CORAL REEF BIODIVERSITY IN THE LOMAIVITI GROUP, FIJI.

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EXECUTIVE SUMMARY

Rapid assessment surveys were conducted from 21-27 April 2001 in the Lomaiviti Group, located east of the main island of Fiji. This study provides scientific information on the biological diversity and community structure of coral reefs in this island group, and provides research, conservation and management recommendations. The study was conducted in conjunction with a tourist dive cruise aboard the MV Nai'a, thus sites were selected with high fish, soft coral and hard coral abundance and diversity, representing the more diverse and complex reef communities in the Lomaiviti Group.

Surveys were conducted on SCUBA at 18 sites located in Eastern Bligh Waters (Vatu-I-Ra Passage), Namena Barrier Reef and waters surrounding Wakaya and Gau Islands. One site was surveyed in the Mamanuca group. Assessments were undertaken of corals, invertebrates, turtles and sharks at the majority of sites and individual specimens of marine algae were collected by hand. An emphasis was placed on obtaining habitat descriptions, and assessing the state of the reefs following Fiji's first La Niña-related coral bleaching event in 2000. Fish data is presented from surveys undertaken between February to April 2001.

This study recorded a complex range of reef types including seamounts, barrier reefs, bommies, pinnacles, and more typical reefs types such as patch and channel-edge reefs. Vertical walls, steep slopes and deeper sites, were dominated by fan and tree-shaped soft corals, while shallower waters, and the tops of bommies and pinnacles were dominated by carpeting soft corals and hard corals. One hundred and twenty seven species of hard corals were identified, consistent with species numbers in other parts of Fiji, and made up of massive, submassive and branching growth forms. Coral mortality resulting from the 2000-bleaching event averaged 20%, with a high of 50%. Mortality in this island group appeared to be less than other parts of Fiji, where mortality rates of 60%, and as high as 100%, were recorded. A second bleaching event affect Fiji's reefs in 2001, and <10% bleaching was recorded during these surveys. However mortality was low to nonexistent, and the area was less affected than southern and eastern parts of Fiji. It may be that the Lomaiviti region was more resilient to the 2000 bleaching event due to the presence of deep channels and upwelling of cool water by the prevailing winds and currents from the southeast, while the epicenter of the 2001 bleaching event passed over the southern parts of Fiji.

The algae community was taxonomically typical of Fijian reefs with all 46 species previously recorded for Fiji. Mobile invertebrate populations were low reflecting the types of habitat available and possibly high rates of predation from healthy fish populations, while sedentary invertebrates such as sponges, ascidians, and bivalves were abundant. Fish populations were generally abundant and diverse, with abundant schooling planktivorous and pelagic fish, indicating low fishing pressure. The presence of a diversity and abundance of fish species is likely to have played an important role in the control of the proliferation of algae following the 2000 bleaching. Sharks and large groupers were generally rare, though significant grey reef shark (*Carcharhinus amblyrhynchos*) aggregations were observed at two sites. Only four hawksbill turtles (*Eretmochelys imbricata*) were observed during the surveys.

Ten of the 19 sites surveyed during this expedition were identified as being important for one or more of the taxonomic groups. Along with the great range of reef types recorded, this

indicates that the region as a whole has a complex assemblage of coral reefs and reef fauna, and that further rapid assessment surveys, as well as more systematic ecological and biodiversity surveys, are necessary to adequately sample the area. Sites surveyed and highlighted in this report may be regarded as illustrative of the potential diversity of the Lomaiviti group, as well as being representative of the types of reefs that should form the focus for management planning. However systematic planning will need more comprehensive surveys, concurrent with the establishment of the social, legal and institutional foundations for conservation and management.

The findings of this study support the importance of the reefs of the Lomaiviti group nationally, and the need to develop a conservation and management regime, involving customary resource owners, managers, national decisions makers, the tourism sector and other stakeholders, to ensure the long-term protection of the biodiversity in this region. Of particular significance in the national context, reefs displaying resilience to bleaching, such as those found in Lomaiviti Group, are likely to play an important role in providing refugia for corals and subsequent reseeding of adjacent reefs in Fiji more widely damaged by coral bleaching and global climate change.

ACKNOWLEDGMENTS

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INTRODUCTION

Fiji is made up of approximately 844 islands and islets (106 are inhabited), which contain only 18,500 km^2 of land, while its Exclusive Economic Zone covers an estimated ocean area of 1.29 million km^2 (SPREP, 1999). While the exact number of coral reefs is currently unknown, it is believed that there are at least one thousand different reefs in Fiji's waters, including the following major types: fringing, platform, patch, barrier, oceanic ribbon, atolls, near atolls and drowned reefs (UNEP/IUCN 1988; Zann, 1992). Fiji holds 3.52% (i.e. 10,020 km^2) of the world's coral reefs, placing it in the top 10 of the 80 countries and geographical locations with reefs (UNEP-WCMC 2001).

Most authors find it difficult to describe Fiji's coral reefs because of the scattered and very limited scientific data available. However, a number of scientists have recognised Fiji's coral reefs as being of high ecological significance from a biodiversity standpoint (Zann 1992; Zann *et al*. 1997, Vuki et al. 2000). Fiji's marine biota includes almost 198 species of scleractinian corals, 15 zoanthids, 123 species of gastropods from 12 families, 253 species of nudibranch gastropods, 102 species of bivalves from 25 families, 60 species of ascidians, 1,900 species of fish from 162 families, 5 species of sea turtles and 3 species of seasnakes (Vuki et al. 2000). Coral reef studies in Fiji over the last two decades have focused on water and sediment quality and biological monitoring (Morrison and Naqasima 1992; 1999) lagoonal fish and community fisheries (Emery and Winterbottom 1983), heavy metal levels (Morrison *et al*. 1997), inventories of algae (South 1991) and molluscs (Koven 1997), and fishing strategies and resource use (Vuki 1991; Jennings and Polunin 1996a; 1996b).

Most scientific studies have been conducted on the Suva reef and the Great Astrolabe Reef, with other parts of the island system being virtually unstudied (Vuki et al. 2000). The Lomaiviti group has received little attention, though coral reef surveys have have started recently with assistance from the MV Nai'a (Sykes, 2001; unpublished data), focussing on benthic monitoring for coral bleaching and general reef state and fish populations. Coincident with this study, two other surveys of coral reefs have been undertaken, one by WWF in Kadavu (Obura and Mangubhai 2002) and another by Coral Cay Conservation in the Mamanucas (Harborne et al. 2001).

While Fiji's reefs have historically been reported to be in excellent condition (Morrison and Naqasima 1992, Vuki et al. 2000), they were significantly affected by coral bleaching associated with the El Niño Southern Oscillation (ENSO) of 2000. This was associated with a warm pool of surface waters moving north into Fijian waters, affecting the south and western parts of the islands (Cumming et al. 2001). Bleaching and mortality levels of 60-100% were reported for the worst hit parts of the country, but low impacts were reported for northern and eastern reefs.

The Fiji government drafted a National Biodiversity Strategy Action Plan (NBSAP) in 1999 to meet Fiji's obligations under the Convention on Biological Diversity, and demonstrate its commitment to preserving the country's biodiversity (Fiji Government 1999). The draft NBSAP specifically provides for the protection of marine biodiversity and has listed a number of sites that are considered of 'national significance'. It is recognised that sites listed in the NBSAP may in part reflect areas where reefs are more known and scientists have undertaken research in the past, rather than areas of high biodiversity from a national perspective that require protection and management. Only one of the sites listed in the NBSAP is located in the Lomaiviti Group, namely Namenalala Island, located in the Namena

Barrier Reef system. The island and the patch reefs around it are a popular destination for live-aboard dive boats, but there is no component of marine ecosystem management in place.

The relevance of sites nominated for Marine Protected Area (MPA) status needs to be re-examined nationally, especially in the aftermath of mass coral bleaching event in the year 2000 (Cumming *et al*. 2001). Coral bleaching has become the primary threat to coral reefs around the globe (Wilkinson 2000; Goreau *et al*. 2000), and demands reassessment of coral reef protected area networks to expand reef representation and a buffer for local and global threats (Salm *et al*. 2001). In Fiji in 2000, the bleaching occurred during the months February to June, when seawater temperatures remained above the 28.3ºC expected maximum, which resulted in bleaching of corals on reefs around Viti Levu and south of Vanua Levu. The state of Fiji's reefs following this bleaching is still not fully described, with reports from 3 sites detailing the impact of bleaching in the Lomaiviti Group (Cumming *et al*. 2001).

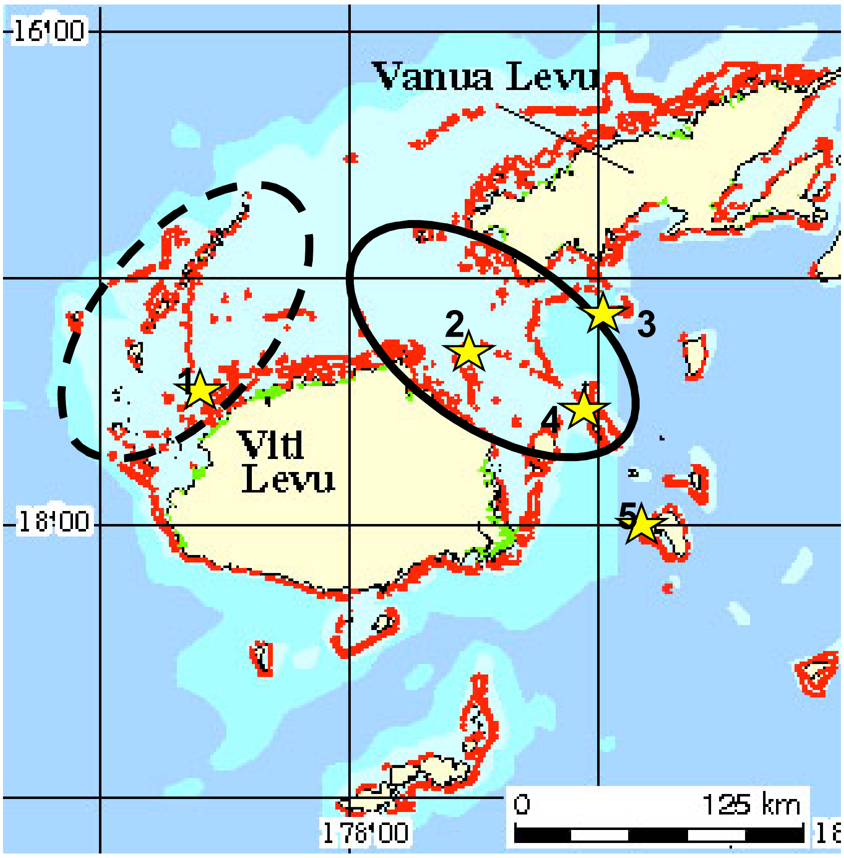

Figure 1. Map of Fiji showing the Lomaiviti (solid line) and Mamanuca (broken line) Island Groups, and the general locations of study sites (stars): 1-Samu Reef; 2-Eastern Bligh Waters/Vatu-I-Ra Passage; 3-Namena Barrier Reef; 4-Wakaya Island; 5-Gau Island. See Table 1 for individual site names.

The Lomaiviti Group is situated roughly east of Viti Levu (the main island of Fiji) and south of Vanua Levu, bordering the deep Bligh Waters or Vatu-I-Ra Channel that divides the two large islands, and comprising a number of island and barrier reef systems, and isolated seamounts (Figure 1). It comprises one of 17 reef provinces identified in Fiji (Zann, 1992, Vuki et al. 2000), characterized by being "moderately windward mid- and outer-shelf reefs". The main islands in this group include Ovalau, Koro, Moturiki, Makogai, Batiki, Naria, Nairai, Gau and a number of smaller islands such as Toberua and Wakaya, situated in or near the Koro Sea. All islands in this group are of volcanic formation, and for the most part are heads of cones that have undergone erosion, or are accumulation built up from the sea floor (Derrick 1965). Wakaya Island has a steep western coast with a fringing reef, while its eastern shore has a wide lagoon and a barrier reef 13 miles long, located nearly 4-6 miles offshore. Wakaya is currently privately owned and was one of the first islands to be sold to Europeans. Gau, the largest and southernmost island of the Lomaiviti Group has a fringing reef, which is narrow in the south and wider (over 1 mile) in the north.

