Marine Biological Survey Report
of the Fiji Great and North Astrolabe Reef, Ono kadavu

Fiji Barrier Reef Ecoregion
Fiji Islands

By David Obura and Sangeeta Mangubhai

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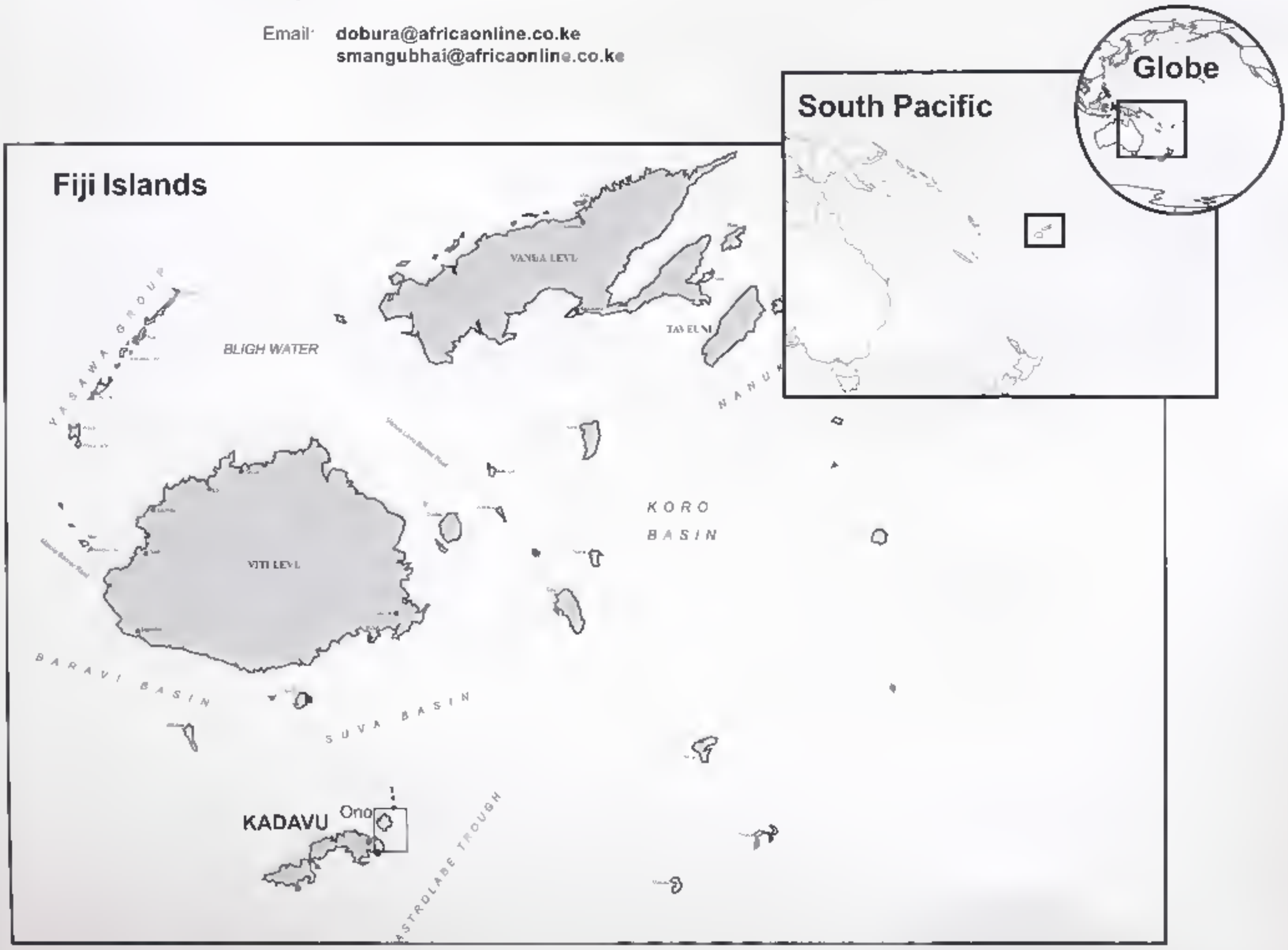

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Executive Summary

Marine biological surveys of coral reefs of the Great Astrolabe Reef (GAR) and North Astrolabe Reefs (NAR) were conducted from the 29 April – 3 May, 2001. The GAR and NAR are found on the northeast and northern end of the Kadavu island group, within the Ono *tikina*, or customary fishing area, situated approximately 70km south of Viti Levu, the main island of Fiji. The surveys were conducted for the World Wide Fund for Nature's (WWF) South Pacific Programme, as a component of the development of community-based management of the reefs. A separate study commissioned by WWF, on the first marine protected area in Kadavu, the Yavusa Ulunikoro Marine Conservation Area, run by Waisomo village on Ono Island, was conducted immediately preceding this study, and the results are incorporated here.

All surveys were undertaken on SCUBA using standard long term monitoring techniques to sample benthic cover, coral diversity and condition, invertebrate abundance and diversity and fish abundance and diversity. Two survey teams of 4-5 divers each operated from the 120-foot vessel M/V NAI'A, focusing on the 12-15 m depth zone and covering 47 sites.

The GAR and NAR have a classic barrier reef and lagoon structure with four reef zones being identified, namely eastern (windward) barrier reefs, western (leeward) barrier reefs, lagoon reefs and channels. The blue hole and backreef sites comprising the Waisomo village protected area were treated as separate habitats. The barrier reef and bommie complexes of the windward reefs had the highest cover (>25%) and most diverse coral communities, providing extensive habitat for invertebrate and fish populations. Leeward barrier reefs showed less topographic complexity. Lagoon patch reefs, back reef slopes and blue holes had the lowest topographic complexity, with low coral cover (<10%) and high abundance of turf and fleshy algae (20-30%).

Coral communities of the GAR and NAR showed significant evidence of bleaching related mortality during the 2000 La Niña phenomenon, with a low average coral cover of 12%, and abundant evidence of newly dead colonies. Many surfaces were covered with an early successional filamentous algae/microbial mat assemblage. The eastern barrier reefs were least affected, probably due to upwelling of cooler oceanic water during the bleaching in 2000, resulting in lower stress. Lagoon and leeward reefs had extremely low coral cover, with higher mortality during the La Niña as calmer conditions in these zones and higher water residence time would have allowed greater heating of the water. Affected coral communities were dominated by massive corals, as branching corals tend to be more vulnerable to bleaching and mortality. Low levels of coral bleaching were observed, though at the time of surveys, in June 2001, it was common in other parts of Fiji. Crown-of-thorns starfish were common on windward and channel sites of the NAR, with high numbers of feeding scars seen. Coral species richness was recorded as 148 species, compared to a national list for Fiji of 210 species.

The algae community was taxonomically typical of Fijian reefs with all 46 species previously recorded for Fiji. Mobile invertebrate populations were low reflecting the impact of intense harvesting of once-abundant resources. Bivalves and sea cucumbers were the most abundant invertebrate groups, and found primarily in lagoon sites with high runoff and/or sediment bottoms. Fish populations were low throughout the study sites (116±101 per 250m^2, mean±stdev), though highest on the NAR, and on leeward and windward reefs. Evidence of fishing was seen in the generally low populations and small fish sizes, the scarcity of preferred fish such as snappers (*Lutjanidae*) and rabbitfish (*Siganidae*) and the high abundance of fish such as fusiliers (*Caesionidae*) and surgeonfish (*Acanthuridae*). Sharks and other large predatory fish targeted by fisheries were scarce, and found mostly on channel and windward sites due to their low accessibility. Fish species richness was recorded at 249 species, in 24 families and 3 higher level groups.

The main threats to the GAR and NAR were identified as climate change induced coral bleaching, crown-of-thorns and overfishing. Coral populations on leeward, lagoon and channel sites were so strongly affected by mortality in 2000, that all other habitat comparisons were swamped by this one event. Recovery of reefs in the GAR and NAR will depend heavily on recruitment of new corals, and the existence of source reefs where reproduction is high. The less-impacted windward barrier reefs may prove critical for recovery of the decimated lagoon and western parts of the GAR and NAR. Emerging hypotheses on the role of such reefs that are resistant or resilient to temperature related coral bleaching point to their importance for the long term survival of coral reefs subject to further temperature-related threats caused by global climate change. Because of this potential long term importance, windward barrier reefs should be considered a first priority in a conservation management plan, with protection granted to 50% of more of reefs in this zone. Crown-of-thorns (CoTs) were observed at moderate abundance on the NAR, and in the light of past COTs outbreaks in Fiji, should be monitored carefully. Further surveys may be necessary to establish the health of the windward barrier reef of the GAR, to ensure that COTs have not spread from the NAR.

Fishing is identified as the principal local threat, and primarily to the GAR. The cessation of fishing boats visiting the NAR from Suva, due to the loss of economically viable stocks has relieved fishing pressure on the NAR. The GAR is primarily fished from villages within the *tikina*, and continues to face high fishing pressure. Continuing pressure on reef fish populations in the lagoon and on the accessible leeward reefs will continue to result in degradation of the environment. For invertebrates as well as fish, several large no-take zones, located in areas important for dispersal and recruitment, will be necessary to rehabilitate these resource populations. The inaccessibility to fishing of windward reefs zones can be used in the designation of no-take zones, resulting in little loss of fishing area. The spillover of adult fish from such protected areas, and recruitment of young fish from adults reproducing in the reserves will be critical to the long term maintenance of reef fish populations for fishing. Dual protection status for windward reefs will further safeguard their integrity and importance for resistance to coral bleaching impacts for the entire reef system.

The development of a management framework for the GAR and NAR will be critical to their future health. The community-based approach already initiated in the Yavusa Ulunikoro Marine Conservation Area of Waisomo village should be expanded to include more and larger no-take areas in all the village fishing areas. Beyond the windward barrier reefs, site selection should focus on representativeness of habitats, consistency with village needs, ease of surveillance and enforcement and new biological information that is relevant.

Of the many components of a management plan required to be effective, those that focus on fisheries management (area and seasonal closures, fishing restrictions, etc.) in a co-management framework will be most important to long term sustainability of conservation. As part of this, and reflecting the need for more information on this large and diverse reef system, participatory monitoring can provide substantial benefits in the development of successful management. In the context of Fiji's national priorities for coral reef management and conservation, the GAR and NAR, and the communities that depend on them, can expand their role as flagship reefs and villages for co-management.

Introduction

Fiji is made up of approximately 300 islands and islets (100 inhabited), which contain only 180,000 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% (equivalent to 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). Fiji reefs are recognized as being of high ecological significance from a biodiversity standpoint (Zann 1992; Zann *et al.* 1997), and research has recorded 198 species of scleractinian corals, 15 zoanthids, 123 species of gastropods from 12 families, 60 species of ascidians and 1900 species of fish from 162 families (Fiji Government 1999). These numbers are likely to increase with greater sampling of Fiji's reefs. Most authors find it difficult to describe Fiji's coral reefs because of the scattered and very limited scientific data available. Of these, however, the Great Astrolabe Reef is perhaps one of the best known, having been reported in primary literature (Littler and Littler 1995; Littler *et al.* 1997; Morrison *et al.* 1997; Morrison and Naqasima 1999) and featured in studies of fisheries impacts on Fiji's coral reefs (Jennings and Polunin 1996a, b, c).

The Great and North Astrolabe Reefs are found on the northeast and northern end of the Kadavu island group, which is situated approximately 70km south of Viti Levu, the main island of Fiji. The Great Astrolabe Reef is a barrier reef composed of oceanic ribbon reefs, which encompasses seven main islands with fringing reefs – Ono, Buliya, Dravuni, Vurolevu, Yaukuvelevu, Namara, and Vanuakula. The lagoon characterized by soft bottom sands has a network of patch reefs in an average depth of 20m, and maximum 37.5m (Morrison and Naqasima 1999). Windward and leeward barrier reefs vary considerably in relation to prevailing wind and waves. The North Astrolabe Reef is an isolated circular atoll with a lagoon is characterized by soft bottom sands and small patch reefs, approximately 10km north of the Great Astrolabe Reef. Solo, a rocky peak of a volcano situated in the middle of the lagoon has an abandoned lighthouse perched on it.

