habitats for parrotfish), had greater abundance of parrotfish than Gizo.

One could argue that the greater densities outside the CBMPAs in Kinda and Nusa Hope resulted from the spillover effect of neighboring CBMPAs (see Fig. 1). Nevertheless, Gizo has a marine conservation area spanning 10 small MPAs, and outside MPAs the densities remain generally lower than those of Kinda and Nusa Hope. These differences are likely due to human predation and lack of usage and access controls for local reefs in Gizo (even within the MPAs, which are unknown to many inhabitants). Especially inside MPAs, parrotfish size and abundance were generally greater in Nusa Hope, which has the most effective customary management (e.g., sea-tenure governance) compared with Kinda, which has a moderately effective traditional system. Gizo, with a virtually nonexistent customary management organization, was similar to Nusa Hope and Kida open areas in 2004, but dropped to half by 2005. In Nusa Hope and Kinda, villagers control interlopers from poaching inside and outside their respective CBMPAs because they live adjacent to their marine territories and have governance strategies that restrict use and access to nonmember fisher folk.

The greater abundance of parrotfish inside the CBMPAs seems intuitive, given current scientific knowledge regarding the role and function of marine reserves. Scientists generally agree that fully protected no-take MPAs can theoretically enhance ecological processes and fisheries management (Roberts & Hawkins 2000). The MPAs we studied, however, are not conventional top–down, science-driven marine reserves; rather, they are CBMPAs designed around customary management principles and under customary custodianship. Both the Nusa Hope and Kinda CBMPAs have sections that are opened for harvesting temporarily during certain occasions (e.g., death of a chief) or times of the year (e.g., for bêche-de-mer to pay for school fees). The CBMPA management sites in our program were selected with the help from local authorities. They were selected on the basis of their social and ecological value through social- and natural-science research (see Aswani et al. 2007 for further discussion) in a fashion the local people could relate to and integrate into their own historical and cultural reality.

Our results suggest a gradient in parrotfish management and conservation success among sites according to their governance effectiveness, from Nusa Hope, which had the greatest parrotfish abundance, to Gizo, which had the least. The average size and abundance of reef fish is higher in traditionally managed areas than in national parks and most co-managed areas in sites across Indonesia and Papua New Guinea (McClanahan et al. 2006). Additionally, there is a negative correlation between effective conservation and human population size (beyond a threshold of more than 1000 people) and between market integration and wealth, which suggests that as rural communities urbanize and monetize in Melanesia, their capacity to conserve resources weakens (McClanahan et al. 2006). Brewer et al. (2009) found that in the Solomon Islands distance from markets is positively correlated with increased fish abundance across a number of reef fish families, particularly scarids. Similarly, Cinner et al. (2005) found that customary sea-tenure systems in Papua New Guinea weaken with proximity to provincial markets.

These observations correspond well with our results, which showed that the furthermost community, Nusa Hope, had the greatest overall parrotfish abundance and the strongest customary sea-tenure regime. Kida, which is somewhat closer to markets (Noro and Munda) and has a reasonably functional tenure system, had lower overall parrotfish abundance than Nusa Hope but substantially greater parrotfish abundance than Gizo. Finally, Gizo, which has a large artisanal fish market and a moribund sea-tenure situation, had the lowest overall parrotfish abundance. Changes in abundance and size distribution in the sampled community reserves are not restricted to scarids (S. Albert et al., unpublished data), particularly in sites where ethnic and religious homogeneity foster cooperation and decrease transaction costs (Aswani 2002).

Individually, observations from the UVC, recall diary, or creel survey data may not be fully representative of the entire Gizo area and should not be used individually to make generalizations. Nevertheless, when brought together the three data sets make a strong case for the conclusion that parrotfish populations have declined in a short period of time. Removing the bigger fish from a population is not uncommon. In the Caribbean, smaller bodied species dominate fish assemblages in heavily fished areas and as fishing intensifies on parrotfish, the abundance of larger species decline and smaller species constitute a greater proportion of the total assemblage (Hawkins & Roberts 2004). The ecological ramifications of the localized removal of important low-trophic level herbivorous fishes are serious and can lead to negative overall ecosystem changes (Dalzell et al. 1996; Sadovy 2005; Gillett & Moy 2006).

Conserving parrotfish is fundamental because they are of crucial functional importance as grazers and bioeroders in the reef ecosystem and because their abundance can be used as an indication of coral reef health (Mumby et al. 2006). Maintaining a healthy herbivorous fish population is of key importance for controlling filamentous algal growth that otherwise threatens to overtake the reef and contribute to the decline of coral and coralline algal recruitment (Hughes 1994). Increasing fishing pressure on herbivores, therefore, can have a cascading negative effect on the local ecosystem (Hawkins & Roberts 2004). As parrotfish abundance increases as a result of the MPA treatment, so does grazing activity, which reduces macroalgae and enhances coral reef growth (Mumby et al. 2007). In sum, the conservation of this functional group of fish is vital for sustaining the resilience of coral reefs and their associated ecosystem services.

The Nusa Hope and Kida data show that, once afforded protection, scarids respond well to the management treatment. Customary management, therefore, can provide an institutional context, which under certain socioeconomic and political conditions can result in good resource governance and stewardship (Aswani & Hamilton 2004; Cinner & Aswani 2007) and enhance socio-ecological resilience (Hughes et al. 2005). In Gizo most of the reefs targeted by artisanal fisher folk are adjacent to "alienated" land that was seized from its former traditional owners during the colonial era and has been converted to leasehold land presently held by the government. Therefore, it may be especially difficult to revitalize customary management initiatives in Gizo because population densities are relatively high and heterogeneous, traditional practices are not exercised, more effective fishing methods are being used (e.g., SCUBA), and financial incentives override any environmental concerns.

By examining concrete actions and concomitant management strategies within each local customary management institution closely, we find that even within small geographical areas these are shaped by, and are embedded in, particular cultural and historical contexts. Local customary management practices coalesce with foreign influences and localized socioeconomic transformations to generate varying forms of governance and management, including situations in which people are or are not able to solve collective action problems (Aswani 2002). In places such as Nusa Hope and Kida, empowering customary management regimes through the establishment of community-based organizations (CBOs) coupled with the government's judicial protection of customary sea tenure will be of critical importance for the successful hybrid management (e.g., Cinner & Aswani 2007). In contrast, this may not be as realistic for Gizo Town, and alternative strategies that combine approaches like gear-based fishery management (McClanahan & Cinner 2008) with other managerial approaches, such as government sanctioned spatiotemporal closures, may be more suitable to protect crucial functional groups such as parrotfish.

Overall, these customary adaptive management approaches to marine conservation, which encompass many of the principles of ecosystems-based management, can sustain and improve marine ecological resilience and allow for an enhanced response to stochastic environmental events associated with global climate change (Hughes et al. 2005; McClanahan et al. 2008). The settlement history of the region in tandem with different socioeconomic and demographic transformations determines the nature and outcomes of customary management regimes in the present. Multiple and comprehensive approaches, therefore, will be necessary to preserve environmentally critical coral reef ecosystems in the Solomon Islands and Melanesia at large.

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