The geographical location, size and overall logistics make access to this island group difficult and costly from a research perspective, requiring an innovative approach partnering conservation science and dive tourism to open up access to remote locations. Accordingly, the World Wide Fund for Nature's South Pacific Programme (WWF), in collaboration with NAI'A Cruises Fiji, undertook a 7-day scientific expedition to collect biological information on the biodiversity and status of coral reefs in Fiji's Lomaiviti Group, providing a unique opportunity to visit inaccessible locations (Figure 1). Sites were chosen on the basis on use by recreational divers, by a commercial live-aboard dive operator rather than known biological/ecological attributes. Given the lack of biological information on reefs in general in the Lomaiviti Group, this should not pose a problem for preliminary work such as this study.

To fill in the gaps in knowledge about the reefs of the Lomaiviti Group, the study was specifically designed to obtain conduct a rapid assessment of the diversity and health of reef habitats and reef life, and allow comparisons with more studied reefs such as the Great and North Astrolabe Reefs in the Kadavu Province, for which recent baseline data was also collected. The objectives of the study were to:

1. conduct a rapid assessment of the diversity and status of reefs in the Lomaiviti Group,
2. assess the impacts of the year 2000 bleaching event, and
3. make recommendations on the conservation and management of a range of reefs systems in the Lomaiviti Group.

METHODS

Marine biological surveys of coral reefs in the Lomaiviti Group were conducted from the 21-27 April 2001. All sites were accessed using inflatable dinghies from the 120-foot vessel M/V NAI'A. All surveys were undertaken on SCUBA using rapid assessment techniques to obtain a description of the structure and diversity of the reefs, and to cover as wide an area as possible at each site. Sampling was done following a safe diving profile of rapid descent to the deepest sampling point (about 30m), then a slow meandering ascent with most time spent in shallow waters < 10m depth (where allowed by reef topography), and data aggregated over the entire dive. Additionally, sampling had to be conducted in a manner that fit in with tourist dives, preventing fully controlled data collection from different reef habitats and depth ranges.

Site selection was based on the needs of tourist divers on board the M/V NAI'A, and comprised sites with spectacular tophography and abundance fish and benthic life. As such, these will represent the higher range of coral reef diversity and complexity in the island group. The names and geographical coordinates of the 18 sites surveyed are shown in Table

1. Repetitive dives at FanTSea, North Save-a-Tack and Lion's Den meant these areas were surveyed twice. It should be noted that Samu Reef, situated offshore from Lautoka, is the only site sampled in the Mamanuca Group. However, for ease of reporting, it will be included in references to the Lomaiviti Group.

Table 1. Sites surveyed in the Lomaiviti Group, Fiji. FanTSea, North Save-a-Tack and Lion's Den were each sampled twice. Coordinates are of the boat anchorage adjacent to each site.

Date	Region	Site Name	Latitude	Longitude
21/4/01	Mamanuca Group	Samu Reef	17º34'15 S	177º18'04 E
22/4/01	Mutiny Seamount	Yellow Wall	17º20'42 S	178º31'38 E
22/4/01	Mutiny Seamount	North Face	17º20'42 S	178º31'38 E
22/4/01	E6 Seamount	Cathedral	17º19'37 S	178º35'34 E
23/4/01	Eastern Bligh Water	Cat's Meow	17º08'07 S	178º31'05 E
23/4/01	Eastern Bligh Water	Humann Nature	17º08'07 S	178º31'05 E
23/4/01	Eastern Bligh Water	Undeniable	17º10'12 S	178º13'45 E
23/4/01	Eastern Bligh Water	Blueberry Hill	17º10'12 S	178º13'45 E
24/4/01	Namena Barrier Reef	FanTSea (1)	17º03'09 S	178º59'28 E
24/4/01	Namena Barrier Reef	FanTSea (2)	17º03'09 S	178º59'28 E
24/4/01	Namena Barrier Reef	North Save-a-Tack (1)	17º04'19 S	179º06'23 E
24/4/01	Namena Barrier Reef	Kansas	17º04'19 S	179º06'23 E
25/4/01	Namena Barrier Reef	Teton	17º07'33 S	179º04'25 E
25/4/01	Namena Barrier Reef	2 Thumbs Up	17º07'33 S	179º04'25 E
25/4/01	Namena Barrier Reef	North Save-a-Tack (2)	17º04'19 S	179º06'23 E
26/4/01	Wakaya Island	Lion's Den (1)	17º34'57 S	178º58'47 E
26/4/01	Wakaya Island	Blue Corner	17º34'57 S	178º58'47 E
26/4/01	Wakaya Island	Lion's Den (2)	17º34'57 S	178º58'47 E
27/4/01	Gau Island	Anthias Avenue	17º58'20 S	179º13'07 E
27/4/01	Gau Island	Jim's Alley	17º58'20 S	179º13'07 E
27/4/01	Gau Island	Nigali Passage	18º04'58 S	179º16'01 E

Data was collected in the following areas:

1) Reef structure
2) Benthic community structure, using three techniques:
   a) benthic cover proportions, using video transects
   b) algae collection, cumulative for the trip
   c) visual assessment of hard and soft coral diversity and abundance, and coral condition
3) Benthic invertebrate diversity and abundance, by counts of selected groups; and
4) Fish species presence/absence, transect and search data provided by Helen Sykes (Sykes 2001, unpublished data).
5) Sightings of sharks and turtles were recorded for all dives.

Reef structure
Reef profiles were drawn from the deepest to the shallowest points of each dive, noting details of depth, slope and substrate composition (rock, rubble and sand).

Benthic community structure

Benthic cover proportions
Quantitative data on benthic cover was obtained at a subset of the sampling sites, using underwater digital video. Video records of the benthic habitat were taken using a fixed camera-to-subject distance of about 0.5m and holding the camera perpendicular to the

substrate. Video sequences of 5-10 minutes were recorded at each site, covering the major habitats from deep to shallow sections of a dive. Due to limited time available, depth zones were not kept separate for data analysis. During playback, the video tape of benthic cover was stopped at 2-3 second intervals, and 5 fixed points on the screen were sampled for cover. Twenty frames (or 100 points) were compiled into a single 'transect' for calculation of percentage cover. As far as possible, 3-5 transects were recorded for each site, though a few sites had less due to the low video-time recorded. The cover categories used for video analysis were similar to those for the habitat descriptions, with additional detail for hard corals, soft corals and invertebrates (Table 2).

Table 2. Benthic categories recorded for video transects and benthic descriptions during surveys undertaken in the Lomaiviti Group.

Substrate	Hard corals	Soft corals	Algae	Invertebrates/Other
Rubble	*Acropora*	Carpeting	Turf (rock)	Corallimorphs,
Rubble/Sand	Branching	Fans	Fleshy	Zooanthids,
Sand	Encrusting	Tree-shaped fans	Coralline	Anemones,
	Plate	Black coral	*Halimeda*	Hydroids
	Mushroom	Whispy-shaped		Bacterial Mat
	Massive	Nephthiid		Sponge
	Submassive	Whips		Oysters
	Bleached			
	Dead			Unknown

Algae collection
Benthic macroalgae were collected by hand using SCUBA, and presented as a species list for the whole trip. The date, site, habitat, substrate, depth and whether the species was common or rare, were recorded for each specimen collected. Collections were logged at the end of each day, and placed in 4% formaldehyde in seawater for 24 hours. Excess formaldehyde solution was decanted the next day, and the specimens stored in sealed containers. Specimens were delivered to the University of the South Pacific's Marine Studies Programme in Suva, Fiji for identification. Details of laboratory methods are provided in Appendix 2, with species identification done with the aid of dissecting and, where necessary, compound microscopes to confirm anatomical details. Specimens are housed at the Phycological Herbarium, South Pacific Regional Herbarium in Suva, Fiji and will be accessioned in the Marine Studies Programme 'Collections' database.

Visual assessment
Visual assessment of the benthos in general, and the hard and soft coral communities in particular was conducted at each site by estimation of cover in an approximately 5m^2 area in front of the observer. Estimation was done by a single observer, selecting areas representative of the depth zone and site, according to the site profile. The number of replicates for any one zone varied depending on time in the zone and habitat variability. The same categories were used as in the video transect analysis (Table 2). The dominant hard and soft coral genera were listed for each sample. A cumulative checklist of coral species was built up over the course of the trip, using *in situ* identifications of most corals, backed up by collection of small voucher specimens for confirmation on the boat. Identifications were confirmed using field guides, principally Veron (2000).

Coral condition was estimated as percentage of the benthos, using categories of pale (tissue paler than normal, but not white), bleached (tissue a bright white colour), newly dead (skeletal details are clearly visible), and old dead (skeletal details are eroded or covered by algal growth). While pre-bleaching data is not available for a definite assessment of the impact of the 2000 bleaching event, the presence of many colonies with a consistent algal community at the same stage of succession can be used as an indicator of a large recent mortality event. This can be used to hindcast mortality up to 12-18 months, but is limited to places where only one mortality event is known to have occurred. These conditions appear to hold for this part of Fiji due to the 2000 bleaching event, so the "old dead" category is interpreted to represent mortality in 2000 (see Discussion).

Other common threats to corals were included in the visual assessments, including presence of the corallivores *Drupella* (a gastropod snail), crown-of-thorns starfish (*Acanthaster planci*), and coral diseases. Observations on coral bleaching, additional to the visual assessment plots, were recorded on an individual colony basis, to document species-specific bleaching patterns among coral species. Coral colonies showing some level of bleaching were identified to species level, and the percentage of tissue that was normal, pale, bleached or dead estimated. The frequency of particular species and bleaching combinaitions were recorded in broad categories of 'few' and 'common'. This method excludes colonies that are 100% normal, thus it documents the characteristic bleaching response of a species once they become affected, but not the proportion of colonies that are affected versus those that are normal.

Benthic Invertebrates
Important benthic invertebrate resource species were counted during each dive. The identity (to genus or where possible to species level), number and sizes of individuals were recorded for the following invertebrate groups: sea cucumbers, lobsters, molluscs (giant clams, oysters, *Trochus* spp.), and crown-of-thorns starfish (*Acanthaster planci*). Size was measured using a tape measure. These groups were chosen because of their importance as commercial or subsistence resources in Fiji, or in the case of the crown-of-thorns starfish, the potential impact of elevated populations on reefs.

Fish Presence/Absence
Fish populations were not sampled during this expedition, due to the lack of experienced personnel. However, data on fish species presence/absence was generously provided by Ms. Helen Sykes of NAI'A Cruises, derived from transect surveys (replicated 5*50 m belt transects) and general searches conducted in the Lomaiviti Group during dives with diving clients, in February – April 2001.

RESULTS

Reef Structure
Reefs in the Lomaiviti Group had very high three-dimensional structure, composed of complexes of bommies, pillars and patch reefs associated with vertical walls dropping off into deep water >40m and in some locations to >1000m in the deep passes in the area. Four major reef types were observed (Figure 2). A fifth group was identified as a mixture of the four standard reef types. Though these groups were distinguishable, common features were recorded amongst them, such as the presence of tall pinnacles on barrier reefs and as isolated pinnacles (see detailed site descriptions, Appendix 1).