The Great Astrolabe Lagoon, lying within the Ono *tikina* (district), is the only site listed in the Fiji's National Biodiversity Strategy Action Plan (NBSAP) for Kadavu Province (Fiji Government 1999). The NBSAP is a document the government has drafted with its stakeholders to meet Fiji's obligations under the international Convention on Biological Diversity, and demonstrate its commitment to preserving the country's biodiversity. The 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 that require protection and management.

In addition to their diversity, coastal and marine ecosystems such as the Great and North Astrolabe Reef ecosystems provide subsistence, livelihood and income for coastal communities. In recent times traditional systems of natural resource use and management have been eroding, especially with the shift from subsistence living to a cash economy becoming more prevalent, and as communities absorb 'modern' concepts and ideals. In Pacific island countries such as Fiji, where over 98% of its territory is ocean, coral reefs are recognised by resource owners as a valuable resource to meet their modern-day needs.

While resource limitations are increasingly being felt and acknowledged by communities, there is little scientific data and information to make good management decisions on the conservation and sustainable use of marine resources and habitats at either a local or national level. Over the last decade, the failure of conventional and legislated marine reserves to protect intrinsic, cultural, economic and biological values marine ecosystem, has motivated resource communities to want to define and manage their customary fishing areas. This has led to increased efforts to strengthen and incorporate traditional management regimes, particularly in isolated islands where under-funded and under-staffed authorities cannot adequately police the use of marine resources and other marine-based activities.

To support these efforts, World Wide Fund for Nature (WWF) South Pacific Programme commenced a project in 1997 to work with communities in the province of Kadavu to assist them with the design and implementation of marine reserve areas and 'no-take' zones as a means for protecting coral reef and adjacent ecosystems within customary fishing areas (*i qoliqoli)*. The success of Waisomo village in establishing a community-managed marine protected area (MPA) in the Great Astrolabe Reef, has led to a surge of interest by other communities both within and outside the Ono *tikina* to develop a similar management system within their own *i qoliqoli*.

Detailed surveys of Waisomo Village's MPA were conducted from 24-28 April 2001 by the University of the South Pacific. Surveys were conducted inside and outside of the MPA, in two blue holes and on back reef slopes. The aim was to assess the impact of 'no-take zones' on the coral reef community compared to the control unprotected areas. Benthic cover, invertebrate and fish data collected in the Waisomo surveys is combined in this report with data from the wider geographical area. A full description and analysis of the Waisomo surveys is contained in Sauni (2001).

At present, the University of the South Pacific manages a research station situated on Dravuni Island within the Great Astrolabe Reef ecosystem. Research carried out over the past decade has provided some understanding of the physical and biological environment of the Great Astrolabe lagoon and leeward facing barrier reef.

Morrison and Naqasima (1992; 1999) undertaking water and sediment quality and biological monitoring in the Great Astrolabe Reef lagoon between 1989-1992, found that reefs in the lagoon was healthy and relatively unimpacted by pollution, though localized depletion of resources was noted at sites more accessible to local villagers. Prior to this, the only major study on these reefs focused on lagoonal fish and community fisheries (Emery and Winterbottom 1991). Since 1989, smaller studies have been undertaken including the description of a unique coral reef formation of fungiid corals, (Littler *et al.* 1997), assessment of heavy metal levels (Morrison *et al.* 1997), inventories for algae (South 1991) and molluscs (Koven 1997), and recording of fishing strategies and resource use (Vuki 1991; Jennings and Polunin 1996a; 1996b) within the Great Astrolabe Reef system.

Despite these research efforts, the Great and North Astrolabe Reef remain complex ecosystems for which there is still insufficient current scientific information to develop a management regime that will protect the biodiversity and ecological integrity of these reefs, and the fisheries resources which communities rely on. Previous sites that have been surveyed by Morrison and Naqasima (1992; 1999) and the expansion of protected areas for conservation, need to be reassessed, especially in the aftermath of mass coral bleaching event in the year 2000 (Cumming *et al.*, in review).

Methods

Marine biological surveys of coral reefs in Kadavu were conducted from the 29 April – 3 May, 2001. All surveys were undertaken on SCUBA using standard long term monitoring techniques (adapted from English *et al.* 1997) to obtain a description of the structure and biological diversity of these reefs. To cover as wide an area as possible, two survey teams, each with 4-5 divers, operated simultaneously at adjacent study sites using inflatable dinghies from the 120-foot vessel M/V NAI'A. Primary sampling was conducted at 12-15 m depth, with transects being laid along the depth contour.

The names and geographical location of all sites surveyed on the Great and North Astrolabe Reefs are shown in Table 1 (pg 79) and Figure 1 (pg 63). The Great Astrolabe Reef is from this point on abbreviated to GAR, and the North Astrolabe Reef to NAR

Data was collected in the following areas:

- Reef structure,
- Benthic community structure, using video transects, and visual assessment of coral condition, particularly bleaching,
- Invertebrate and fish diversity and abundance, using 50m belt transects,
- Large indicator fish abundance, using general searches, and
- Diversity surveys of algae and hard corals.

Reef Structure

Site descriptions and reef profiles were recorded at each site focussing on reef topography and general benthic community characteristics. This information was used to define the main habitat features of the sites, such as slope and substrate types, and as a reference for video transect analysis.

Benthic Community Structure

Quantitative data on benthic cover was obtained at all sites using underwater digital video, using a method adapted by Obura (Stone et al. 2001). 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. During playback, the video 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. Five transects were analysed for each individual site. The cover categories used for video analysis are shown in Table 2 (pg 80).

Observations on coral condition were made for corals that showed some evidence of stress, e.g. bleaching or crown-of-thorns starfish (COTs) feedings scars. Categories for bleaching status used were: 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 (Obura, pers.obs.), but is limited to places where only one mortality event is known to have occurred. These conditions were true for this part of Fiji due to the widespread mortality already reported for the 2000 bleaching event (Cumming et al., in review), so the "old dead" category is interpreted to represent mortality in 2000.

Summaries of benthic community structure are presented of the Waisomo MPA and adjacent unprotected sites, reported in Sauni (2001) and conducted just prior to these surveys of the GAR and NAR. Line intercept transects were used, thus the data is not compared directly with video transect data collected here.

Invertebrate and Fish Populations

Benthic invertebrates and fish were surveyed using belt transects of 50m length by 5m width. Three divers were used in establishing and recording transects. The transect was laid by the diver counting fish, to avoid scaring off the shy fish species. They were followed by the diver counting invertebrates, after which the line was taken up in the rear by an assistant.

The identity (to genus or where possible to species level), number and sizes (using a tape measure) were recorded for the following key invertebrate groups: sea-cucumbers, lobsters, giant clams, and crown-of-thorns (COTs, *Acanthaster planci*) starfish. General searches (outside the transects) were also undertaken at some of the sites, and included additional groups such as oysters, starfish and T*rochus* spp. These groups were chosen because of their importance as commercial or subsistence resources in Fiji, or in the case of the COTs, the potential impact of elevated populations on reefs.

All large non-cryptic diurnally active fish families were censused, with the exception of the damselfish (*Pomacentridae*) and wrasses (*Labridae*), due to their abundance and small sizes. A single pass was done of each transect. Size was recorded in 10cm size classes, starting with a minimum size of 10cm.

General searches were conducted for a short-list of 33 prominent reef fish, which are often missed by transects due to their low abundance, shy behaviour and/or wide ranging movement. These included sharks, rays, fast-swimming pelagic fish, barracuda, snappers, groupers, Maori wrasse and fusiliers. Fish were counted by a single observer who covered a larger area and depth than the other data collectors.

Algae and Coral Diversity

Benthic macroalgae were collected by hand using SCUBA. 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 3. 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.

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 (1986, 2000) and a working list of Fijian coral species (E. Lovell pers.comm.)

Statistical Analyses

Datasets were entered and stored in Microsoft Excel spreadsheets, statistical analyses conducted in JMP and the R Package, and figures prepared in CricketGraph (all on a Macintosh platform). Descriptive statistics (number of samples, mean, standard deviation) are presented for all variables, with multi-factorial Analyses of Variance (ANOVA) where appropriate. Multivariate analysis was conducted using cluster analysis and Principal Components Analysis to illustrate groupings among the data. Factors used in analysis are influenced by geomorphology and habitat structure of the GAR and NAR, as well as on sampling and methodological constraints imposed by this survey versus that of Sauni (2001) (Table 3, pg 80).

Comparisons with Waisomo MPA and Unprotected Areas.

A similar, though not identical survey was applied in the Waisomo MPA and adjacent unprotected sites by Sauni (2001). Reef morphology differed between the two studies, as this survey focussed on lagoon, channel and east and western barrier reefs, while Sauni (2001) focussed on backreef and blue hole environments. Methodological differences also occurred, relevant to benthic, mobile invertebrates and fish. Line Intercept Transects (LIT) were used for benthic surveys, instead of video transects, as applied here. The two methods yield similar results for cover of large recognizable benthic forms (e.g. hard corals, sponges and soft corals, but can be different in the ability of the observer to record more cryptic and smaller benthic forms (e.g. algae, rubble; M. Schleyer pers.comm., D. Obura, pers.obs.). For fish, Sauni applied belt transects of 25*5 m and sampled a smaller list of fish families. Invertebrates, other than crown-of-thorns starfish, were excluded. To enable fish comparisons with this dataset, two of Sauni's fish transects were combined to achieve the same area as used here, and because of the smaller fish sample, results are not treated statistically, and mainly by visual comparison.

Results

Reef Structure

The GAR and NAR reefs are classic reef complexes, with steep rugged windward and leeward slopes, extensive deep lagoons with coral backreef margins and intermittent patch reefs, and vertical and sloping channel walls. Five major reef types were observed (Figure 2), including leeward and windward barrier walls, channel edges, back-reef margins, lagoon patch reefs, and blue holes. A common feature to both windward and leeward barrier reef walls was extensive development of pinnacles and bommies, leading to complex three-dimensional structure and a maze of steep-sided channels into the reef framework (see detailed site descriptions, Appendix 2).

- ***Leeward Barrier walls*** (Figure 2.1, pg 63) – the western sides of the GAR and NAR con sisted of steep outer walls from <1m to 25-40m depth, grading into rubble slopes into deep water. In places, the outer walls were broken up into complex pillars and bommies. The tops of the eastern walls were hard substrate, generally flat, and up to 100m wide, and the inner lagoon walls were vertical to about 20m depth, where the sand and/or the rubble slope of the lagoon started. On the GAR, the reef flats were interrupted by several channels.
- ***Windward Barrier walls*** (Figure 2.2, pg 63) – the eastern sides of the GAR and NAR were similar to the leeward sides, but with greater complexity and development of pillars and bommies, and high hard and soft coral cover. The reef flats were very broad, typi cally >100m wide and uninterrupted by channels.
- ***Channel edges*** (Figure 2.3, pg 63) – the channels in the leeward reefs of the GAR and northern edge of the NAR had vertical and sloping edges. Vertical walls were similar to the inner and outer walls of the leeward barrier changing into slopes below 20m, drop ping off to maximum depths of 30-50m in the centers of the channels. Sloping edges were a mix of rock walls and ledges, with sand and rubble slopes in between.
- ***Lagoon patch reefs*** (Figure 2.4, pg 63) – lagoon patch reefs were isolated rocky reefs rising from >30m in the lagoons, or on rocky spurs extending down from islands in the GAR.
- ***Back reef slopes*** (Figure 2.5, pg 63) – back reef slopes on the inner edges of the eastern barrier reefs had gentle slopes of hard, rubble and soft substrates extending from the reef flat at <1m to >30m depth. Hard substrates and coral communities were more highly developed at <15m, with occasional large rocky outcrops and coral heads >4m in diam eter.
- ***Blue holes*** (Figure 2.6, pg 63) – blue holes are large 'sinkholes' or pools typically found at the inner edge of the reef flat, to depths of over 20m and diameters of 100m or more, containing hard and soft substrate reef communities. On the GAR, 3 such holes are found to the east of Ono Island.