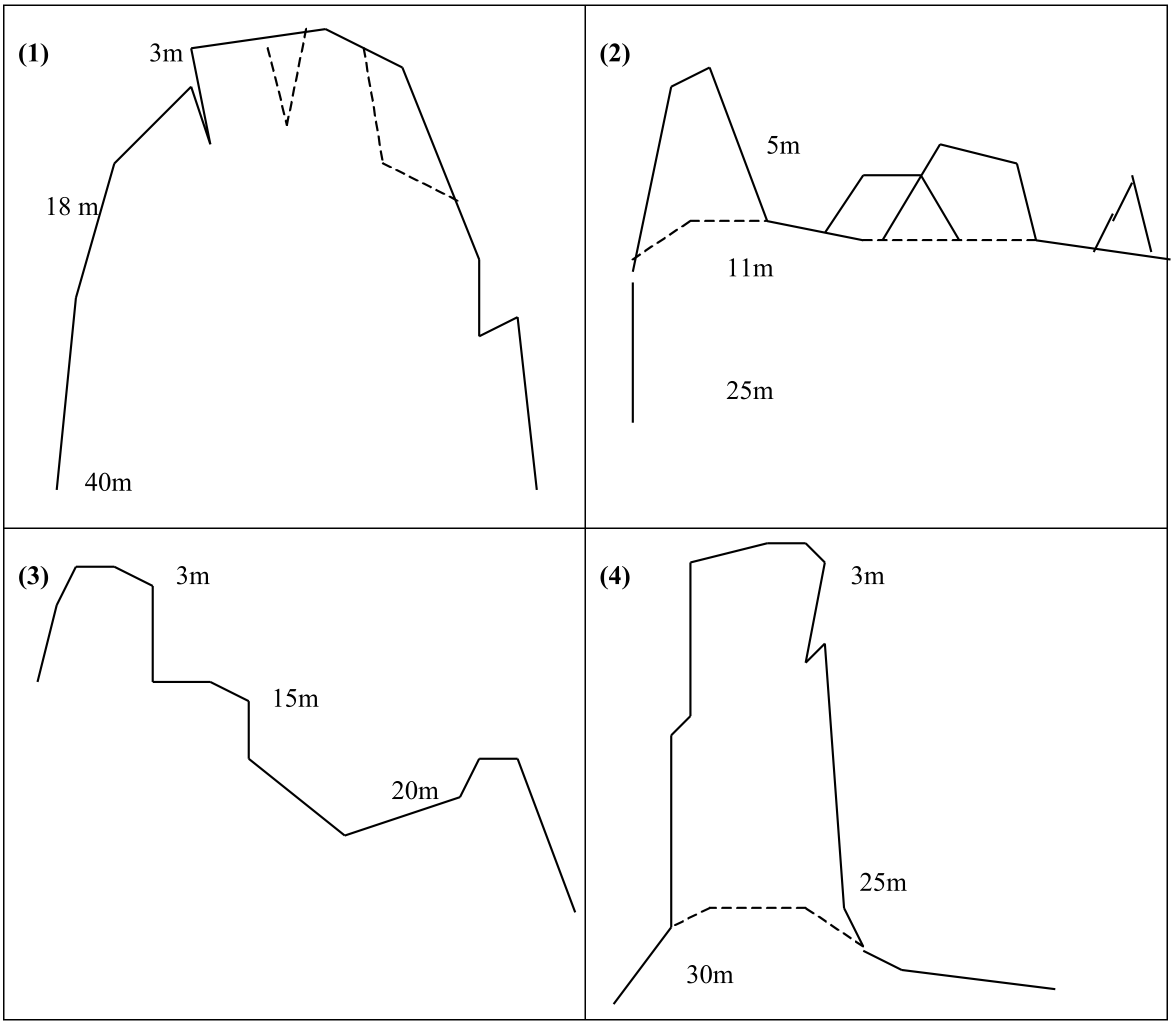

Figure 2. Profiles of the primary reef tyupes surveyed in the Lomaiviti Group: (1) Seamount (2) Barrier reefs (3) Bommies (4) Pinnacles. See Appendix 1 for detailed structure of individual survey sites.

1) ***Seamounts*** (Figure 2.1) – undersea mountains rising from the bottom of the Bligh Waters Channel in >1000m of water, with near-vertical walls, changing into horizontal and highly complex topography of surge channels, coral heads and rubble deposits at the tops of the seamounts at <7m depth. Sites: Mutiny Seamount (Yellow Wall, North Face), E6 Seamount (Cathedral).
2) ***Barrier Reefs*** (Figure 2.2) – extensive vertical walls rising from deep water 100s of metres deep, usually to about 10m, with isolated pinnacles and coral bommies perched on the edges of the walls. Behind the lips of the walls, extensive shallow patch reef areas and lagoon systems. Sites: FanTSea, North Save-a-Tack, Lion's Den.
3) ***Bommies*** (Figure 2.3) – large rocky, uneven structures of variable shape and dimensions with vertical and sloping sides leading down into deeper water >30 m. Sites: Cat's Meow, Humann Nature, Undeniable, Blueberry Hill.
4) ***Pinnacles*** (Figure 2.4) – tall vertical pillars up to 30m in height, mostly on monotonous sandy and hard substrate platforms, and some on the edge of deep walls. A gradation between pinnacles and bommies occurs at some sites where the difference between the two becomes unclear, though bommies tend to have more complex and uneven structures

where pinnacles are distinctly simple and vertical. Sites: Teton, 2 Thumbs Up, Anthias Avenue, Jim's Alley.

5) ***Other*** – patch reefs and reef channels without the extensive development of walls, bommies and pinnacles in groups 1-4 above. Sites: Samu, Blue Corner, Nigali Passage.

Benthic Community Structure

Benthic cover

Video transects were recorded at all sites with the exception of Yellow Wall, Blueberry Hill, North Save-A-Tack, Kansas, 2 Thumbs Up and Blue Corner. Overall cover is shown in Fig. 3, with site-specific results in Table 3. Coralline algae was the most common cover category, averaging 50% over all sites, followed by turf algae, hard coral and fleshy algae at 10-15%.

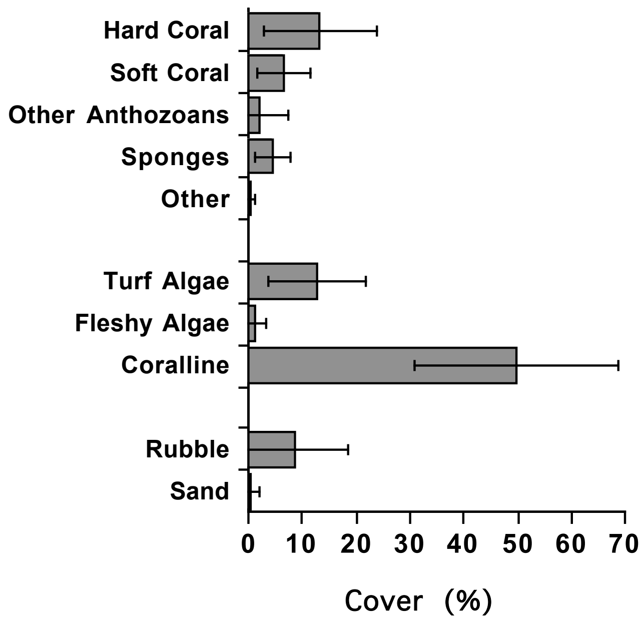

Figure 3. Overall percent cover of benthic categories, all sites combined.

The principal patterns of the benthic cover groups are as follows:

- ***Hard coral cover*** – Highest cover was at Cat's Meow (33.5%), Cathedral (24.9%), Undeniable (24.5%), Mutiny North Face (18.8%), and Samu Reef (17.1%). Very low cover at Lion's Den and Jim's Alley which both recorded 1.5% cover. Hard corals were most abundant on the medium-depth slopes of the bommies and seamounts in the Eastern Bligh Waters. Though not sampled here, Blueberry Hill also had high coral cover. Within these sitese, all shallow zones, such as the tops of pinnacles and bommies, and shallow reef slopes, showed evidence of high mortality from the bleaching event, with many coral skeletons still in growth position or already broken as rubble, covered with brown filamentous and turf algae, and coralline algae. This was particularly evident at Humann Nature, and on the pinnacles and reefs of Wakaya and Gau Islands.

Table 3. Percentage benthic cover for (A) principal invertebrates groups and (B) algae and substrate categories (mean and standard deviation) recorded in the Lomaiviti Group, Fiji. Site order follows Table 2. n = number of transects, m = mean, sd = standard deviation. 'Other Anthozoans' includes non-scleractinian and octocorallian anthozoa, such as zoanthids, corallimorpharians, anemones and hydroids. 'Rubble' category includes mixed rubble and sand substrate. Sites not sampled by video transects incude: Yellow Wall, Blueberry Hill, North Save-A-Tack, Kansas, 2 Thumbs Up and Blue Corner.

(A)			Hard Coral		Soft Coral		Other Anthozoans		Sponges		Other Invertebrates	
Site		n	m	sd	m	sd	m	Sd	m	sd	m	sd
Samu Reef	1	2	17.1	4.1	2.1	1.2	-	-	-	-	0.8	0.3
Mutiny North Face	2	5	18.8	17.7	8.3	6.9	0.4	0.8	10.6	6.2	1.6	1.9
Cathedral	3	5	24.9	8.1	5.4	8.4	3.6	2.3	5.2	4.3	1.6	0.6
Cat's Meow	4	6	33.5	15.3	5.8	9.1	18.1	14.8	1.8	2.6	0.2	0.4
Humann Nature	5	4	8.3	4.7	7.9	4.3	0.3	0.5	9.8	4.7	0.3	0.5
Undeniable	6	6	24.5	7.4	5.7	5.5	0.7	1.0	2.3	2.1	1.2	1.6
FanTSea	7	4	2.6	3.0	7.8	4.3	-	-	3.8	2.9	-	-
Teton	8	1	8.0	-	19.0	-	-	-	4.0	-	-	-
Lion's Den	9	2	1.5	2.1	2.5	3.5	-	-	1.0	-	-	-
Anthias Avenue	10	5	5.6	3.6	1.2	1.6	0.6	0.9	5.2	2.8	-	-
Jim's Alley	11	2	1.5	0.7	10.5	10.6	-	-	3.5	3.5	-	-
Nigali Passage	12	4	13.7	9.1	1.7	1.5	0.7	1.0	7.6	5.2	0.2	0.4

B)			Turf Algae/ Rock		Fleshy Algae		Coralline Algae		Rubble		Sand	
Site		n	m	sd	m	sd	m	sd	m	sd	m	sd
Samu Reef	1	2	30.0	4.2	0.8	0.3	24.0	4.3	20.3	0.5	4.8	3.1
Mutiny North Face	2	5	9.1	7.5	0.0	0.0	51.3	8.5	0.0	0.0	0.0	0.0
Cathedral	3	5	16.4	5.4	0.4	0.5	40.5	6.8	2.2	2.0	0.0	0.0
Cat's Meow	4	6	0.5	0.5	2.3	3.6	21.4	8.1	16.3	12.5	0.0	0.0
Humann Nature	5	4	29.5	9.1	0.0	0.0	44.1	10.7	0.0	0.0	0.0	0.0
Undeniable	6	6	10.3	9.6	0.5	0.8	32.3	14.7	22.4	21.3	0.0	0.0
FanTSea	7	4	5.2	4.2	0.0	0.0	80.6	8.7	0.0	0.0	0.0	0.0
Teton	8	1	13.0	-	0.0	-	56.0	-	0.0	-	0.0	-
Lion's Den	9	2	10.5	4.9	0.0	0.0	62.5	13.4	21.0	1.4	1.0	1.4
Anthias Avenue	10	5	7.0	4.4	1.0	1.7	74.4	8.3	4.2	6.0	0.8	1.1
Jim's Alley	11	2	9.5	4.9	7.0	9.9	65.5	4.9	2.5	3.5	0.0	0.0
Nigali Passage	12	4	12.1	6.9	1.3	2.5	45.2	3.3	16.7	13.8	0.6	0.8

- ***Soft coral cover*** - High at Teton (19%) and Jim's Alley (10.5%), and low at Anthias Avenue (1.2%) and Nigali Passage (1.7%). Using the video transect method, soft coral cover was highest where the carpeting soft corals *Sinularia* and *Sarcophyton* were dominant, generally in shallow waters (<10m). Soft corals with fan and tree-like morphologies were abundant on all vertical slopes and deep reefs (>15m), however they are not adequately sampled using video transects, which tend to record the narrow base stem and exclude the spreading upper branches. The abundance and visual dominance of soft corals, especially of the tree-like forms (eg. *Nephtia* spp., *Dendronephthya* spp., *Subergorgia* spp., *Siphonogorgia* spp. and black corals), on these reefs is therefore not fully reflected in the data presented here (Table 3).

- ***Other anthozoans*** - Very high cover at Cat's Meow only (18.1%), where a brightly coloured *Zoanthus* sp. covers the rubble and rocky substrate at 15-20m. In general 'other anthozoans' were common at all sites, though mainly cryptic, thus not showing up on the video transects.

- ***Sponges*** - High at Mutiny North Face (10.6%), Humann Nature (9.8%) and Nigali Passage (7.6%). Sponges were abundant at all the sites, though like the tree-like soft corals, not well sampled by the video method. They are primarily cryptic and low-lying, thus difficult to see when not *in situ*, and often mixed with algal turfs and fronds. A distinctive yellow ball-sponge was abundant on all vertical walls, particularly at Mount Mutiny's North Face.

- ***Other invertebrates*** – no strong patterns were observed of other invertebrates in the video transects, the primary ones recorded being oysters and clams, which are discussed in a later section.

- ***Turf algae/rock*** - High at Samu Reef (30%), Humann Nature (29.5%) and Cathedral (16.4%). Turf algae were abundant at a number of reefs where coral mortality in 2000 was particularly evident, and thus likely to be at higher-than-normal levels.

- ***Fleshy algae*** - Generally very low, with the highest of 7% at Jim's Alley. Fleshy algae were very minor components of all reefs surveyed. One species, *Tydemania expeditionis* (a finger-like green algae, Appendix 2), was particularly noticeable at a majority of sites and especially at Cat's Meow, where it was visually abundant in spite of a low cover percentage.

- ***Coralline algae*** –high values for coralline algae were recorded, ranging between 21% and 81%. Highest values were observed at sites with low live coral cover that had suffered high mortality (Anthias Avenue, FanTSea, Jim's Alley, Lions Den, Nigali Passgae, Teton), and along the vertical faces of pillars and walls at depth (Mutiny North Face).

- ***Rubble***. High at Undeniable (22.4%), Lion's Den (21%), Samu Reef (20.3%), Nigali Passage (16.7%) and Cat's Meow (16.3%). Coral rubble was abundant at many of the sites, and particularly on horizontal ledges and platforms below vertical walls and pinnacles with abundant hard coral growth (live or newly dead).

Algae

The algal community of the sites surveyed was overwhelmingly dominated by coralline algae (from 20-80%, Table 3B), followed by turf (0-30%) and lastly fleshy algae (0-7%). Representatives of the four main algal groups were collected - Cyanophyta, Rhodophyta, Phaeophyta and Chlorophyta, numbering 45 species (Table 4). All species had previously been recorded for Fiji. Further details of the collections are provided in Appendix 2.

Table 4. Algae species list collected in the Lomaiviti Group, Fiji. See Appendix 2.

Cyanophyta (Blue-green)	**Phaeophyta**
Lyngbya confervoides C. Agardh	*Dictyopteris repens* (Okamura) Børgesen
Lyngbya majuscula (Dillwyn) Harvey	*Dictyota bartayresiana* Lamouroux
Lyngbya semiplena (C. Agardh) J. Agardh	*Dictyota crispata* Lamouroux
Lyngbya sp.	*Dictyota friabilis* Setchell
Schizothrix sp.	*Dictyota* sp.
Symploca hydnoides (Harvey) Kützing	*Lobophora variegata* (Lamouroux) Womersley ex Oliveira
Unidentified Cyanophytes	*Padina australis* Hauck
Rhodophyta	*Sphacelaria novae-hollandiae* Sonder
Actinotrichia fragilis (Forsskål) Børgesen	**Chlorophyta**
Amphiroa foliacea Lamouroux	*Caulerpa microphysa* (Weber van Bosse) J. Feldmann
Antithamnionella sp.	*Caulerpa nummularia* Harvey ex J. Agardh
Ceramium macilentum J. Agardh	*Caulerpa webbiana* Montagne var disticha Vickers
Champia compressa Harvey	*Chlorodesmis fastigiata* (C. Agardh) Ducker
Chondria sp.	*Cladophora ryukyuensis* Sakai & Yoshida
Dasya sp.	*Dictyosphaeria versluysii* Weber van Bosse
Galaxaura sp.	*Halimeda macrophysa* Askenasy
Griffithsia sp.	*Halimeda opuntia* (Linnaeus) Lamouroux
Hypoglossum caloglossoides Wynne & Kraft	*Halimeda* sp.
Hypoglossum sp.	*Rhipidosiphon javensis* Montagne
Lomentaria sp.	*Rhipilia orientalis* A. Gepp & E. Gepp
Mesophyllum erubescens	*Rhipilia* sp.
Peyssonnelia bornetii	*Tydemania expeditionis* Weber van Bosse
Pleonosporium caribaeum (Børgesen) R. Norris	*Udotea orientalis* A. Gepp & E. Gepp
Polysiphonia sp.	

Hard and Soft Corals

Branching, massive and submassive corals dominate most sites, particularly those with low coral cover (Figure 4, towards the top of the figure). Sites with more abundant and complex coral communities (towards the bottom of the figure) show high proportion of *Acropora*, and plate corals. Dead coral was particularly evident at Cat's Meow on the top of the bommie. While corals showing crown-of-thorns scars were evident at some of the sites, these were not sampled by the video transects.

A checklist of 127 coral species is given in Appendix 3, derived from in-water identifications and cross-checking with an established coral species list and current texts (Veron 1986, 2000). Eighty-nine species were identified reliably, while 38 species identifications remained uncertain due to a number of reasons that included natural variation and range extensions of species not previously reported for Fiji (see Veron 2000). The total number of species is comparable to that recorded for Kadavu on similar surveys the following week (126, Obura and Mangubhai 2002), and less than the total number reported for Fiji (198, Zann 1992.).

Dominant coral genera recorded during habitat surveys included *Acropora*, *Diploastrea*, a variety of faviids (*Favia*, *Montastrea*, *Platygyra*, *Leptoria*, etc.), fungiids (*Fungia*, *Halomitra*), *Millepora*, *Montipora, Pocillopora*, *Porites* (both massive and branching species), *Tubastrea* and *Turbinaria*. Coral diversity was highest at mid-depths from 10-20 metres (Table 5). Lower diversity at shallow depths may be due to mortality from the La Niña bleaching in 2000. *Acropora* and *Pocillopora* were dominant in shallow water (< 10m), with *Pocillopora* common at 10-20m, and *Acropora* reappearing as common genus at > 20m. The mixed and *Porites*-dominated communities were most frequently found in middle

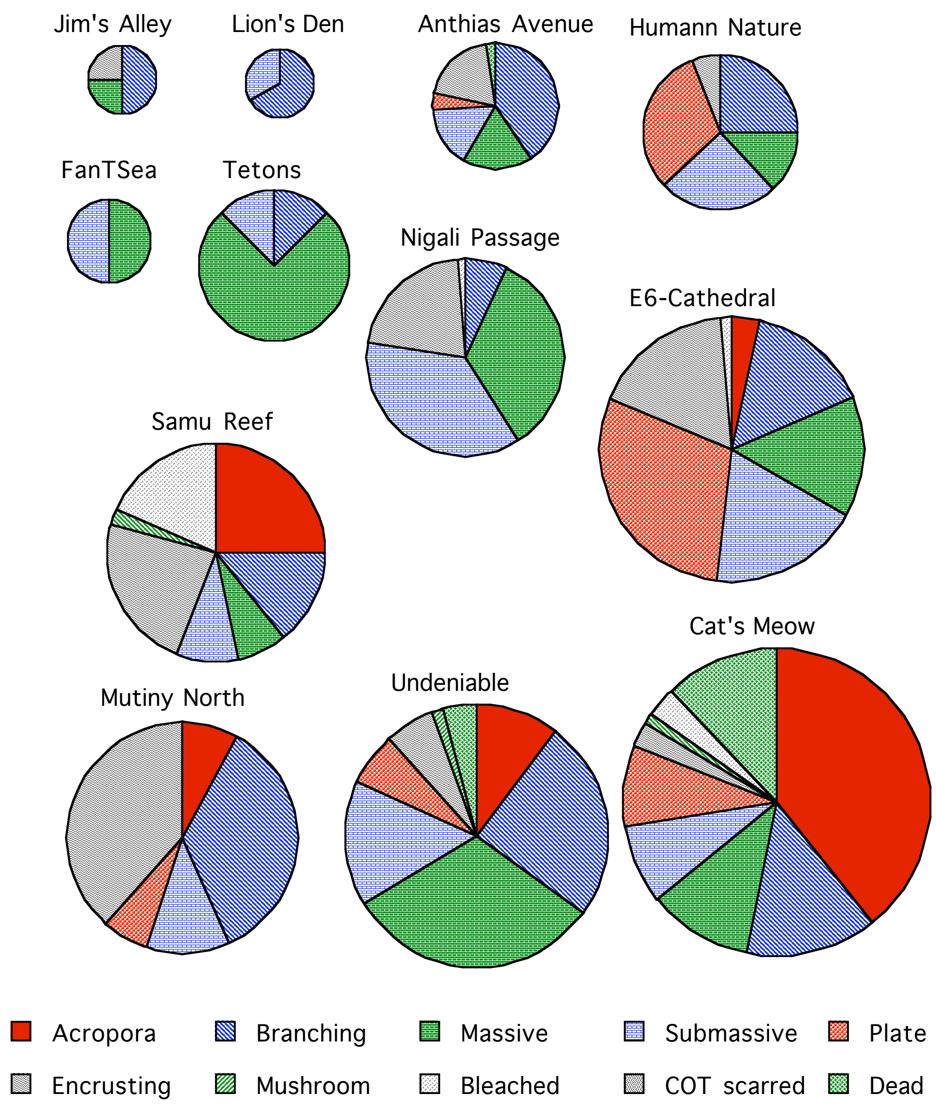

Figure 4. Composition of hard corals by growth form at sites surveyed in the Lomaiviti Group, Fiji. The area of the pie charts is proportional to the hard coral cover (see Table 3). COT=crown-of-thorns starfish

Table 5. Distribution of major hard coral genera by depth, from visual assessments. Genera are ordered by decreasing abundance from top to bottom. 'Mixed' coral communities made up of a variety of families (e.g. siderastreids, agariciids, faviids and others). mass=massive, fol=foliaceous, branch=branching.

0-5 metres	5-10 metres	10-20 metres	>20 metres
Pocillopora	*Pocillopora*	*Pocillopora*	Acropora
Acropora	*Acropora*	'mixed'	*Tubastrea*
'mixed'	'mixed'	*Porites* (mass)	Faviids
Porites (mass)	Diploastrea	*Acropora*	Fungiids
Montipora	*Porites* (branch)	*Tubastrea*	Montipora
Diploastrea	*Porites* (mass)	*Montipora*	*Diploastrea*
Montipora (fol)	*Montipora*	*Diploastrea*	
Porites (branch)	*Millepora*	*Millepora*	
Fungiids	Faviids	faviids	
		fungiids	
		Turbinaria	

depths, while *Tubastrea* was abundant at some deep sites. *Millepora* was locally abundant at some sites where coral bleaching and mortality had been high, such as FanTSea and the tops of some of the bommies and pillars.

A high diversity of soft corals was recorded by the visual assessment technique (Table 6), spread among the various depth zones on the reef (Table 7). In the shallow and mid-depths to 20m the soft coral community was dominated by carpeting growth forms. With increasing depth, fans, trees, and nephthiid soft corals became increasingly abundant, visually dominating the overall benthic community with their large canopy size. The lowest prevalence of soft corals was recorded for Samu Reef and Blue Corner, both of which being previously dominated by hard corals and having suffered high hard coral mortality in 2000 (Samu Reef) and 1999 (Blue Corner).

Table 6. Soft coral genera and growth forms recorded during surveys in the Lomaiviti Group, Fiji.

Soft coral form	Genera recorded.
Carpeting	*Sinularia, Sarcophyton, Lobophytum*
Nephthiids	*Dendronephthia, Nephthea*
Tree-shaped fans	*Chironephthya, Echinogorgia, Siphonogorgia, Subergorgia*
Whispy-shaped	*Paraplexaura, Pinnigorgia*
Whip-shaped	*Elisella*
Fans (regular)	*Siphonogorgia, Anella*
Black Coral	*Antipathes* sp.

Table 7. Distribution of soft coral growth forms by depth, in the Lomaiviti Group, Fiji. Growth forms are ordered by abundance from top to bottom.

0-5 metres	5-10 metres	10-20 metres	>20 metres
Carpeting	Carpeting	Carpeting	Fans
	Fans	Fans	Nephthia
	Nephthia	Nephthia	Black coral
	Black coral	Tree-shaped fans	Carpeting
		Black coral	Tree-shaped fans
		Xeniids	

Coral Condition

No evidence of *Drupella* or coral diseases was seen, and a single crown-of-thorns starfish was recorded (see 'Invertebrate' section).

Estimates of 'old dead' coral ranged from a high of 50% at Blue Corner, with a mean of 20%, to zero at 2 Thumbs Up (Figure 5). Sites with the lowest levels of coral mortality – Yellow Wall, North Face (both on Mount Mutiny), Teton and 2 Thumbs Up – had low abundance of hard corals even on their summits,and their vertical wall faces were dominated by soft corals. The low value presented for Cat's Meow is incomplete, as coral mortality on its summit was observed to be high, but was ommitted by sampling.