Benthic Community Structure

Overall, reefs in the GAR and NAR were dominated by coralline algae, at levels of 43% cover (Figure 3, pg 64). Hard coral cover averaged 12.5%, while soft corals were only 2% and dead coral 2.8%. Algal turf, rubble and sand all varied around 10-15%.

Highest coral cover was found on windward reefs (25%) and lowest at leeward, lagoon and channel reefs (5-10%). Coralline algae was most abundant (50-60%) at windward, leeward and channel reefs, with low levels (<30%) on lagoon reefs. Rubble and sand were only found on lagoon reefs where there were sufficient flat surfaces to catch the particles, while the other reefs were too steep (e.g. leeward and lagoon walls) and/or were subject to high water circulation (e.g. windward and channel reefs) that are not suitable for rubble and sand. For the GAR and NAR sites, in spite of the many differences among cover types, habitat differences were only statistically significant (Table 4, pg 80) for soft coral, coralline algae and rubble, while reef differences were significant for soft coral and algal turf. There was no significant interaction between reef and habitat.

Sites within the Waisomo area were different from other sites in the NAR and GAR (Figure 3 pg 64), with higher values for live and dead coral, rubble and sand (differences in methodology prevent a statistical analysis of differences). Live and dead coral cover were significantly higher within the MPA sites compared to the unprotected sites (Figure 3, Sauni 2001, pg 64).

Coral Community Structure

Coral cover was highly variable among the sites surveyed (Figure 4, pg 65), though with non-significant differences by reef and habitat (Table 5, pg 81). The percent composition by coral morphology is shown in figure 5. Massive corals were dominant, followed by a variable mix of submassive, encrusting, branching corals and *Acropora*, with plate and mushroom corals the least abundant. The abundance of different coral morphologies varied by habitat, shown in an ANOVA of abundance by reef, habitat and morphology (Table 5, 81). Principal components analysis of sites by colony morphology showed 3 main groups (Figure 7, pg 67)– the MPA and unprotected sites at Waisomo (with high levels of bleached and mushroom corals), a second group mainly comprised of windward barrier reef sites (dominated by branching corals and *Acropora*) and a more diverse third group of lagoon and leeward sites with abundant massive, submassive and encrusting corals. Leeward sites had the lowest diversity of growth forms (Figure 6, pg 67). Comparing the Waisomo MPA and unprotected sites, the former had a higher relative abundance of branching and bleached corals.

A total of 16 families, 52 genera and 148 species of corals were identified during the expedition (Table 6, pg 81, Appendix 4, pg 49). The family Acroporidae had the highest number of species, followed by the Faviidae, Agariciidae and Fungiidae. The species list compares favourably with a current list of 210 species for corals in Fiji (Lovell, pers.comm.).

Coral condition was noted for colonies showing bleached or pale tissue and/or evidence of recent mortality (Figure 8, pg 68). A total of 54 records were noted, dominated by the three genera *Acropora*, *Pocillopora* and *Porites*, which comprised 63% of all records. *Acropora* tended to show highest levels of mortality and even levels of normal, pale and bleached tissue, *Pocillopora* showed higher levels of bleaching and normal tissue and lower mortality, and *Porites* showed highest proportion of normal tissue with some pale tissue, low bleaching and low partial mortality. Less frequently, bleaching was observed in the genera *Astreopora*, *Sinularia*, *Pachyseris*, *Montipora*, and *Platygyra*, as well as an anemone species.

The incidence of other threats to corals, such as crown-of-thorns starfish (*Acanthaster planci*), the corallivorous snail *Drupella* and incidence of diseases were also surveyed. No evidence of *Drupella* or coral diseases were seen. Crown-of-thorns starfish were seen and recorded at a number of sites (see later section) and feeding scars were also found. The prevalence of feeding scars was highest on the NAR windward and channel sites, with low incidence of scars at other sites.

Invertebrates

The diversity and abundance of invertebrates was low. An average of 1.7 species per transect was recorded, with a maximum of 5 at Yamotubalavu and Yanuyanu-i-usau. All sites except one had densities of <5 individuals per 100m^2, with the highest density of 20 per 100m^2 being found at Yamotubalavu (Figure 9, pg 69). The most abundant invertebrate taxon recorded was the oyster genus *Lopha*, principally due to the high density at Yamotubalavu (Figures 9, 10, pg 69). The high current and nutrient conditions at the site are ideal conditions for filter feeding oysters, with the two most abundant taxa recorded being *Lopha* spp. (12.8±3.3 per 100m^2) and *Hyotissa hyotis* (3.3±3.3 per 100m^2). Second in overall abundance to *Lopha* spp. was the crown-of-thorns starfish *Acanthaster planci*, which was one of the most widely distributed of the invertebrates recorded.

ANOVA of invertebrate species density was conducted by reef and habitat, but was only meaningful for two species with large enough numbers to provide interpretable results (Table 7, pg 82). All *Acanthaster planci* individuals in transects were found on the NAR in all reef zones, with highest densities on the windward and channel sites. The sea cucumber *Bohadschia argus* was found only in channel and lagoon sites, on both reefs, hence the significant interaction and reef zone factors. Oysters were widely distributed but with no significant differences between reefs and zones, though the high abundance of *Lopha* spp. at Yamotubalavu skewed the data to show a preference of lagoon sites.

General searches for invertebrates outside of transects were carried out at 17 of the sites, and yielded higher diversity figures of 1 to 7 species per site (Table 8, pg 83). The greatest diversity and number of individuals recorded was at Solo Lighthouse and NAR South Lagoon. The higher diversity of invertebrates at these sites included giant clams, sea cucumbers and oysters. The sites with the lowest diversity and numbers of individuals included NAR Lee South and Narikoso North.

Overall, sea cucumbers were the most diverse invertebrate group sampled, with 10 species spread among four genera, *Bohadschia*, *Stichopus*, *Holothuria* and *Thelenota* (Table 9, pg 83). A single individual of a possibly undescribed species in the genus *Actinopyga* (Gustav Pauly, Yves Samyn, David Pawsen, pers.comm.) was photographed at Naigoro Passage. This species has been recorded from Tonga, and appears most closely related to *Actinopyga flammea*, known only from New Caledonia (Gustav Pauly, pers.comm.). The greatest numbers of sea cucumbers were recorded at NAR Southern Lagoon and Yamotubalavu. No sea-cucumbers were recorded at Naigoro Inner, Herald Outer South, NAR Southern Point, NAR Lee South and NAR Eastern Point. The three most abundant species were *Bohadschia argus* (14), *Stichopus chloronotus* (12) and *Thelenota anax* (9).

Crown-of-thorns starfish were the most abundant starfish, but were only found at windward and channel sites on the NAR. The highest abundance was observed at NAR Southern Point (Table 10, pg 84) at depths ranging from 2-35m. Weather conditions limited the amount of time spent doing general searches for invertebrates at the site, and several more other individuals, as well as many feeding scars were seen at the site. All individuals recorded were adults with sizes ranging from 15 to 60cm (Average = 37.6cm; Std.Dev.=10.88, Table 13). *Choriaster granulatus* was observed only at Yanuyanu-i-sau.

Twenty-one giant clams (tridacnids) were recorded at 9 of the sites, over half of which belonged to the species *Tridacna squamosa* (Table 11, pg 84). The maximum number of giant clams recorded at any one site was only 5 individuals observed at Herald Outer South. While the NAR lagoon was reputed to support a large adult population of giant clams, very low numbers were recorded in most of the sites surveyed in the lagoon. Good sandy and small patch reef habitat was available in the lagoon for species such as *T. squamosa,* which has the ability to attach itself to rock or a sandy substrate.

The most abundant genus of oyster was *Lopha*, for which 76 individuals were recorded, principally at Yamotubalavu (51, Table 12, pg 84). It should be noted that large numbers of oysters (*Hyotissa spp.*) were also observed at Yamotubalavu, but time restrictions limited the amount of data that could be collected. Sizes of *Lopha spp.* ranged from 15 to 35cm (Table 13, pg 85).

Fish

Fish transects were sampled at 42 sites, yielding total counts of 20,300 fish, 249 species, 24 families and 3 other higher level groups (i.e. sharks, rays and 'unknown'). Due to differences in methodology between the Waisomo MPA study (Sauni 2001) and this one, data could not be directly compared statistically, though general patterns will be interpreted.

The abundance of fish populations varied considerably among sites (Table 14, pg 86), from peak levels of 465 fish/250m^2 at the NAR Lee site to < 30 fish/250m^2 at 7 of the 9 sites sampled at the Waisomo MPA and adjacent control (unprotected) sites. Differences among site abundances were not significant (One Way ANOVA, excluding Waisomo sites), due to high variance in abundance among replicate transects at all sites. One more transect per site is predicted by a power analysis to be sufficient to show differences. One particularly large influence on variation was due to two species of acanthurid, *Zebrasoma scopas* and *Z. veliferum*: the four sites with the highest standard errors (NAR Windward, Vanuakula Outer Barrier, Western Barrier and Narikoso South, Table 14, pg 86) each had records of large numbers of the two species, which were otherwise widespread in small groups or singly. The number of families and species of fish recorded at a site were positively correlated with abundance ($r=0.55$ and 0.58 respectively).

Patterns of reef fish abundance, family and species diversity were not consistent among reefs and zones (Figure11, pg 70) for the GAR and NAR. ANOVA of the three variables showed that variation among them was not statistically significant (Table 15, pg 87). Comparing the same variables among MPA and adjacent control sites (unprotected backreef and blue holes) with the overall data for the NAR and GAR (Figure11, pg 70) showed significant differences (Table 15, pg 87). The MPA site had a marginally higher fish abundance than the adjacent unprotected sites (Figure11, pg 70), though this is small and not significant (Sauni 2001).

Fish were identified to species level during sampling, and aggregated at the family level for analysis. The acanthurids (surgeonfish) and caesionids (fusiliers) were the most abundant fish families (Figure 12, pg 72) and significantly higher than others (ANOVA $F=9.0$, $p<0.01$). All other fish families had high variation in numbers among individual sites such that though average abundance declined over a broad range (Figure 13, pg 71), differences were not significant.

Figure 13 (pg 72) presents the abundance of the more abundant fish families by reef and zone. The high standard error bars are clearly seen, highlighting the variability of fish density among transects at a site and among sites. The acanthurids, caesionids, anthiids (fairy basslets, in the grouper family) and mullids (goatfish) are clearly shown as the most abundant fish. The main fish families targeted for fishing, the lutjanids (snappers), lethrinids (emperors), haemulids (sweetlips) and siganids (rabbitfish) were not very abundant at any of the reef zones. Invertebrate feeders – the balistids (triggerfish), tetraodontids (puffers and porcupinefish), pomacanthids (angelfish) and chaetodontids (butterflyfish) – were the least abundant, with very large standard error bars.

Cluster analysis of fish abundance data (Figure 14, pg 73) shows that there are consistencies among reefs and zones, with the channels and lagoon sites grouping with each other, and the NAR outer sites on the leeward and windward sides being most dissimilar from the other sites.

Of the 10 most abundant fish species 8 were acanthurids and caesionids (Table 16, pg 87), with one species each of anthiids (the fairy basslets, within the grouper family) and lethrinid (emperors). The 10 most abundant fish species accounted for 50% of the fish censused, another 95 species accounted for another 45% of the fish, while the remaining 5% of fish was split among the remaining 147 species.

Fish Sizes

Fish size was recorded in 10cm size classes, to examine the size distribution of fish, and to enable biomass calculations in the future. The largest 6 species were all elasmobranchs, including a manta in first place at 2.2m long and sharks and an eagle ray between 1 and 2m. The largest finfish were the Maori wrasse (*Cheilinus undulatus*, 90cm), the dogtooth tuna (*Gymnosarda unicolor*, 70cm) and barracuda (*Sphyraena qenie*, 70cm). These species comprised the large fish, being located on the steep beginning of the curve (Figure 15, pg 73), numbering 22 individuals in all, and a maximum of 8 individuals in any one species (white-tip sharks). The remaining fish species were predominantly small, and numbered over 16,500 (in Figure 15, pg 73). The most abundant species, with over 1,000 individuals each, were *Ptercaesio tile* and *P. triluneata* (both fusiliers, family Caesionidae), both of small average size (<20cm).

The size class structure of 2 of the most abundant species, *Zebrasoma scopas* and *Ctenochaetus striatus* (Table 16, Figure 16), and 2 fishery target species, *Lujanus bohar* and *Monotaxis grandoculis* (Figure 17) are shown for illustration. In both *Zebrasoma* and *Ctenochaetus*, populations are dominated by fish in the 10-15cm size class with almost no fish >20cm in size. This compares to potential maximum sizes of 40 and 26 cm, respectively (Lieske and Myers 1994). *Z. scopas* is a schooling herbivore, with highest densities recorded at two MPA Sites and an outer windward reef on the NAR. Both of the fisheries species, *L. bohar* and *M. grandoculis* were most abundant at the Waisomo MPA and adjacent sites, but fish were predominantly small (<25-20cm and <15-20cm, respectively). The largest individuals of *L. bohar* were found at channel sites (41-60cm). These sizes compares to potential maximum sizes of 90 and 60 cm, respectively (Lieske and Myers 1994).

Large Indicator Fish

Of 33 large indicator fish species that were counted in general surveys, the highest diversity was found at NAR North Channels (22 species, Table 17, pg 87), followed by NAR Southern Point (18) and several GAR channel and windward sites (13-16). Inner sites in the GAR had the lowest diversity of these fish, with 6 or less. Of these 33 species, 19 species were of large predatory fish that were not adequately sampled in fish transects (Table 18, pg 88).

The North Channels site on the NAR had the highest abundance of sharks, followed by Solo Lighthouse and Eastern Point, both also on the NAR (Table 19, pg 88). Pelagic fish and barracuda were most abundant at reef passages on both the NAR and GAR and on windward and leeward sites (Table 20, pg 89). Interestingly, two lagoon sites adjacent to populated islands – Yamotubalavu and Yanuyanu-i-sau – had higher populations of pelagic fish than some of the other more exposed sites.

White-tip sharks were the most abundant sharks (Table 19, average of 1.6 per dive, seen at 11 of the 15 sites censused, pg 88), followed by grey reef sharks (0.67 and 5, respectively). Other sharks and rays were rare, being sighted on only 1 or 2 occasions. The most abundant pelagic fish were striped mackerel, rainbow runner and bigeye trevally, which schooled by the hundreds at some sites. Barracuda species were seen at 3 or less sites, with some large schools.

Discussion

The Great and North Astrolabe Reefs, part of the Ono *tikina* at the northeastern tip of Kadavu Island, are a complex and highly developed reef system stretching some 50km north-south and 15km east-west. The surveys reported here, conducted from 29 April – 3 May 2001 by a team supported by the WWF South Pacific Programme, revealed a number of patterns that are summarized in Table 21. Implications of these findings are discussed in the subsequent sections.

Comparison of North versus Great Astrolabe Reefs

Reefs in the NAR appeared to be healthier and more intact than those of the GAR. Benthic communities and coral diversity were highest on the windward sides of the NAR. Only one GAR windward site was surveyed due to sea conditions, though a COTs survey in February 2001 on the windward reefs south of the GAR established that coral cover and diversity were high there (Mangubhai 2001). Further surveys are desirable to establish the health of the windward barrier reef of the GAR..

Overall, fish populations in the NAR were higher than in the GAR, particularly in the lagoon and leeward reefs that are vulnerable to fishing. The windward reefs had more similar fish populations. Noticeably, fish abundances in the single channel into the NAR were less than the channels in the GAR. The NAR has historically been fished by fishermen from Suva (J. Korovulavula, pers. comm.), though declining fish catches in recent years have led to fishers targeting other more distant reefs. By contrast, the GAR is more heavily targeted by fishers living within the Ono *tikina*, from the villages on Dravuni, Buliya and Ono islands, resulting in continuing pressure on reef fish populations in the lagoon and on the accessible leeward reefs. As a result, GAR fish populations were noticeably more depressed than NAR fish populations.

The greater size and complexity of the GAR over the NAR was seen in the more abundant and diverse fish communities in the channels in the leeward barrier reef, as well as in the unusual fish species encountered at some sites (such as of schooling jacks at the passes and adjacent to the islands at Yamotubalavu).

Habitat Comparisons

Analysis of data from the surveys was organized by habitat, contrasting windward barrier reefs, leeward barrier reefs, reef channels and lagoon/backreef communities. Windward and leeward barrier reefs had the most complex topographic structures often with pillars and bommies forming a maze of water channels, though some individual sites were monotonous walls or slopes. Lagoon sites had the lowest structural complexity, with many sites being gentle slopes with small, mostly dead coral heads. As a result, diversity and abundance of corals and fish was highest on the windward sites. Coral populations on leeward, lagoon and channel sites were so strongly affected by mortality in 2000, that all other habitat comparisons were swamped by this one event.

Coral Bleaching and the Current Status of the GAR and NAR

Coral bleaching in 2000 apparently affected almost the entire GAR and NAR, probably with levels over 80% mortality at some sites in the lagoon and leeward reefs. At the time of these surveys, approximately 1 year following the mortality, overgrowth of coral skeletons by algal filaments, coralline algae and a soft mat of microbial and algal filaments was evident. Little bleaching was observed during this expedition, in spite of the passage of a high temperature anomaly in the region that caused observable bleaching to other parts of Fiji, Samu Reef near Lautoka and the Lomaiviti Group (Obura and Mangubhai 2001).

Lowest levels of coral mortality were observed on the windward and east-facing reefs of both the GAR and NAR, where prevailing winds carry cooler oceanic water to the reefs from the south and east. Nevertheless, bleaching and mortality were significant in waters shallower than 10m, but below 15-20m coral communities were healthier, with larger colonies and higher species diversity than in the shallows. By contrast, dead corals were observed at 30m and greater on the leeward barrier reefs and in the lagoons, where water mixing is less and water resident in the lagoons had more time to heat up before flowing over leeward reefs.

Optimistically, the surviving corals on the eastern barrier reefs will re-populate the lagoon and western sites by transport of larvae with the mass flow of water from east to west. As a source for repopulation, these sites may be critical for recovery of the decimated lagoon and western parts of the GAR and NAR. Emerging hypotheses on the role of such reefs that are resistant or resilient to temperature related coral bleaching point to the importance of these reefs for the long term survival of reefs subject to further temperature-related threats such as global climate change (Salm *et al.* 2001).

Fishing

The fish populations of the GAR and NAR were noticeably affected by fishing, with low densities at almost all sites, averaging 112±101 per 250m^2 (Figure 11, pg 70). The low abundance of fisheries species (snappers, emperors, sweetlips and rabbitfish) was noticeable, as was the lack of large predatory groupers, jacks and sharks. The high abundance of herbivorous acanthurids and other low-trophic-level fish is also indicative of overfishing of higher trophic levels (Jennings and Polunin 1996a).

As indicated earlier, the NAR is more affected by fishermen from Suva, who have now abandoned that reef in search of less impacted ones elsewhere. The GAR is more heavily utilized by local fishermen from the islands within the reef system, with no alternative fishing grounds to use. As a result, fish populations in the GAR are more impacted than those on the NAR, and more predators such as jacks and sharks were observed on the NAR. It was also highly noticeable that windward reefs had more abundant and diverse fish populations than lagoon and leeward reefs, due to the inaccessibility of the sites and the more risky conditions there.

Invertebrate populations were uniformly low throughout the sites sampled, save for small areas with high abundance of oysters. The site sampled at Yamotubalavu was on a ridge reef in a pass between two islands, and is likely to receive high influx of nutrients from runoff from the islands, as well as high water exchange, factors that would promote the growth of filter feeders such as oysters. Resource invertebrates, including giant clams, sea cucumbers and lobsters were extremely poorly represented in the surveys, though habitat suitability is high, and they have previously been reported at high abundance's prior to heavy fishing pressure. As with fish, several large no-take zones, located in areas important for dispersal and recruitment, will be necessary to rehabilitate these resource populations.

Combined with the absence of corals following bleaching and mortality in 2000, the absence of normal reef invertebrate and fish populations gave the GAR and NAR the appearance of a highly degraded reef system.

Crown-of-thorns, *Acanthaster planci*

A COTs outbreak has been reported for the NAR since August 2000, part of a series of outbreaks that have hit Fijian reefs predominantly around Viti Levu since 1979 (South and Skelton 2000). In this study, high densities of crown-of-thorns were seen on windward and channel reefs of the NAR, with abundant feeding scars, as well as in the Waisomo MPA (Sauni 2001). While the numbers seen were not at outbreak levels, they were high enough to show significant degradation of the coral communities, and lower coral abundance. Coupled with last year's bleaching event, it is possible that the present levels of crown-of-thorns starfish on the NAR sites and in the Waisomo MPA may lead to further degradation of the reef community, potentially with negative effects on reef resources.

The Waisomo Marine Protected Area

A detailed assessment of the MPA and adjacent sites is contained in Sauni (2001), in which the higher coral cover within the MPA compared to control sites, and the marginally higher fish populations in the MPA are noted. Broader surveys of the GAR and NAR showed, however, that while coral populations within the MPA are high (due to a combination of habitat and protection, as well as impacts of the bleaching event in 2000 to other sites), fish populations are lower than at all sites beyond Waisomo in the GAR and NAR. This may reflect the long history of intense fishing in the newly protected MPA and an inadequate time for recovery since protection started.

A number of other considerations are also implied, that may influence future management at the site and other parts of the GAR and NAR. These are:

A. The blue hole sites are a different habitat from all other sites on the reefs, being deep pools in the reef flat. They may therefore have different ecological dynamics, and in particular related to the abundance and diversity of fish that can be contained in them. The more open reef slopes in the lagoons and on the outer edges may have larger fish populations because of their greater depth, diversity of micro-habitats and greater water exchange.

B. The blue holes are also very limited in area, and may be too small to effectively retain fish protected from fishing pressure. If these fish can easily swim to the edges of the protected zone and out, they are likely to be caught before the population of fish inside the MPA has a chance to rebuild. While this spillover of fish out of an MPA is a desirable character for enhancing fisheries adjacent to the MPA, if the MPA is too small to build up an internal fish population, full benefits of protection will never be achieved (McClanahan and Mangi 2001).

State of the NAR and GAR

The effect of the 2000 La Niña on coral communities in the GAR and NAR was severe. Many sites had coral cover of less than 5%, and several less than 1%. Historically, the GAR has been reported as being a prime coral reef with abundant resources and dynamic reef communities (Morrison and Naqasima 1999; UNEP/IUCN 1988). Particularly striking on this expedition, were the fields of dead staghorn *Acropora* colonies on the back reef slopes at Narikoso, and recognizable dead corals overgrown with algae on all surfaces – all stark testaments to the extreme degradation of the reefs.