While overall bleaching levels were low, it was recorded for a wide diversity of coral genera and species (Figures 6, 7). Commonly bleached corals, with 25-50% partial mortality belonged to the genera *Acropora*, *Pavona*, *Porites*, *Lobophyllia* and the soft coral carpeting genus *Sinularia*. High levels of bleaching and pale tissue were recorded for *Pocillopora*, *Fungia* and *Merulina*, though with no or low evidence of mortality from the current bleaching event.

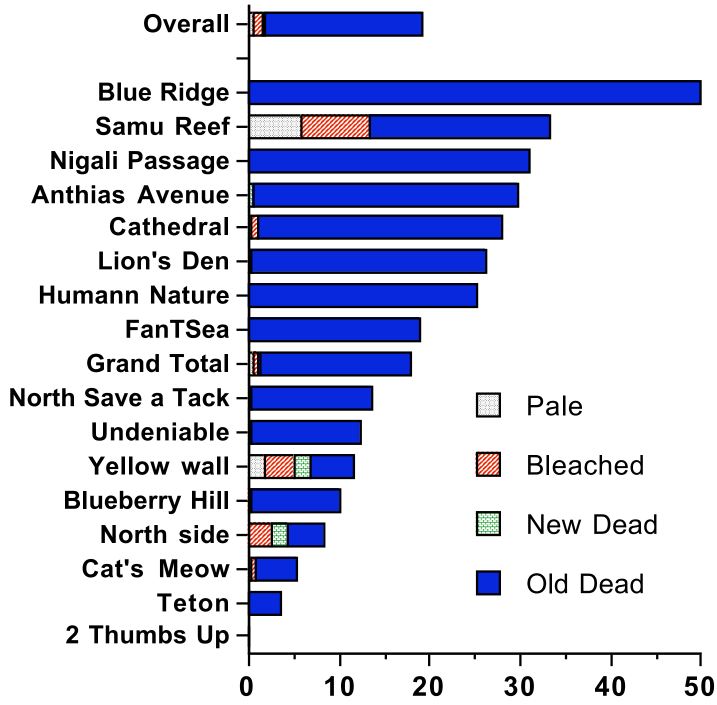

Figure 5. Coral condition estimates from visual assessment surveys, as percent of total benthic cover.

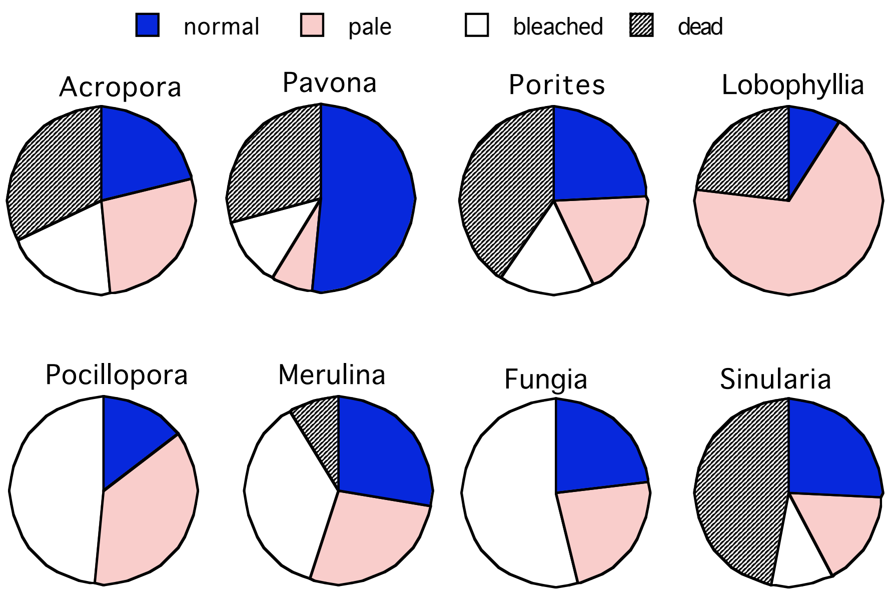

Figure 6. Condition of coral colonies showing highest levels of bleaching and mortality, Lomaiviti Group, Fiji. Pie sectors are proportional to the condition of each coral genus. Colonies that were 100% normal were excluded.

Corals showing lower levels of bleaching and mortality are shown in figure 7. These corals were as abundant as those in Figure 4, but had a higher proportion of normal colonies unaffected by bleaching. *Montipora*, *Platygyra* and *Diploastrea* in particular were very common, showing minor influence of bleaching. *Diploastrea* is one of the main genera that forms large massive colonies at the survey sites and is commonly reported as having survived bleaching (Cumming *et al.* draft), supported by observations on this trip. *Halomitra*, like *Fungia*, displayed high levels of bleaching, but low or zero mortality rates. *Millepora* suffered extensive mortality in 2000, seen on this trip by many still recognizable dead colony skeletons, however low mortality was found associated with current bleaching.

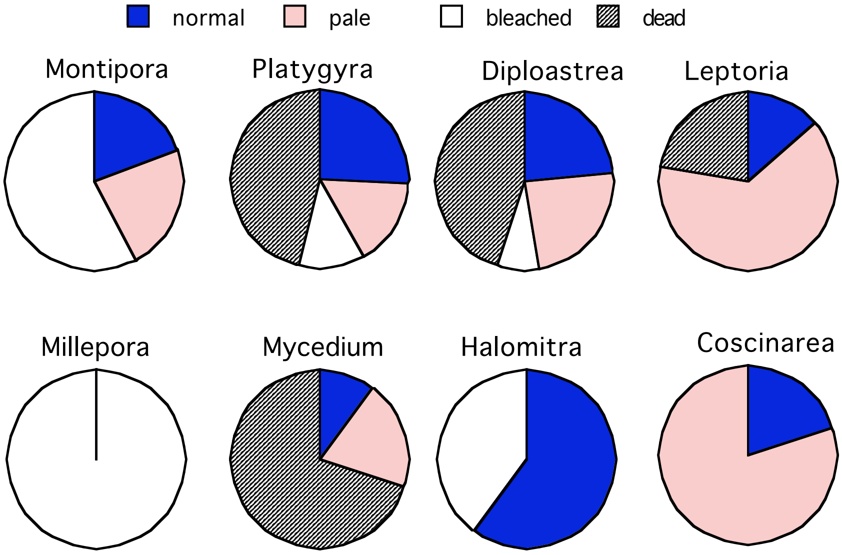

Figure 7. Condition of coral colonies showing some level of bleaching and mortality, Lomaiviti Group, Fiji. Secondary genera showing less bleaching than those in fig. 4. Pie sectors are proportional to the condition of each coral genus. Colonies that were 100% normal were excluded.

3) Benthic Invertebrates

Invertebrate surveys were undertaken at all sites with the exception of Samu Reef, Blueberry Hill, Kansas, Blue Corner, Jim's Alley and Nigali Passage. Of the sites sampled, the greatest species diversity and number of individuals were recorded at Anthias Avenue, Humann Nature and FanTSea (Table 8). These sites were characterised by large pillars and bommies with complex small-scale topography such as caves, boulders and ledges breaking up the vertical walls. Diversity and abundance at these sites was due principally to holothurians, which require flat surfaces. Many of the sites with solid vertical wall faces, such as Yellow Wall, Cathedral and Teton had lower numbers and diversity of invertebrates, and were dominated by oysters (molluscs), which attach to the vertical walls. Overall, the diversity and abundance of the selected groups was relatively low, perhaps due to high predation levels and low shelter availability on the vertical walls at most sites.

Sea cucumbers

Holothuridae, (i.e. sea cucumbers) was the most common invertebrate group observed in the Lomaiviti Group, with 69 individuals counted. Sea cucumbers were present at all of the sites surveyed with the exception of 2 Thumbs Up, Cathedral and Yellow Wall. The absence of individuals at these three sites most likely reflects the unsuitability of the habitat (i.e. deep water, vertical seamount walls) for sea cucumbers, which are generally bottom-dwelling detritivores. Large numbers of sea cucumbers (>30 individuals), predominantly *Holothuria edulis, H. nobilis* and *H. atra*, were observed at Samu Reef, but no counts were recorded at this site.

Of the 8 species recorded, the three most common were *Thelenota ananas, Stichopus chloronotus* and *Holothuria nobilis*, though all three species were present in low numbers at most sites (Table 9). Sea cucumbers belonging to the genus *Thelenota* were generally larger than other genera, with individual sizes ranging from 45 to 93cm for *Thelenota anax* (64±16.29cm, mean±standard deviation, Table 10) and ranging from 40 to 57cm for *T. ananas* (52±3.88cm).

Table 8. The total number of species (#sp) and number of individuals (N) of major invertebrate groups found at each site surveyed in the Lomaiviti Group, Fiji. Sites (rows) are ordered from top to bottom by decreasing number of species and invertebrate groups (columns) from left to right by decreasing abundance. FanTSea and North Save-a-Tack were each sampled twice.

	Overall		Sea cucumbers		Other Molluscs		Giant clams		Starfish		Lobsters
	#sp	N	#sp	N	#sp	N	#sp	N	#sp	N	N
Anthias Avenue	8	25	3	4	2	7	1	1	2	13	0
Humann Nature	8	12	3	6	2	2	2	3	0	0	1
FanTSea (1)	7	23	4	8	3	15	0	0	0	0	0
FanTSea (2)	7	24	5	21	0	0	2	3	0	0	0
North Save-a-Tack (2)	6	8	6	8	0	0	0	0	0	0	0
North Save-a-Tack (1)	5	8	5	8	0	0	0	0	0	0	0
Teton	5	9	1	1	2	2	1	3	1	3	0
Cat's Meow	5	9	4	6	0	0	1	3	0	0	0
Lion's Den (1)	4	5	3	4	0	0	1	1	0	0	0
Mutiny North Face	4	4	1	1	2	2	1	1	0	0	0
Undeniable	4	7	1	2	3	5	0	0	0	0	0
Yellow Wall	4	9	0	0	2	2	2	7	0	0	0
2 Thumbs Up	3	23	0	0	3	23	0	0	0	0	0
Cathedral	2	4	0	0	1	1	1	3	0	0	0
Total abundance		170		69		59		25		16	1

Table 9. The species and number of sea cucumbers recorded at sites surveyed in the Lomaiviti Group, Fiji. FanTSea and North Save-a-Tack were each sampled twice.

Sites	*Thelenota ananas*	*Stichopus chloronotus*	*Holothuria nobilis*	*Bohadschia argus*	*Bohadschia graeffei*	*Thelenota anax*	*Holothuria atra*	*Holothuria edulis*
Anthias Avenue		2			1	1		
Cat's Meow	1		1		3	1		
FanTSea (1)	4		1		1			2
FanTSea (2)	6	5	6	1			3	
Humann Nature				4	1			1
Lion's Den (1)			1	1		2		
Mutiny North Face				1				
North Save-a-Tack (1)	2	3	1	1		1		
North Save-a-Tack (2)	1	3		1	1	1	1	
Teton						1		
Undeniable					2			
Total	14	13	10	9	9	7	4	3

Table 10. Number (N) and size distributions (mean, standard deviation, minimum and maximum in cm) of sea cucumbers recorded during surveys in the Lomaiviti Group, Fiji.

Species	N	mean	sd	min	max
Thelenota ananas	14	52	3.9	40	57
Stichopus chloronotus	13	27	4.9	18	35
Holothuria nobilis	10	31	5.9	24	40
Bohadschia argus	9	35	10.7	18	50
Bohadschia graeffei	9	40	8.3	29	55
Thelenota anax	7	64	16.3	45	93
Holothuria atra	4	23	5.1	17	28
Holothuria edulis	3	27	3.0	24	30

Giant clams & Other Molluscs

Twenty-five recordings of giant clams (Tridacnidae) were made, 80% of which belonged to the species *Tridacna squamosa* (Table 11). *Tridacna squamosa* was the second most common invertebrate species found in the Lomaiviti Group, with 20 individuals recorded. No giant clams were recorded for 2 Thumbs Up or North Save-A-Tack. Sizes of *T. squamosa* varied from 12 to 50cm (30±14.3cm, Table 12). No dense aggregations of giant clams were observed at any of the sites, with the single highest number being 7 individuals at Yellow Wall.

Table 11. The species and number of giant clams (Tridacnidae) recorded at sites surveyed in the Lomaiviti Group, Fiji. FanTSea and Lion's Den were each sampled twice.

Individuals	*Tridacna squamosa*	*Tridacna maxima*	*Tridacna derasa*
Anthias Avenue	1		
Cathedral	3		
Cat's Meow	3		
FanTSea (2)	1		2
Humann Nature	2	1	
Lion's Den (1)	1		
Mutiny North Face	1		
Teton	3		
Yellow Wall	5	2	
Total	20	3	2

Table 12. Number (N) and size distributions (mean, standard deviation, minimum and maximum in cm) of giant clams recorded during surveys in the Lomaiviti Group, Fiji.

Species	N	mean	sd	min	max
Tridacna squamosa	20	30	14.3	12	50
Tridacna maxima	3	12	6.0	6	18
Tridacna derasa	2	31	7.1	26	36

Individuals belonging to the genus *Hyotissa* and the species *Spondylus* sp. C were the most abundant oysters observed at the sites (Table 13). The largest number of individuals of *Hyotissa* spp. were recorded at 2 Thumbs Up, while FanTSea recorded the highest number of *Spondylus* sp. C. Difficulty in identification meant most oysters were identified to genus level only. The mean size of most oysters fell in the range of 20-24cm, with the exception of 'Oyster sp. A', which had one individual of 50cm. (Table 14). One giant triton (*Charonia tritonis*) was observed at Samu Reef.

Table 13. The species and number of molluscs (excluding giant clams) recorded at sites surveyed in the Lomaiviti Group, Fiji. FanTSea was surveyed twice.

Individuals	*Hyotissa* spp.	*Spondylus* sp. C	*Hyotissa hyotis*	*Lopha* spp.	*Trochus* spp.	*Oyster sp. A*	*Lambis* sp.	*Pinctada* sp.	*Spondylus* sp. A	*Spondylus* sp. B
2 Thumbs Up	16	1		6						
Anthias Avenue		3	4							
Cathedral							1			
FanTSea (1)	2	10	3							
Humann Nature					1	1				
Mutiny North Face					1			1		
Teton		1			1					
Undeniable	3					1				1
Yellow Wall			1						1	
Total	21	15	8	6	3	2	1	1	1	1

Table 14. Number (N) and size distributions (mean, standard deviation, minimum and maximum in cm) of oysters observed during surveys in the Lomaiviti Group, Fiji.

Species	N	mean	sd	min	max
Hyotissa spp.	21	22	8.1	8	35
Spondylus sp. C	15	24	5.8	12	32
Hyotissa hyotis	8	20	4.6	15	30
Lopha spp.	6	23	7.8	15	35
Trochus spp.	3	5	1.5	3	6
Oyster sp. A	2	34	23.3	17	50
Lambis sp.	1	25	-	25	25
Pinctada sp.	1	18	-	18	18
Spondylus sp. A	1	25	-	25	25
Spondylus sp. B	1	25	-	25	25

Starfish

Only one crown-of-thorns starfish (*Acanthaster planci),* measuring 45cm in length, was recorded, at Anthias Avenue, during invertebrate surveys. A small number of additional individuals were sighted by divers at Anthias Avenue and Jim's Alley, and evidence of numerous feeding scars was present at these sites. The second species of starfish recorded was *Choriaster granulatus*, which was found at Anthias Avenue (12 individuals) and Teton (3 individuals) measuring 22.8±1.8cm in size.

Lobsters

Only one small lobster (*Panulirus* sp.), measuring 6cm in length, was observed during the surveys. This result is likely to reflect the cryptic nature of the animal and/or localized depletion resulting from over-harvesting in one or two sites. The latter half of the statement is based on anecdotal information provided by NAI'A dive staff, as one of the Eastern Bligh Waters sites held several large lobsters 3 months prior to this survey.

4) Fish

Fish populations in the Lomaiviti Group were abundant and diverse, influenced by the nutrient-rich deep waters bathing the reefs from southeast in the Bligh Waters channel and the high topographic complexity of the barrier and island reefs systems (see Habitat section, above). Fish sampling was not conducted during this trip due to the absence of an experienced fish observer. However data has been collected in early 2001 by Helen Sykes, on board the NAI'A, at survey sites visited in this trip and adjacent ones. Presence/absence data is presented here (Table 15), obtained from a mixture of transect-based and open-search dives.

Table 15. Species richness of fish families at sites in the Lomaiviti Group, Fiji in early 2001. Sites ordered by decreasing number of families per site (left to right), and families by decreasing frequency of incidence (top to bottom) in the right-hand column. The sites Grand Central Station and Magic Mountain are adjacent to North Save-A-Tack and South Save-A-Tack on the Namena Barrier Reef.. Data supplied by Helen Sykes.

Family		Grand Central Station	Anthi-as Ave	Magic Mount-ain	E6	2 Thumbs Up	Fan-T-Sea	Unden-iable	Lion's Den	Mount Mutiny	Freque ncy
Number Families		25	24	23	23	21	21	20	19	18	
Number Species		117	143	127	96	103	100	96	70	92	
Family Names											
Acanthuridae	Surgeons	10	11	12	11	8	8	8	7	8	9
Balistidae	Triggers	6	7	4	4	4	3	1	2	2	9
Blenniidae	Blennies	5	7	4	2	5	2	3	2	1	9
Caesionidae	Fusiliers	4	4	5	3	5	3	4	1	2	9
Chaetodontidae	Butterflys	11	15	12	16	10	11	13	6	14	9
Gobiidae	Gobies	1	6	4	1	3	2	1	1	2	9
Labridae	Wrasses	15	16	19	13	12	20	15	13	13	9
Lethrinidae	Emperors	4	3	3	1	2	3	2	1	2	9
Lutjanidae	Snappers	5	3	5	6	5	2	5	2	3	9
Mullidae	Goatfish	1	2	1	1	3	3	1	1	2	9
Pomacanthidae	Angelfish	4	7	4	4	4	4	4	4	5	9
Pomacentridae	Damsels	13	19	23	12	15	21	19	13	21	9
Scaridae	Parrots	4	5	7	5	5	5	7	3	6	9
Carangidae	Jacks	2	1	1	1	1		2	1	1	8
Cirrhitidae	Hawkfish	3	5	4	1	5	1	1	1		8
Holocentridae	Soldiers		6	2	1	1	1	1	1	1	8
Serranidae	Groupers	9	12	8	6	6	2	3		5	8
Siganidae	Rabbitfish		1	2	1		3	1	2	2	7
Tetraodontidae	Puffers	1	2	2	1	2	2	1			7
Scombridae	Tuna	1	2	1	1			3	1		6
Apogonidae	Cardinals	1	2	2		1	1				5
Haemullidae	Sweetlips	3	1			1				1	4
Ostraciidae	Boxfish	1	1	1	1						4
Pinguipedidae	Sandperch	1	3				1				3
Scorpaenidae	Scorpions	1		1					8		3
Zsharks	Sharks	1			1		1				3
Sphyraenidae	Barracuda	3			1						2
Syngnathidae	Lizardfish					2					1
Other	Other	7	2		2	3	1	1		1	7

A total of 273 species of fish in 27 families were sampled among the 9 sites presented in Table 15. Higher overall species diversity was related to greater sampling effort at some sites and to different sampling methods and intensities, with no particular pattern discernible among the sites according to reef system or structure. The overall fish populations were found to be very similar among all the sites, with total species number varying between 92 and 117 (a 27% difference) and total family numbers between 18 and 25. This similarity is partly due to site selection for tourist diving, where high diversity and abundance of reef fish are a preferred feature. These numbers are likely represent the upper distribution of fish abundance and diversity on reefs in the Lomaiviti Group, and can be useful as reference sites for future monitoring and management.

The upper 13 families in Table 15 were found at all sites, with highest within-family diversity being found in the damselfish, wrasses and butterflyfish (Table 16). These and the other most common families are typical residents of coral reefs. Some of the less common families, were either characteristically rare on coral reefs (e.g. sandperches, puffers, barracuda), non-resident visitors (e.g. tuna), cryptic (e.g. scorpionfish, cardinalfish), or vulnerable to exploitation (e.g. sharks, barracuda, sweetlips). It is worth noting the low diversity of butterflyfish (Chaetodontidae) at Lion's Den, reflecting the almost total lack of *Acropora* at the site, and overall low coral cover.

Table 16. Average, minimum and maximum species diversity of the 12 most common fish families, at each sites surveyed in the Lomaiviti Group. Data supplied by Helen Sykes.

		Number of species per site		
Family		Average	Min	Max
Pomacentridae	Damsels	17.3	12	23
Labridae	Wrasses	15.1	12	20
Chaetodontidae	Butterflys	12.0	6	16
Acanthuridae	Surgeons	9.2	7	12
Scaridae	Parrots	5.2	3	7
Pomacanthidae	Angelfish	4.4	4	7
Lutjanidae	Snappers	4.0	2	6
Balistidae	Triggers	3.7	1	7
Blenniidae	Blennies	3.4	1	7
Caesionidae	Fusiliers	3.4	1	5
Gobiidae	Gobies	2.3	1	6
Lethrinidae	Emperors	2.3	1	4
Mullidae	Goatfish	1.7	1	3

5) Sharks and Turtles

Sharks were present at 7 out of the 17 sites surveyed, with the greatest numbers recorded at Anthias Avenue and Nigali Passage, both at Gau Island (Table 17). One scalloped hammerhead (*Sphyrna lewini)* was observed at Cathedral. Grey reef sharks (*Carcharhinus amblyrhynchos)* were the most common species of shark observed, at Anthias Avenue, Nigali Passage and North Save-a-Tack reefs. Individuals present in Nigali Passage displayed territorial behaviour, circling continuously, and are present throughout the year. It appears that these sharks are exclusively/predominantly female, and males are seen within the channel mainly during the mating season (Sykes pers. comm., Holloway, pers. comm.). The large schools of fish in deep waters on the edge of the North Save-A-Tack reef are likely to be drawing the grey reef sharks to this site.

Table 17. The species and numbers of sharks observed at survey sites in the Lomaiviti Group, Fiji. FanTSea and North Save-a-Tack were each sampled twice.

Sites	*Carcharhinus amblyrhynchos* (grey reef)	*Triaenodon obesus* (white-tip reef)	*Carcharhinus albimarginatus* (silver-tip reef)	*Sphyrna lewini* (scalloped hammerhead)
2 Thumbs Up		1		
Anthias Avenue	6	2		
Cathedral				1
FanTSea (1)		1	3	
FanTSea (2)		1	1	
Mutiny North Face		2		
Nigali Passage	6	2		
North Save-a-Tack (1)	5	2		
North Save-a-Tack (2)	4	1		
Total	21	10	4	1

Turtles

Four hawksbill turtles (*Eretmochelys imbricata*) were the only turtles observed during the seven days of surveys. Two sightings were recorded at Cat's Meow, and one each at Humann Nature and Mutiny North Face.

DISCUSSION

Reefs in the Lomaiviti Island group exhibit a high diversity and complexity of physical form, including seamounts, barrier reefs, bommies, pinnacles and other typical reef structures such as patch and channel-edge reefs. The reefs rise from depths of over 1000m in the Vatu-I-Ra channel that separates the main islands of Viti Levu and Vanua Levu, which lines up with the predominant wind and wave direction from the southeast. As a result, the reefs are bathed in upwelling nutrient rich waters, which interact with their topographic complexity to result in high habitat diversity and consequently high biological diversity and abundance.

Highly characteristic of the area and of Fiji in general, the vertical walls of the seamounts, barrier walls and pillars are covered with an abundance of filter-feeding invertebrates, particularly soft corals, sponges, ascidians and bivalves. Erect, branching, fans and tree-like soft corals (such as *Dendronephthia, Nephthea, Echinogorgia, Siphonogorgia,* and *Subergorgia*) were visually dominant at almost all vertical or sloping locations at depths >10m, though the standard transect techniques used indicated greater dominance by carpeting forms (*Sinularia, Sarcophyton, Lobophytum*) particularly in shallower water, as these are better sampled by surface area projection than the vertical form of the erect soft corals. A broad range of sites were recorded with high diversity and/or abundance of soft corals, or for being visually dramatic (Table 18), emphasizing the general richness of soft coral communities in the Lomaiviti Group. These sites are from a broad range of habitat types, including pillars (Teton, Jim's Alley), bommies (Undeniable, Cat's Meow) and vertical walls on barrier reefs and seamounts (FanTSea, Yellow Wall). Taxonomic identification of soft corals, and of other soft-bodied invertebrates such as ascidians and sponges, requires considerable experience, laboratory skills, improved accessibility of reference materials (Fabricius and Aldersdale 2001) and considerable work needs to be done to adequately describe and estimate the biodiversity of this important group.