In addition to the effects of the La Niña, the fish populations of the reefs have been noticeably decimated by fishing, with the GAR more impacted than the NAR, due to the proximity of several villages dependent on fishing as a way of life. Attempts to protect reef areas and rehabilitate fish stocks in the Waisomo MPA are timely and necessary, but they may be on too small a scale to have any impact on the whole reef. Expansion of a system of fisheries protection sites is a necessary precondition to improvements in the state of the reefs.

Lastly, coral mortality by crown-of-thorns starfish is noticeable at the sites on the outer NAR where coral cover is highest following the La Niña mortality. At normal coral densities the COTs may not be at threatening levels, but with the low coral cover due to the bleaching in 2000, the sites affected appear to be badly impacted by COTs and potentially at levels that may prevent recovery of corals from bleaching.

Rehabilitating the Great Astrolabe Reef?

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. 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.

There is an overwhelming body of scientific research and practical experience in both tropical and temperate seas, which supports the establishment of networks of marine protected areas (MPAs) as effective tools for the conservation of biodiversity, and the replenishment of fish resources (Roberts and Polunin 1993). MPAs can range from areas under complete protection from any forms of exploitation to those which are zoned to allow for a range of uses and users.

The establishment of a community-managed MPA by Waisomo Village demonstrates the opportunity for communities to design conservation and management systems that are culturally appropriate and work within the local context. However, ecological and human boundaries are rarely the same, and threats occurring in one part of the ecosystem can have direct or indirect impacts to other parts. To ensure the biological and ecological integrity of the Great and North Astrolabe reef ecosystems as a whole, and to ensure its productivity for future generations, requires that a conservation and management plan be developed to include the whole Ono *tikina*, and not just one part of the area under the jurisdiction of one community.

Recommendations

Recommendations for the conservation and management of the Great and North Astrolabe Reefs are divided below into a series of sections that start with ecologically-based management actions, through general good management practices to monitoring of reefs to enable assessment of the success of management and status of the reef. 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.

A conservation and management plan developed for the Great and North Astrolabe reefs should address the following key issues:

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

The GAR and NAR form a large and heterogeneous geomorphological and ecological structure. The core of protection for species and habitats in the reef system, as well as for continued or even improved fisheries production will rely on three areas for action:

- protecting the 'breadbasket' of reproduction and productivity of the system, namely the windward barrier reef system
- protecting a number of sites representative of the remaining habitats – leeward barrier, lagoon, channel, back-reef and blue hole – covering a significantly high proportion of their areal coverage. A figure is not yet established in the scientific literature, but a long term target of 30% would be desirable.
- Establishing workable management practices consistent with local resource users and village organization.

1. Habitat Protection

The distribution and extent of habitat to be protected should vary according to the size and boundaries of different *i qoliqoli* areas. For example, Buliya and Dravuni have considerably larger *i qoliqoli* areas, and hence should be encouraged to contribute a larger portion of their customary resource area for protection within an overall conservation and management plan.

1.1 Full Protection & Habitat Representation

Full protection from all forms of extraction and development should be extended to include the full range of reef habitats found within the Great and North Astrolabe Reefs. These habitats include: (a) outer windward reefs; (b) outer leeward reefs; (c) lagoon patch reefs; and (d) channels. Reefs should be selected on the basis of their biological attributes, community needs, and suitability for protection.

The following areas should be considered for full protection:

Outer Windward Barrier Reef – while sampling in this area was somewhat limited due to weather conditions, it was evident that the windward reef was more diverse and abundant for corals and fish, and had been more resilient to the mass bleaching event of 2000.

Ocean waves and the prevailing wind cause a steady flow of cooler oceanic water (from the surface and deeper levels) to impinge on the windward reefs, resulting in lower sea surface temperatures and lower stress from El Niño and La Niña conditions. As a result, corals suffer less stress from bleaching and fewer die. The reefs therefore recover faster, and also provide a source of corals for more impacted reefs downstream.

Difficult weather conditions (i.e. oceanic swell), limited accessibility (i.e. few channels leading from the lagoon to outside reef) and travel costs are prohibitive for communities and hence there is less fishing pressure on the reef. Thus the windward reefs receive natural protection from fishing, a fact that could be formalized in a Management Plan.

"A proportion of the outer windward barrier reef should be strictly protected, which will be important for the regeneration of lagoon and leeward reefs following bleaching and intensive fishing. A specific proportion cannot be given, but a conservative and precautionary starting estimate could be ~ 50%."

Outer Leeward Reefs - these reefs while generally degraded and more broken up, provide different habitat and host a different reef assemblages. They also harbour large schooling fish populations important for fishing and regeneration of overexploited sites.

"A proportion of the outer leeward barrier reef should be strictly protected"

Lagoon Patch Reefs and Back-reef Slopes – lagoon patch reefs and back reef slopes are important areas for subsistence fishing and form a mosaic of relatively similar patches. All of these sites are in a degraded state due to bleaching and over-fishing.

"A number of patch reefs should be closed to all forms of harvesting to act as seeding areas for adjacent reefs. The decision to close patch reefs within the lagoon should be based on community interests and needs. However, it is recommended that these reefs be located close to communities to ensure compliance, ease of enforcement and to enable communities to monitor differences between closed and fished patch reefs."

Channels/Passages – currents and tidal influence usually make channels and passages productive environments, and can be important areas for spawning and refuge of fish and invertebrate species. Such importance may be limited to certain times and seasons and offer an opportunity for temporary closures (see below). Only one passage exists in the windward barrier reefs, at Naigoro Passage, all the others are in the leeward sides of the reefs.

> "Channels should be protected, either with long term or seasonal measures. Up to half the leeward channels may need protecting. Naigoro Passage, as the only channel in the windward reefs should be strongly considered for full protection."

North Astrolabe Reef – the NAR was primarily used by commercial fishermen from Suva who have moved on to other fishing grounds, while the GAR is primarily used by subsistence fishermen from within the Ono *tikina*. Additionally, given the higher fish and coral populations on the NAR, and the threat from crown-of-thorns starfish on the outer reefs, it may be possible to protect it completely without taking away resources from the local villages.

> "The entire North Astrolabe Reef should be considered for full protection."

1.2 Seasonal or Rotational Protection

A number of reefs could be considered for seasonal or rotational closures. Seasonal closures have a number of benefits, a principal one being that resource users do not have to give up completely access to certain areas. Additionally, closure can be targeted for specific vulnerable life history stages of target organisms to reduce fishing impacts at critical times. For example, seasonal closures are well suited to the occurrence of major spawning events for fish at certain times of the year; or to regulate the duration or intensity of fishing pressures on a particular reef.

The period of closure could vary depending on the objective of the closure. For example, some reefs could be closed for one month a year during major spawning events, while others could be closed for 1-2 year periods and then rotated with other reefs.

> "Consideration should be given to protecting channels with seasonal measures. Using seasonal measures, all sites could be protected during some part of the year."

1.3 Multiple Use Zoning

Overlap between different uses, especially if they are competitive, can potentially be reduced by zoning reefs to allow certain activities in specified areas. A primary objective should be to ensure that community subsistence needs can be met now and into the future. Monitoring differences between multiple-use reefs and fully protected or seasonally protected reefs will be important, and allows management to adapt to changes in the environment.

> "Reefs should be zoned to recognize and allow multiple uses that do not result in long-term detrimental impacts to the environment."

1.4 Bleached versus Non-Bleached Reefs

Coral bleaching has become a far-reaching phenomenon, which has consequences for communities that rely on those reefs as a source of protein and income, and tourism. 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 (Salm et al. 2001). 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, such as the windward reefs in the case of the GAR and NAR, 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.

> "Consideration should be given to protection of key reefs for recovery from coral bleaching, such as to those listed in the previous section (Full Protection and Habitat Representation)"

2. Species Management

While habitat and area protection are becoming key conservation tools for coral reefs, there are a number of other areas for management interventions, particularly with respect to species-based conservation. Resource species in the GAR and NAR show evidence of high exploitation levels, and species-specific control measures may be necessary enable recovery of their populations.

2.1 Subsistence/Commercial Invertebrates

Giant clams (tridacnids) and sea-cucumbers have been heavily fished in the Great and North Astrolabe Reefs and very low abundances were recorded at all the sites surveyed. Giant clams are considered a valuable resource from a cultural, subsistence, local fisheries and tourism perspective. Sea-cucumbers play an important role on coral reefs and lagoon ecosystems in nutrient recycling, and are also a valuable commodity or resource from a commercial perspective. The low species abundances recorded at all sites warrant management at three levels:

A. *Species Closures* – the complete closing of areas for periods of no less than 3-5 years to all forms of harvesting and collecting of giant clams and beche-de-mer. Sites should be chosen which (i) have a variety of species present, and (ii) are in close proximity to villages to enable them to both monitor the recovery of invertebrate populations at the site and to ensure compliance with the closure.

B. *Size Restrictions and Quotas* – compliance with size restrictions as detailed in Fisheries Legislation. Size restrictions in general should be adopted to protect the reproductive strategy of the species in question. Quota systems should be considered for giant clams and sea-cucumbers that have been over-harvested from areas.

C. *Reseeding of Areas* - Given the numbers of giant clams and beche-de-mer are already very low, recovery of these populations is likely to be slow, even with the designation of complete closures on a number of reefs. Reseeding areas is a real option that should be considered with assistance from the Department of Fisheries and regional institutions such as the South Pacific Community. Areas that are reseeded successfully can be used to reseed other areas, meet local consumption and cultural needs (in the case of giant clams), and potentially could later be developed into small-scale fisheries to provide income.

Crown-of-thorns starfish - Elevated populations of crown-of-thorns starfish may consume most hard corals present on a reef, although remnants of corals may be left behind which can regenerate. While the scientific community is still debating the exact cause of outbreaks, natural or man-induced, over-fishing of the starfish's predators has been suggested as a possible link between human activities and outbreak populations (Moran 1986). Given the size and connectivity within and between the Great and North Astrolabe Reefs, options for the management of the areas with elevated crown-of-thorns populations are limited to reducing the over-fishing of the starfish's natural predators or input of nutrients to the marine environment. The natural predators of the starfish include the following:

- Moustache triggerfish (*Balistoides viridescens)*
- Yellowmargin triggerfish *(Pseudobalistes flavimarginatus);*
- pufferfish (*Arothron hispidus);*
- giant triton (*Charonia tritonis*);
- the shrimp *Hymenocera picta*; and
- a worm *Pherecardia striata.*

Consideration should be given to banning the collection of the above species in areas where crown-of-thorns starfish are present in elevated or outbreak numbers.

Fish Populations – low fish numbers and biodiversity warrants consideration of the following management options:

Protection of spawning aggregations – these may vary seasonally and geographically depending on the species in question, but should be considered essential to fisheries management. Information on spawning aggregations should be available within fishing communities, and should form the basis of an initial management plan.

Size Restrictions – compliance with size restrictions as detailed in Fisheries Legislation. Size restrictions in general should be adopted to protect the reproductive strategy of the species in question. It is important to note that small (juvenile) stages and the largest reproductive adults may require protection.

Quotas – where productivity of a resource can be accurately estimated and catch efficiently monitored, quotas assigned per fisherman, boat or village could be used to cap offtake of fish from the reefs. These can be combined with other forms of management (e.g. site restrictions, seasonal closures).

Sharks – shark fisheries are starting to have a devastating impact on populations in the wild. Sharks play an important role at the top of the food chain and their reproductive strategy makes them vulnerable to over-exploitation. Shark harvesting should be banned within the Great and North Astrolabe Reefs.

3. Good Management Practices

Reef and fisheries management need to be developed in a context of good management practices in general, that affect general use of reefs and/or resources other than fish. The following principles could form the basis of the development of good management practices to be adopted throughout the Great and North Astrolabe Reefs:

- Banning of the use of *duva* (or derris root) in the marine environment.
- The installation of moorings at popular fishing or dive sites. Moorings can also be used to demarcate the location of special management areas.
- Banning of bad/poor land use practices that result in siltation, such as clearing, foreshore modification, etc.
- Banning the destruction of corals during fishing.
- Banning of spearfishing at night, when fish are more vulnerable.
- Banning of small mesh nets.
- Appropriate disposal of all rubbish including plastics, cigarette butts, etc.

4. Coral Transplantation Options

Coral transplantation as a rehabilitation tool for reefs that suffered from severe bleaching in 1998, has been trialed in a number of countries. In general, these exercises, while commendable and serve as a useful education tool, can be costly (both financially and time wise) and result in the rehabilitation of relatively small areas. In the GAR and NAR reef systems, large scale coral transplantation is not feasible, but it may be for rehabilitation of small reefs of particular importance to villages, tourism or others. Of particular importance, however, is the health and proximity of source coral populations and the need to ensure that collection of corals for transplantation does not harm source reefs.. In addition, the recent 2000-bleaching event has highlighted the vulnerability of the lagoonal systems of both reefs to mass bleaching and die-off, and the likelihood that transplantation efforts to such habitats may be futile if repeat bleaching events are likely.

4.1 Enforcement

Enforcement of management regulations on reefs the size of the Great and North Astrolabe Reefs is difficult, particularly if the management approach is not founded on the village governance systems. Community rangers or fish scouts may be a viable option for surveillance and reporting of infractions. However, strong co-management measures are necessary to ensure enforcement follows up on reports, requiring clear roles and responsibilities among the local chiefs, Fisheries Department and law enforcement officers.

4.2 Management Structure

A management body should be established for the Great and North Astrolabe Reefs, with representation from all seven communities comprising the Ono tikina - Buliya, Dravuni, Narikoso, Nabouwalu, Naqara, Vabea and Waisomo. Each village would need to define its own working group at the village level, to address their community views and needs.

A technical group should also be established to provide support and guidance to this management group as required. The technical group should include representatives from Kadavu Provincial Office, Fisheries Department, Department of Environment, Ministry for Tourism, NGOs such as WWF, the University of the South Pacific, and the commercial tourism sector.

4.3 Monitoring Programme

Ecological and resource monitoring are necessary components of successful conservation management, and reefs with the size and complexity of the Great and North Astrolabe Reefs pose a strong challenge to effective monitoring. To be cost-effective and practicable, a monitoring programme will have to include some scientific components and some participatory components, linked through a common, hierarchical sampling strategy and specified levels of resolution. Monitoring can cover ecological components, species and resource dynamics, resource extraction and socio-economic areas. The development of coral reef and resource monitoring in the Ono tikina should be firmly founded in customary tenure and rights, while also integrated with national monitoring programmes (South and Skelton 2000).

Options for monitoring include:

- Volunteer and tourist-based monitoring through the dive industry and local citizens clubs. A number of methods have been developed in various parts of the world, and ReefCheck is already active in Fiji, with a network and national coordinator.
- Fishermen's participatory monitoring has great potential for generating data, and facilitating the process of co-management between users, fisheries officials and scientists (Obura et al. 2002). In the context of Fiji's well-developed customary marine tenure system, this should be a central component of long term monitoring strategy in the GAR and NAR.
- Traditional scientific monitoring, carried out as a higher-level and verification exercise for volunteer and participatory monitoring, is a necessary component to ensure data quality and assess trends identified in the overall monitoring programme. Partnership with the University of the South Pacific and linkages with the Global Coral Reef Monitoring Network should be developed to support this component of monitoring.
- Additional areas for monitoring can include species programmes (e.g. for endangered or vulnerable species, or specialized resource species), fisheries catch monitoring, socio-economic monitoring and others.

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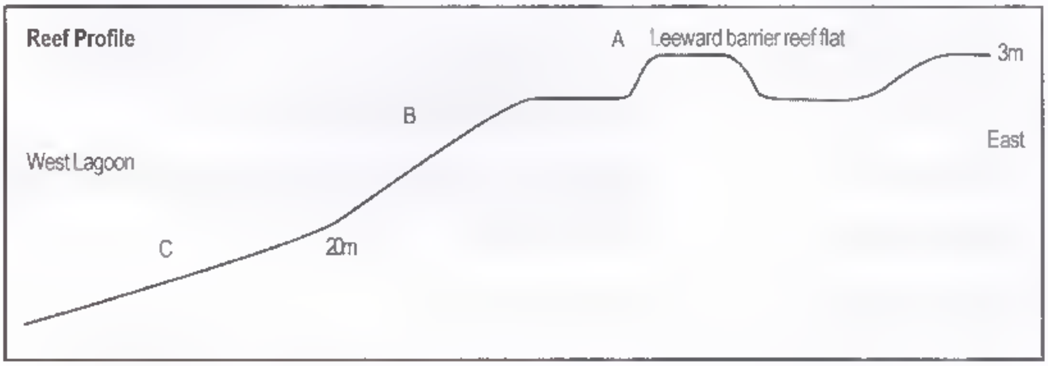
Appendices

Appendix 1: Expedition Members And Survey Responsibilities

Method	Participant
Benthic cover/state	
-Video transects	Bruce Thayer/David Obura
-Visual assessment	Ed Lovell
Coral diversity	Ed Lovell, David Obura
Bleaching/condition	Ed Lovell, David Obura
Invertebrates	Sangeeta Mangubhai, Etika Rupeni
Fish	
-Belt transects	Samasoni Sauni, Etika Rupeni, Helen Sykes, Joseph Korovulavula
-Large fish surveys	Cat Holloway
Algal collection	Sangeeta Mangubhai

Appendix 2: Detailed Site Descriptions from Surveys undertaken on the Great and North Astrolabe Reefs, Kadavu, Fiji.

Site	Type	Date
Naigoro Inner	Back reef flat and slope	29 April 2001

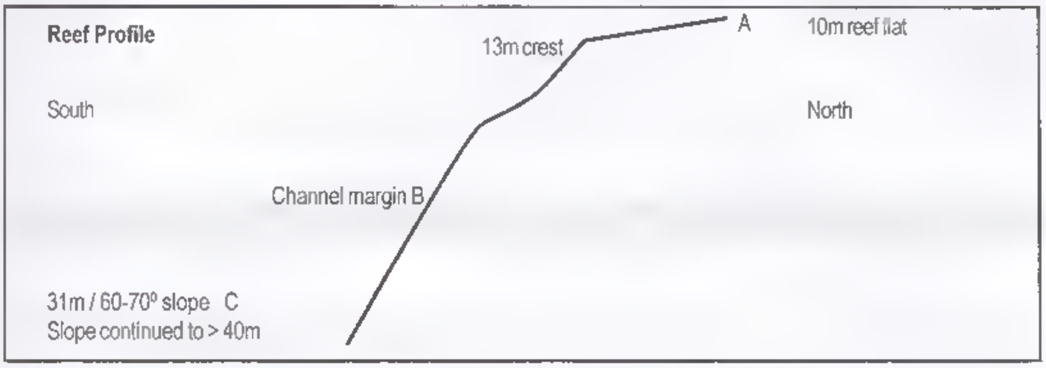


Located just inside Naigoro Passage, the survey began at 12m depth but inspection ranged down to 20m and up to the top of the reef flat at 3m. The substrate was predominantly reef rock with coral outcrops, boulders, sand and rubble talus below. High coralline algae on the exposed rock but low macroalgal cover, was noted. Thin turf algae and *Halimeda* occurred on the reef slope.

No coral bleaching was observed. Some colonies had white dead areas but were probably a result of predation, though no crown-of thorns starfish or Drupella were observed during the survey. Elevated numbers of crown-of-thorns starfish have been reported by resort owners and communities residing in the area in January 2001.

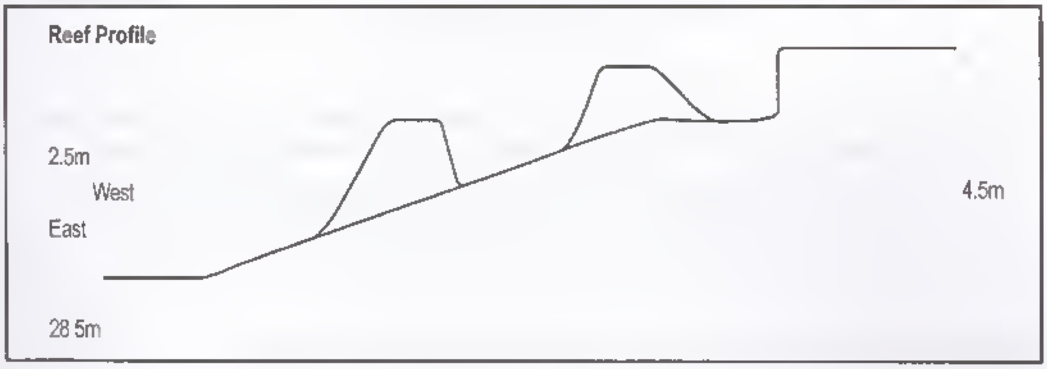
Death from the bleaching event of 2000 was evident by the large dead colonies of *A. clathrata and A.hyacinthus (*many evident in the shallower water). Generally the living coral was abundant and showing good luxuriance. Survival and good coral growth is attributed to the proximity to the passage, which is characterised by substantial tidal, and wind generated currents. A large tabulate *A. cytherea* which was largely killed by the bleaching, appeared to be recolonised by surviving living tissue which was progressively recovering the surface with a prominent margin.

Site	Type	Date
Naigoro Passage	Back reef flat and channel margin	29 April 2001



Large surface areas of rock were generally uncolonised. Sea-whips and soft coral were common throughout, while hard coral was more prolific at 15m, though *Acropora* species did not monopolize at this depth. In general, there was good overall diversity with most coral living and healthy. Coralline algae was the dominate substrate at the site, though encrusting *Montiporas* were also notably present. Some *Halimeda* and surface turf.The crest at 12.5m was dominated by *Acropora*, particularly the large branching species. Dead plates and large areas of dead standing coral were evident from the year 2000 bleaching event, and rubble was abundant on the horizontal reef flat. With large coral mounds and outcrops. Large *Porites* colonies were the major feature of the reef flat.Slope increases from 45 to 75°, into channel. Deep, is rock w. sand/ rubble channels, w. incr. HS into shallows. Dominated by Acr, Por, Mtp - also good sea fan/ Antipath in > 15 m

Site	Type	Date
Narikoso North	Back reef sand margin	29 April 2001
Narikoso South	descending into the lagoon	
Nakoro		30 April 2001



The reef flat of the barrier reef is at a depth 2.5m. This drops abruptly 2m to a sand bottom with rubble and boulders strewn on the back sand apron. Large *Porites* and *Diploastrea* colonies present and abundant (10-15m between them). Large patch reef-like bommies present. Apron descended to 28.5m and leveled with no rubble or boulders.

Widespread bleaching death evident behind the reef flat. 5% 0f the colonies were alive. Extensive 'forests' of dead *Acropora grandis* still standing. Some minor bleaching observed on *A. muricata*, with new growth evident already.