Table 18. Sites with high abundance and/or diversity of sampled organisms, Lomaiviti Group, Fiji.

Group	Sites	Characteristic	Conservation Value
Soft Corals	Teton, Jim's Alley	High cover	Biodiversity and dive tourism
	2 Thumbs Up, FanTSea, Undeniable, Teton, North Save-a-Tack	High diversity	
	Yellow Wall, Blueberry Hill, Cat's Meow	Visually dramatic	
Hard Corals	Cat's Meow, Cathedral, Undeniable, Mutiny North Face	High cover	Biodiversity, reef resilience and dive tourism
	Cat's Meow, Undeniable, E6	High diversity	
	Cat's Meow, FanTSea, Blue Corner, Nigali Passage, Anthias Avenue, Cathedral, Lions Den	High recent mortality	
Sea cucumbers	North Save-a-Tack, FanTSea, Cat's Meow, Humann Nature	High diversity and abundance	Special habitat
Molluscs (incl. Giant Clams)	FanTSea, Undeniable, 2 Thumbs Up	High diversity and abundance	Special habitat

Shallow slopes and horizontal surfaces were dominated by hard corals characteristic of tropical coral reefs, giving them their typical coral reef attributes. The Fijian islands, located in warm tropical waters, harbour a vast area and diversity of coral reefs (IUCN/UNEP 1985, NBSAP-TG7 1999). In the Lomaiviti Group, coral growth over the years has led to highly complex barrier and isolated-reef structures in spite of the fact that the vertical relief limits coral cover at depth. The tops of the bommies (Cat's Meow, Undeniable) and seamounts (Cathedral, Mutiny North Face) had the highest diversity and abundance of hard corals (Table 18), though a number of locations had suffered high mortality from the 2000-bleaching event. The important hard coral sites may require some level of conservation management as an "insurance policy" against climate change related degradation such as happened in 2000 and was repeated on a lesser scale in 2001.

At the time of this survey, coral mortality due to bleaching in 2000 was clearly evident in the low cover of live coral (not more than 33% where some locations would have had over 90% coral cover) and the high incidence of dead coral skeletons. The hard coral community was dominated by submassive, branching and massive growth forms, with lesser quantities of *Acropora* species (staghorn and cushion-shaped), plates, encrusting and mushroom forms. Common coral genera include *Acropora*, *Diploastrea*, and a variety of faviids (*Favia*, *Montastrea*, *Platygyra*, *Leptoria*, etc.), with secondary roles for fungiids (*Fungia*, *Halomitra*), *Millepora*, *Montipora Pocillopora*, *Porites* (both massive and branching species), *Tubastrea* and *Turbinaria.* The low abundance of branching *Porites* species was notable as it is normally a dominant group particularly in back reef environments. Branching *Porites* species tend to be particularly susceptible to coral bleaching and mortality, and may have been selectively reduced during the bleaching event in 2000.

Out of the 166 coral species recorded in Fijian waters (Appendix 3), this study recorded 127 records. A number of species represent a combination of range extensions, new terminology and/or increased availability of reference documentation with a new publication in 2000 (Veron 2000). Given the rapid assessment nature of the expedition, significantly more work is required to accurately document the biodiversity of hard corals in the Lomaiviti Group. The number of coral species recorded suggests the total species diversity of corals in the area is comparable to the most diverse sites in Fiji..

Taxonomically, the algal community of the Lomaiviti Group is typical of Fijian reefs, with all 46 collected species having been previously recorded for Fiji (Appendix 2). In terms of benthic cover, the algal community was dominated by coralline and turf growth forms, with low abundance of fleshy algae. Together, coralline and turf algae accounted for up to 85% of benthic surfaces with only two sites (Undeniable and Cat's Meow) with <50%. Coralline and turf algae are characteristic of sites in early successional stages and/or subject to high herbivory (Littler et al. 1989, McClanahan 1997). Both of these factors may be applicable here. Bleaching-related mortality of corals in 2000 and subsequent colonization by algae to be one factor contributing to the high cover early successional algae on newly dead surfaces. The large and diverse fish populations in the area, unimpacted by fishing, includes numerous herbivores (surgeonfish, parrotfish) that would maintain the dominance of coralline and turf forms.

The diversity and abundance of key macroinvertebrate groups (sea cucumbers, giant clams and other molluscs, starfish, lobsters) was relatively low at all study sites. Sea cucumbers were most abundant in sandy habitats, while oysters were most abundant on vertical and high-relief surfaces. The primary sites for macroinvertebrates were North Save-a-Tack and FanTSea, where the large reef-top expanse with complex topography of bommies and sand channels provided optimal habitat for sea cucumbers and other mobile invertebrates (Table 20). Additionally, complex topography of rocks and small caves on bommies and pinnacles (such as Cat's Meow and Humann Nature) contributed to high diversity and abundance of macro-invertebrates at these sites. The low overall macroinvertebrate population is likely due to high predation levels from the abundant fish populations and low shelter availability on the vertical walls. Lobsters were very rare with only one being sighted, though this may be due to fishing as a group of 5-10 lobsters present at one location for several years (up to 3 months before this survey) had suddenly disappeared.

Fish populations in the Lomaiviti Group are large and diverse, with abundant schooling planktivorous and pelagic fish in the rich waters flowing onto the reefs from deeper waters. The species composition of fish is typical of coral reefs, with the highest number of species in the damselfish, wrasses and butterflyfish. Additionally, groupers and surgeonfish had high numbers of species. Evidence of fishing impacts was low, except perhaps in the patchy distribution of sharks and large groupers, with grey reef sharks being found in significant numbers at 3 sites. Turtles were infrequently sighted, and other large marine species of interest such as dolphins, were not sighted at all.

The rapid assessment surveys presented here have shown a broad outline of the biodiversity and habitats of the Lomaiviti Group and some of the key sites. While more detailed surveys will give more accurate and precise biological data, an earlier priority is to expand sampling of different sites in the group to establish the representativeness of the data reported here. Looking at Table 20, a high proportion of the sites surveyed are named, suggesting greater sampling of additional sites is needed to identify priority sites for different types of protection and for different objectives. Also, sites surveyed in this study were selected according to their interest for dive clients, thus may over-estimate the presence of large fish and attractive benthic scenery over other sites where small-fish and cryptic benthic community diversity might be higher and need representation in a science-based conservation strategy. A more rigorous sampling of the different reef habitats of the Lomaiviti Group is recommended, and it is likely to be necessary to build further collaborations between tourism, conservation and science organizations to undertake these surveys.

Threats to the Reefs in the Lomaiviti Group

The widespread impacts of La Niña-related coral bleaching and mortality in 2000 has been reported for the whole of Fiji, including the Lomaiviti Group (Cummings et al. 2001). As discussed above, the effect of this mortality is evident directly in the low cover of corals, and indirectly in the high cover of coralline and algal turf on recently eroded coral surfaces – characterized as "old dead" in the visual assessment surveys. This category varied in extent from 0 – 50% (figure 5), while mortality in other parts of Fiji averaged 60% and reached up to 100% in some locations (Cummings et al. 2001). Lower mortality of corals in Lomaiviti may be related to the prevailing wind and currents from the southeast that push cool deeper waters in the Vatu-I-Ra Passage (Eastern Bligh Waters) up into the reefs between Viti Levu and Vanua Levu, reducing the high temperature associated with coral bleaching. If this does occur, the increased resilience that this confers to reefs in the Lomaiviti Group may be nationally significant in the long-term survival of coral reefs in the face of climate change.

High coral mortality at two sites was known to have occurred before the La Niña in 2000, estimated to have killed 90% of corals (Cummings et al. 2001; C Holloway, H Sykes, pers. comm.). At Blue Corner and Lion's Den, both on Wakaya Island, coral mortality was observed in November 1999 – affecting 50% of the benthos at Blue Ridge, and ≈25% at Lions Den (figure 5). The cause for this mortality is unknown, and the event appears to have been limited to Wakaya Island. Crown-of-thorns infestation is the most likely cause, and outbreaks and small aggregations have affected several reefs in Fiji. COTs feeding scars were common at Anthias Avenue and Jim's Alley. Other potential causes include nutrient or waste flushing from the lagoon, though the low-density human population on the island is unlikely to cause significant eutrophication, or even cold water influx from deeper waters over an extended period.

Other threats, whether biotic (the corallivorous snail *Drupella*, and coral diseases) or anthropogenic (fishing, pollution, litter) were generally absent at the sites surveyed. An additional threat that may have contributed to recent coral mortality and physical destruction of coral heads was cyclone Paula in February 2001, though this passed south of the current survey sites. This may have caused additional mortality, as well as breaking up newly dead corals from the bleaching event, and converting them into the large amounts of rubble observed.

Fishing pressure in the Lomaiviti Group appeared to be low, evidenced by the abundant fish populations and no visible signs of resource extraction. This is likely due to the isolation of reefs in the area, particularly the seamounts and Namena Barrier Reef system. Nevertheless, locally intensive resource use does occur, seen in the disappearance of a resident group of lobster and in low levels of fishing reported for the area. Commercial Beche de Mer fishing is intense in Namena, and extending towards Gau Island and the northern parts of the Vatu-I-Ra Passage. Coral, invertebrate and fish collecting for the aquarium trade is common. Long line fishing is conducted in the Vatu-I-Ra passage, evidenced by fishing line entangled in corals found during the sruveys. With increasing development of fishing and navigation technology, and diminished resource bases in more accessible fishing grounds, fishing use in the Lomaiviti Group is likely to increase in the future.

A repeat bleaching event in 2001 was recorded in the Lomaiviti Group, other parts of Fiji and the South Pacific at the time of this survey. Bleaching levels up to 10% of living corals were recorded in this survey (figure 5). Mortality associated with the bleaching was generally low to non-existent, except at Samu Reef, Yellow Wall and North Face. All three sites are in the north- and western-most sector of the surveys, suggesting that bleaching in 2001 was more severe in this region, with corals in the eastern part of the Lomaiviti Group relatively unaffected. The threat of more frequent and intense coral bleaching caused by high-temperature stress is increasing globally (Wilkinson *et al*. 1999; Goreau *et al*., 2000), emphasized by the short interval between the 2000 and 2001 bleaching events in Fiji. From observations during this survey regarding upwelling of deep, cool waters, and the fact that the Lomaiviti area of Fiji was less affected by widespread coral bleaching in 2000 (Cummings et al. 2001), the Lomaiviti area may have an important role as a refuge for corals during bleaching events in other parts of Fiji (Salm et al. 2001). This potential should be built into projections of coral reef management at the national level.

The impact of the bleaching-related coral mortality on species diversity is an important issue with increasing threats of climate change impacts (i.e. of global processes) on local fauna. In this survey, this impact could not be estimated, though it is likely that some rare species may become locally eradicated and take many years to reappear from chance recruitment of larvae from the water column. Globally, there have been only two cases of potential hard coral species extinction from a region due to bleaching-related mortality (Glynn 1996), and while the threat from climate change to Lomaiviti reefs is increasing, it may not yet affect species richness. Decreased populations of coral-dependent fish, *Chaetodon trifasciatus* (chevron butterflyfish) and *Neocirrhites armatus* (flame hawkfish) were reported following coral mortality in 2000, though it is not possible to determine if this is due to mortality of the coral *Pocillopora eydouxi*, on which they live, or aquarium fish collecting (H Sykes, unpublished data). Total loss of a species from the Lomaiviti region is made less likely by the area's physical complexity and upwelling of cooler deep waters by prevailing winds and currents from the southeast. Because of this, and with the area's downstream location for important reefs of the northern and western island groups in Fiji, the Lomaiviti region may provide ecological and biogeographically significant refuges from the climate-related temperature stress that caused the bleaching event and will increasingly affect reefs in Fiji (Salm and Coles 2001).