Small Astreopora and faviid 'ball' heads common

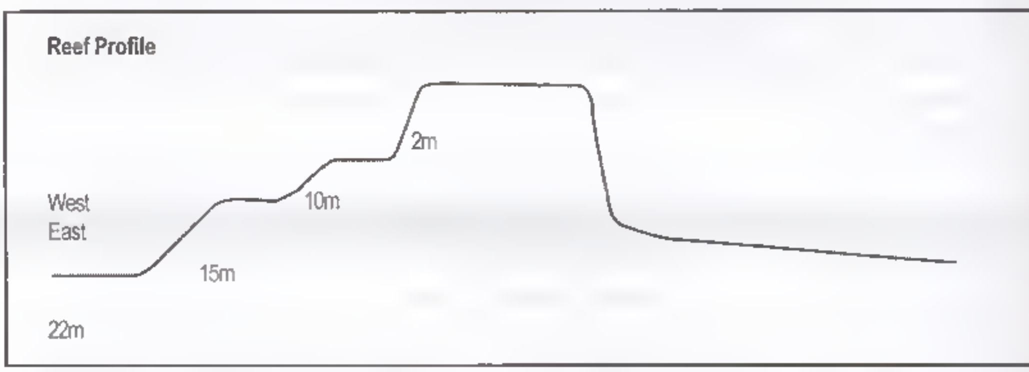
shallow lagoon HS/rubble patch reefs and staghorn thickets on sand. 12 to 4 m deep. V. degraded, prob. Suffered 90%+ mortality in 2000 bleaching

Nakoro
Lagoon patch reefs of hard substrate and staghorn on sand. From 10 m. to 25, corals/heads dispersed on sandy bottom. Similar to Narikoso North, slightly less mortality.

Site	Type	Date
VatiVati Point	Fringing reef slope	30 April 2001

Fringing reef, from 2 to 23 m. Very degraded HS.rubble top, increasing rubble/sand w. depth, to sloping sandy bottom. Long filamentous algae, > 90% mortality, from dead standing corals. Porcyl, porrus, pocdam in shallows, others deeper

Site	Type	Date
Kawakawa Reef Yamotubalavu	Lagoon patch reef, inter-island ridge	30 April 2001



Kawakawa Reef

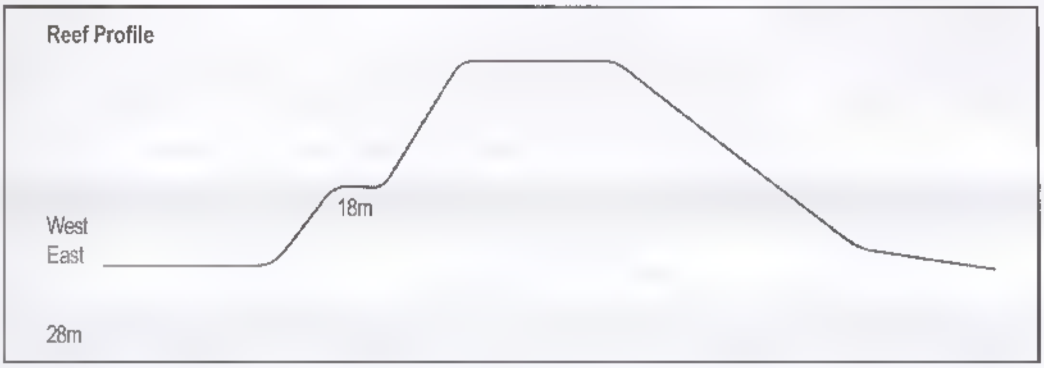
Rising off of a horizontal sand bottom, the patch reef has steep relief with two prominent steps on the west side. The east side much steeper. The vertical relief give rise to lots of sand and rubble spilling down the side of the reef often in sand or rubble laneways. Outcrops are covered with dead standing coral, which has presumably died from the 2000-bleaching event. These are dramatic 2m high thickets of *A . grandis* which are now dark and algal covered. Presently, corals on the reef top are bleached. These include all of the *Acropora* and *P. eydouxi.* As well, *A. selago* occurs on the reef slope.

No COTS, 2 Tridacna squamosa, Alcyonarians or Gorgonians not common.

Yamotubabalavu
Shelf reef on a ridge running between adjacent islands, the top is mostly hard substrate and rubble, with high cover of dead coral. At edges of ridge, drops down to flat/gently sloping sandy bottoms with scattered corals, maximum at 18 m. Calcareous algae and Halimeda abundant on sandy bottom. Thick filamentous algal mats on dead coral surfaces – collected for ID, and photographed on video. High turbidity.

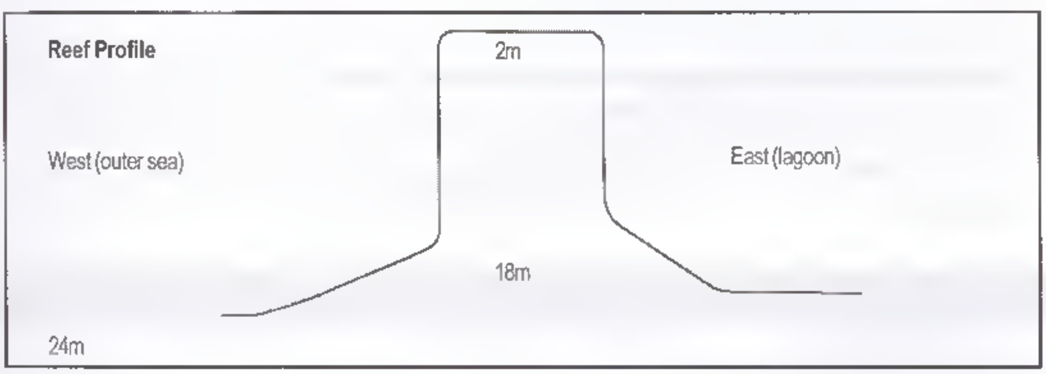
Hard substrate and rubble shelf and reefs, to sandy bottom at 20 m. Small coral heads in crevices and rubble, reef top a hard platform with dispersed large bommies, some large Porites heads (3 m). Very degraded

Site	Type	Date
Buliya Patch Reef	Patch reef	30 April 2001



Site much like the previous lagoon patch reef. Similar dead stands of *A. grandis* but much of the thickets on the east side are alive. Steeper relief on the western slope. 15% heavy bleaching on reef top. 30% living coral comprised principally of *Porites*, Faviidae, Acropora and Diploastrea. The latter represented by large colonies. On the reef top, the dead standing coral was 50% and the sand was 10%. *A. echinata* abundant at 18m.
No bleaching on slope. Sand seabed at base of 29m. Interesting that area deeper than 15m is more turbid, cloudy with suspended silt.

Site	Type	Date
Buliya Western Barrier Buliya Passage-inner Buliya Barrier	Western barrier reef	30 April 2001



This area is located on the western perimeter of the lagoon. It is the a single reef patch in the broad channel that exists to the south of the main barrier (Alacrity Rocks??). Pinnacle-like barrier patch reef. Top at 2m depth. Sides of reef vertical on west side (18m) and near vertical on east. The reef margin extends to depths greater than 24m as an uneven surface with ridges and depressions. Very little colonization of the rock substrate. Coral and other organisms on the face typically encrusting. Large banks of branching rubble at 20m depth indicate that colonies that may have died from the coral bleaehing and the skeletal components removed by storm wave action of cyclone Paula.

Deeply shelving into passage (south face), beyond 40 m. with large rock ridges. Large live Acropora thicket at 28 m. depth. Water turbid on lagoon side and strongly layered with clearer water on top. Low diversity and cover on lagoon side, deeply fissured rock with good cover at seaward edge of channel.

Buliya Passage Inner

Vertical walled inner and channel edge to 20 m, shelving sand with rock butresses and ledges to 35 m, channel bottom sand, continuing slope. Soft corals under deep ledges

Buliya Barrier

High vertical relief - pillars and bommise at edge of barrier reef edge, all tops about 2-3 m. deep. Complex topography. V. degraded, with high rubble at base of pillars/walls and into deeper water

Site	Type	Date
Dravuni Patch Reef	Reef patch West of Dravuni I., GAR	1 May 2001

The site is located to the southwest of Dravuni I and detached from the fringing reef. This is a turbid back island environment. Reef mound with undefined edge. Large massive *Porites Lobophyllia* colonies. Small reef patches on sand away from the patch reef. Lot's of small colonies on the reef and surrounding rubble were observed indicating active recruitment. 5% bleaching of *Acropora* and *Pocillopora*. Dead standing coral from the 2000 bleaching evident. Only small Acropora colonies present. Visibility 15m. Large *Diploastrea* 4m diameter. Large colony of *Pavona clavus* which was bleached. 20% coral cover.

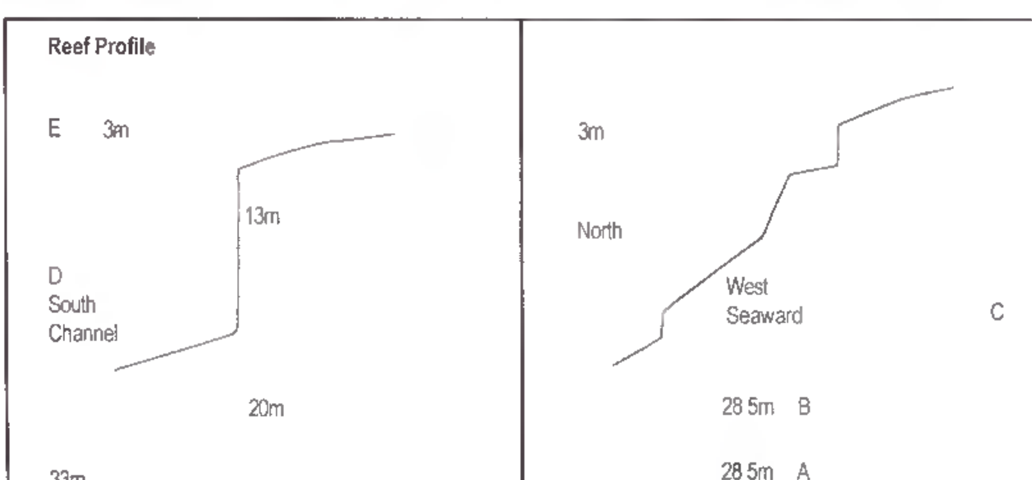
Site	Type	Date
Yanuyanu-I-Sau	Fringing reef	1 May 2001

The site is located to the north and west of Yanuyanu-I-Sau Island. The reef is fringing, dropping from shallow platforms to a gentle rocky slope to 30 m, with increasing cover of sand in channels. Very highly degraded with Acropora grandis skeletons covered with filamentous algae. 100% mortality of Acropora occurred, with no live colonies seen down to > 25 m. Increasing abundance of fungiids with depth.

Colonies/bommies, down through rock ridges and sand channels to 20 m, and open sand/rubble plain with coral heads from 25 m. Very degraded w. heavy fil.algae growth on corals. Close to 100% coral

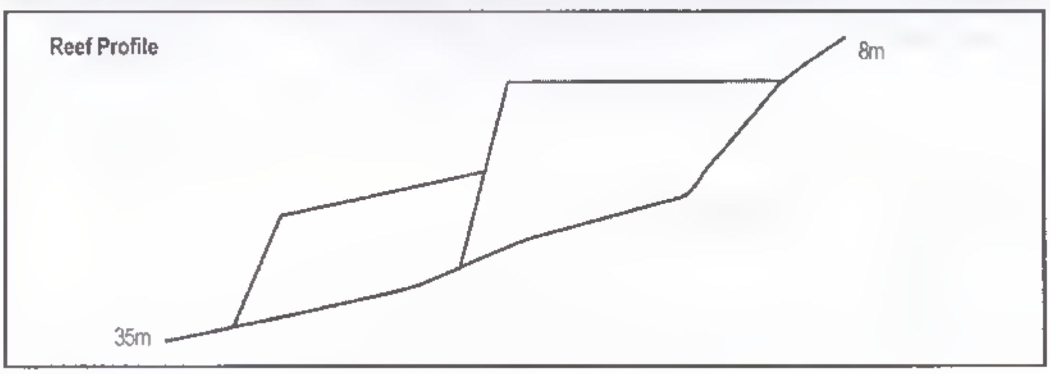
1 COTs observed.