The survey results point to some sites as priority sites for protection (Tables 18 and 19). More appropriately these should be seen as representative of key sites to be included in planning a framework for coral reef management in the Lomaiviti Group, pending further more extensive surveys. It was noticeable that the pinnacles and reefs around Gau Island appeared significantly more degraded compared to the other sites. These reefs were the farthest south in this survey, and potentially more impacted by the La Niña coral bleaching event of 2000 which most strongly affected reefs in the west and south of Fiji (Cummings et al. 2001). Additionally, a COTs outbreak was observed some six months later (Sykes and Holloway, pers.comm.), and the island is the most heavily populated area encountered during this survey. While some of these reefs may not gain special status for biodiversity conservation as a result of their level of degradation, they are nevertheless important for inclusion in a general management plan for the island group due to their importance for resource use, and to assist recovery.

Table 19. Priority sites for planning for protection and management of the Lomaiviti Group, Fiji.

Reef type	Sites	Comments
Seamounts	Mount Mutiny E6	Soft coral and fish fauna are particularly rich, and coral communities on their tops are diverse. Reefs are isolated from other shallow water environments around them, and difficult to access.
Bommies and Pinnacles	Undeniable Cat's Meow Humann Nature 2 Thumbs Up Teton	Diverse and abundant hard and soft coral communities, as well as other soft-bodied attached invertebrates. They all form prominent features in the surrounding reefs systems, and can form key focus points for management of the reefs systems in their vicinity.
Channels	FanTSea Nigali Passage	Heavily damaged by coral bleaching, but had large fish communities. As channels, they are also key aggregation sites for fish and other organisms
Special	North-Save-a-Tack	Distinguished by dramatic deep ledge and wall, and pelagic fish and sharks, though it's benthic community was not remarkable
Damaged sites	Lion's Den Blue Corner, FanTSea - parts of bommies and pinnacles at other sites	These sites surveyed suffered extensive damage to the reef communities. As noted in the recommendations below, these should be incorporated as special sites in a management plan to assist in their recovery

Conservation Management in the Lomaiviti Group

Fiji's National Environment Strategy (1993) and draft NBSAP (1999) have highlighted the need for a comprehensive system of marine protected areas in Fiji's coastal and marine waters to ensure successful biodiversity conservation. The NBSAP specifically mentions the Lomaiviti Group, and in particular Namenalala Island, as a priority for protection, along with the Great Astrolabe Reef (Kadavu), Nadi Bay (Mamanuca), Yadua Taba (Bua) and the Lau Group (no sites specified). However, despite the efforts of national Government and various other organisations, there is currently no established system of representative marine protected areas in place over coastal and marine waters in Fiji. Various resorts and privately owned islands have established marine sanctuaries with the support of the customary resource owners, but these areas are not legally recognised. WWF and University of the South Pacific have been trailing methods of establishing community-managed marine protected areas in Ono (Kadavu) and Verata respectively.

Planning the development of protected area systems is a complex process, but has been broken down into sets of guiding principles and activities by a number of institutions and authors (e.g. Salm et al. 2000). Based on the surveys reported here, the Lomaiviti Group has a number of advantages for development of a protected area system:

- the diversity and productivity of reefs in the area is high;
- human population size in the group is low, resulting in relatively low resource pressure;
- the island group is geographically isolated and presents many navigational challenges, reducing boat traffic in the area; and
- vulnerability of the reefs in the group to coral bleaching appears to be lower than in other parts of Fiji, that suffered higher impacts of bleaching in 2000. This may give the area a greater significance nationally, especially for downstream reefs in the north and west of Fiji.

While low human population numbers and geographic isolation of the Lomaiviti Group have helped to maintain the ecological integrity of coral reefs in the area, local communities are facing the challenge of adapting to the new forces of development and globalization, and climatic impacts such as mass coral bleaching. The greatest long-term security for the communities of the Pacific will be achieved through sustainable, adaptive local management.

The information collected in this study highlights the diversity of habitats and faunal assemblages in the Lomaiviti Group, and supports the need for a system to be developed and implemented to ensure the marine resources in the area are adequately protected and managed sustainably. Equivalent in importance, but at the local scale of implementation, is the interaction between local communities, dive tourism interests, non-government organisations such as WWF and the Fiji Government in the development of working mechanisms for implementing any conservation and management plans.

RECOMMENDATIONS

Recommendations for the conservation and management of reef ecosystems within the Lomaiviti Group are divided into two components that (a) outlines the key components for the development of a management framework to protect biodiversity and critical fisheries resources that communities rely on for subsistence and livelihood, and (b) further research and monitoring to enable informed management decisions to be made. These recommendations are based on the findings of the current study, and the knowledge gained through experience and discussions held with conservation practitioners in Fiji and the wider Pacific.

Conservation & Management Plan
There is an overwhelming body of scientific research and practical experience in both tropical and temperate seas, which supports the establishment of marine protected areas (MPAs) or marine reserves as effective tools for the conservation of biodiversity, and the replenishment of fish resources (Roberts and Hawkins 2000) and increasingly, their importance in mitigating the effects of coral bleaching (Salm et al. 2001). Ideally, these MPAs should form a network, which sits within a broader integrated coastal management framework, and which recognises and addresses the conservation and management of the reef ecosystems as a whole and in relation to the terrestrial environment. The management framework should address a number of key issues including:

(a) protection of marine biodiversity and ecosystem processes;
(b) reduction and where possible elimination of local and broad-based threats to the marine environment;
(c) sustainability of current use of resources for both subsistence and commercial purposes; and
(d) future options for resource use.

The management framework should be locally relevant, culturally appropriate, based on good scientific and traditional knowledge, and designed in a manner that does not reduce, degrade or diminish the rights of customary resource owners. Additionally, the management framework should recognise the value and the importance of the inclusion of other stakeholders including national decision makers, and encompass all use activities specifying what each type of user can and cannot do in the area. The following key components should be considered in the development of an integrated coastal management framework:

- ***Network of Marine Protected Areas -*** The establishment of a network of marine protected areas that include and combine a number of protective mechanisms such as:

  (a) complete and seasonal reef closures;
  (b) species closures and quotas;
  (c) prohibition on destructive land use (e.g. clearing) and fishing practices (e.g. use of poisons such as *duva*, small mesh nets);
  (d) prohibition on the targeting of spawning aggregations or undersized fish and invertebrates;
  (e) prohibition on the collection of species that are nationally, regionally or internationally vulnerable or endangered (e.g. turtles, sharks); and
  (f) prohibition on activities that could alter or damage the ecological functioning of reef system (e.g. modification of foreshore areas, channel blasting, changes to local hydrodynamics).

  The MPA network should include the protection of a diversity of reef types including seamounts, bommies, pinnacles, outer barrier reefs, lagoon reefs, patch reefs and channels. Reefs should be selected on biological attributes, community needs, and suitability for protection. In the case of the latter, it is suggested that reefs such as Mount Mutiny and E6 seamounts, and Cat's Meow, Humann Nature and Undeniable, all of which are isolated and hence naturally protected, could be formally gazetted as MPAs.

  Processes for the establishment and management of MPAs by communities have been successfully used and tested by organisations such as WWF and the University of the

South Pacific in Fiji, and should be modified and used as appropriate in the Lomaiviti Group.

- ***Reefs Resilient to Bleaching -*** The protection of reefs within the Lomaiviti Group, which are more resilient to coral bleaching.

While it is recognised that there is no immediate cure for coral bleaching, management systems can be designed to maximize the survival and recovery of corals from wide-scale bleaching events. Despite the wide variety in intensity, depth and geographical distribution, species affected and rates of mortality and recovery globally, discernable local patterns can be used to make informed management decisions. Reefs resilient to bleaching in the Lomaiviti Group are important for the recovery of nearby devastated reefs and hence require some form of protection. In addition, resource owners, managers, governments and the commercial sector can reduce or eliminate other human impacts on coral reefs to create optimal conditions for reef recovery.

- ***Strategic Partnerships with the Tourism Sector*** – The development of cooperative and mutually beneficial relationships between customary resource owners and the tourism businesses in relation to the protection, use and management of different reef ecosystems. The tourism sector, especially those that offer diving to clients, can potentially play an important role in education, monitoring and enforcement of managed reef areas. This is particularly important in the Lomaiviti Group where access to reef areas is difficult or expensive.

- ***Education & Training*** – Activities relating to education and training should be designed and implemented for both the customary resource owners and tourism operators and should be locally relevant. Site and resource information should be compiled for use by customary resource communities, local schools and community groups as well as divers and other visitors. Involving communities, schools and other sectors of society in monitoring of coral reefs is a powerful tool for improving the coverage of information an in raising awareness, and the planned expansions in ReefCheck and GCRMN monitoring training programmes can form a basis for further Education and Training.

- ***Administration & Management*** – This should ultimately rest with the customary resource owners, and be designed to be compatible with local management and administrative structures at the *i qoliqoli, tikina* and provincial council level. However, the role of other stakeholders, such as the tourism sector, national government and academic institutions should be clearly defined and incorporated into the management framework.

- ***Surveillance & Enforcement*** – Enforcement is one of the most difficulat aspects of management in remote island areas such as the Lomaiviti group. Communities, resource users and the tourism sector can each potentially play a vital role in surveillance and enforcement in such conditions. Dive operators pay regular visits to popular dive sites, and have a vested interest in ensuring reefs are healthy and management regulations are being complied with. Communities frequenting popular fishing sites can also play an important role in surveillance and monitoring.

- ***Sustainable Financing*** – options for sustainable financing should be investigated and tested in the Fijian context. Currently no mechanisms have been successfully developed in Fiji to enable community-based conservation to be self-sustaining.

- ***Institutional and Legal Framework*** – the design and implementation of a management plan should be considered in the context of the current legislative environment in Fiji. Key documents and legislation include the draft National Biodiversity Action Plan (1999), the draft Sustainable Development Bill (1999) and others that interpret Fiji's commitments under relevant international conventions and national priorities.

Research & Monitoring

Research and monitoring are essential to verify that management systems are functioning and to enable management to be adapted in response to either natural or anthropogenic influences. Research and monitoring need not be logistically difficult or expensive, if strategic partnerships are formed and stakeholders are actively involved in a complementary manner, such as that described below:

- ***Community Mapping of Resources*** – Resources should be mapped using the collective knowledge of customary resource owning communities. In particular, communities may be able to provide a history of resource use and help to identify biological processes such as spawning, migration of key fisheries resources, etc. The information gathered through this process should be used in the development of an integrated coastal management plan. The involvement of communities from the beginning will also ensure support and compliance with the management plan.

- ***Community Participatory Monitoring*** – Community monitoring of marine resources should be encouraged, especially in areas that are frequented and which are accessible. Community monitoring provides a mechanism by which communities can make informed decisions about their marine environment, and supports their involvement and role in management. It also provides the opportunity for communities to more closely watch changes that are occurring in their environment.

- ***Monitoring by Dive Operators*** – Options for the involvement of dive operators should be considered. Dive operators may be able to collect information on SCUBA in areas inaccessible by communities, and can provide a mechanism by which sudden changes in the marine environment can be detected.

- ***Scientific Surveys & Monitoring*** – Options for undertaking further surveys in the Lomaiviti Group should be pursued with the technical and logistical support of dive operators, especially those with live-aboard vessels, which can access more remote sites. The surveys should be aimed at providing informative maps, a biological inventory and descriptions of the sites and marine fauna and flora. Further surveys are required to determine if those areas surveyed during this study are truly representative of the diversity of habitats found in the Lomaiviti Group. The surveys and ongoing monitoring should form the basis of the conservation and management plan, and can be adaptive to management needs.

CONCLUSIONS

The Lomaiviti Group is poorly-known scientifically, only lightly impacted by fishing and highly attractive for dive tourism. While its remoteness is an advantage for the protection of biodiversity, it also imposes strong challenges for the development and implementation of a conservation plan for the islands and its enforcement. Implementation of the above recommendations could be started with the following next steps:

- Convene a forum to facilitate the meeting of all interested parties, led by the Government of Fiji, to start the compilation of the interests and contributions of the parties to a conservation management plan for the island group.

- Initiate a process of exchange among customary resource owners in the Lomaiviti Group and other parts of Fiji where communities are actively involved in conservation to improve their resource base and standard of living. Identifying pilot sites for natural resource and biodiversity management in the Lomaiviti Group will greatly enhance development of a comprehensive strategy for the whole island group.

- Initiate a process for prioritizing information and monitoring needs to feed into the development process for conservation management. Additional attention needs to be paid to patterns of fishery resource use and coral bleaching in the island group, their relationship to the national context in Fiji.

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