Site	Type	Date
Herald Passage North Herald Passage South	Western barrier outer slope	1 May 2001



This reef borders the western Herald Channel. It is the southern end of the barrier reef. Sites on the north and south sides of the channel were sampled, which is characterized by a vertical wall, descend to 20m to the slightly sloping floor. Rubble and boulder on the sandy, rubble floor of the channel with a depth of 33m. Water colder at channel floor 84° F. The vertical wall is characterised by surface sediment. Several troughs and canyons in the barrier wall function in the transport sediment into the lagoon from the reef crest. Soft corals proliferate on the reef flat, and small corals common. Common genera were *Porites, Diploastrea, Pocillopora verrucosa, and Millepora.* Some of the *Porites* were bleached. Lot's of dead coral on the crest. Western or seaward reef front slopes to a vertical 2m notch at 28.5m, bordered by a rubble/ boulder strewn floor descending to depth. On the southern side, bommies/pillars from 15 m. to 3m depth broke up the barrier wall. Large amounts of rubble in shallow canyons at sloping base of reef > 25 m, evidence of high storm/hurricane damage

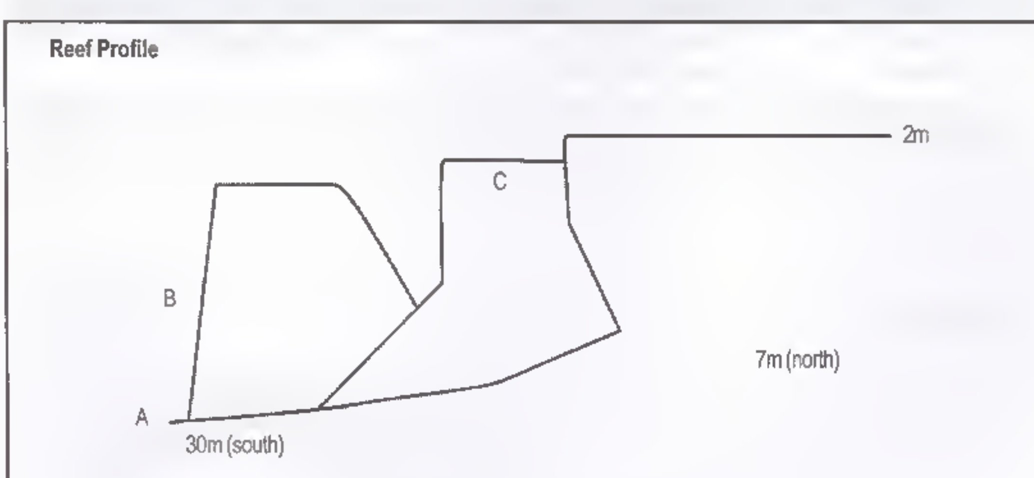
Site	Type	Date
Vanuakula Island	Fringing slope	1/5/2001



Western border of Vanuakula Island – very accidented and dramatic, with steep drops and promontories. Coral mortality very high, with < 1% live cover and expanses of dead *Acropora* colonies. At 20+ m, slopes become gentler with rubble or sandy bottoms, continuing into deep water. To 25 m. v. craggy cliffs with Acropora plates/staghorn (dead) - v. spectacular.

Search for Littler et al fungiid reef - unsuccesful. Searched around the W and SW side of the island

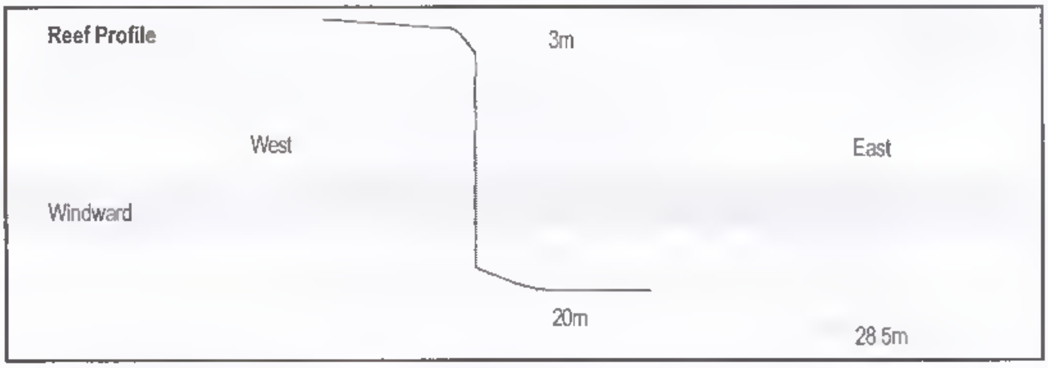
Site	Type	Date
Usborne Passage		1 May 2001



This location is the Usborne Passage, the next passage north of Alacrity Passage. Low coral cover on reef face and reef flat. Reef margin very irregular and complex with a steep face that is broken with small short channels which is characterised by overhangs, arches and caves. Large reef bommies occur to seaward. The reef descends to 7m on the south side, margined by a sand bottom, and to 30 m. and over on the north side. Large colonies of club-like *Pavona clavus*, and common genera include *Diploastrea, Montipora, Porites*. Abundant fish on the reef front and within the channels. 10% coral bleaching evident on the reef top of the 20% living cover. Substantial dead material evident on the reef top and to 10 m..

Very dramatic pinnacles, bommies and complex barrier reef edge, with vertical wall from 20 to 35 m. Life similar to other bommies

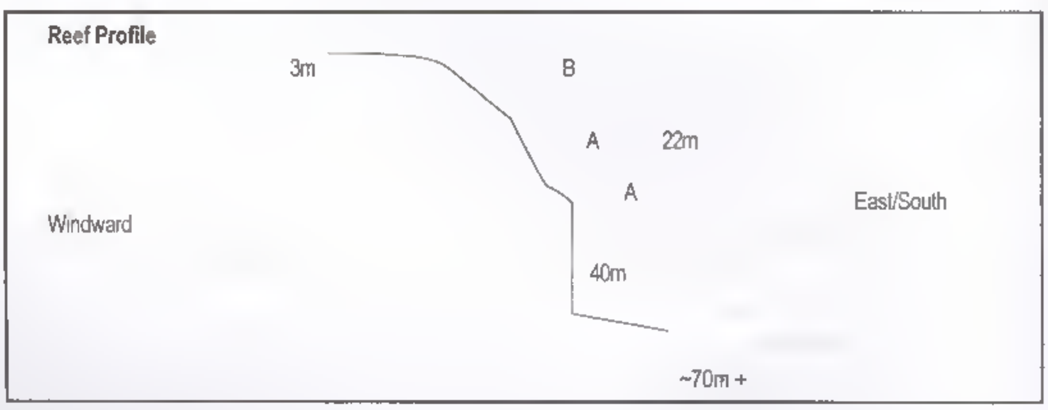
Site	Type	Date
Dravuni North Outer GAR Windward	Windward reef front	2 May 2001



This area is on the northeast seaward face of the barrier, southeast of D'Urville Channel. Reef face descends vertically to talus band of rubble slope at 20m. At 28.5m, the bottom leveled out to a sandy horizontal bottom. Coralline L Orange Disease (CLOD) was seen several times. Lots of dead coral on reef flat with 30% live coral cover. Living coral cover increased to 40% on the wall. The living cover increases to 60% when soft corals and *Millepora* are included. Wall has little relief though many holes and ledges.

-Complex bommies and reef front, to 10-2 m below surface, wall from 15 - 35 m, rubble slope below. Luxuriant coral growth in < 20m, on sides/tops of bommies- hanging Acropora, plates, etc. Tops of bommies w. dead coral, but significant regrowth

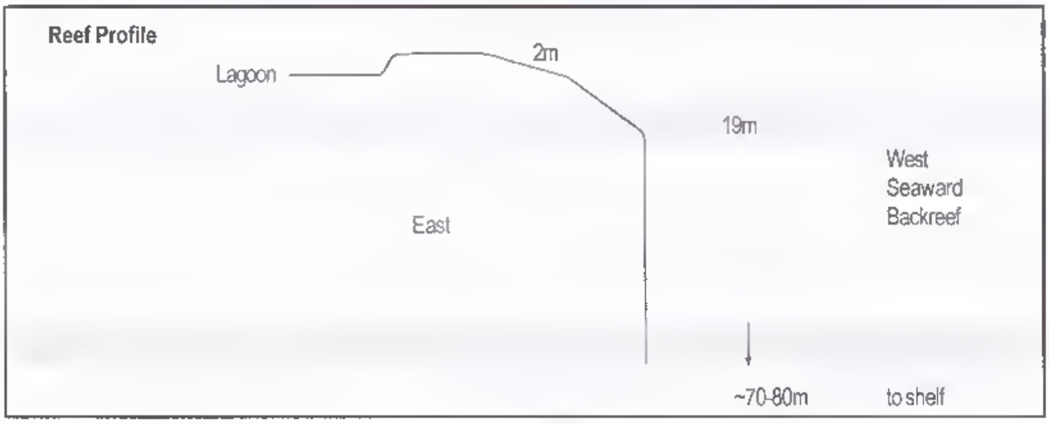
Site	Type	Date
NAR Southern Point NAR Windward	Windward reef front, North Astrolabe Reef (NAR).	2 May 2001



These sites were located on the southeast of the North Astrolabe Reef (NAR). At the reef flat crest (4m), there was widespread death from bleaching. 25% living cover on reef flat. Reef slope was less at 20° before it drops away vertically to substantial depths. The greater slope gives rise to substantially more wave surge than at the GAR, where the reef wall was vertical. The slope descends to 22m where it drops more steeply to 40m and then vertically to an estimated 60-70 terrace. Horizontal parts of the slope with high abundance of rubble and high coral mortality. On the slope at 15-20m, 8 COTs could be seen within a 5m radius. Many COT's were reported by divers at both sites. *Stylophora*, generally absent in the lagoon and elsewhere, was present.

Steep walls in shallow/deep w. intermediate hard/rubble slope (15-30 m), high energy. Coral impacted by 2000 EN, plus current COTs infestation (low level). Entered at edge of high wave zone, drifted to lee.

Site	Type	Date
NAR Lee South	Western back reef and slope	2 May 2001
NAR Lee North		

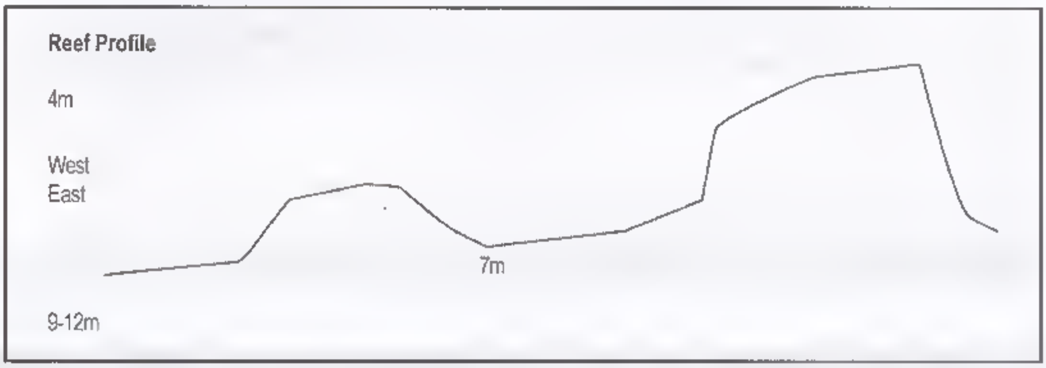


Reef flat largely dead from the 2000 bleaching. Lots of algal covered dead standing coral (40%). 5% of this area has live coral cover comprised of *Porites*, soft coral and *Pocillopora verrucosa*. From the surface there is a slope to a wall, which is vertical and descends to 70-80m from 19m. The wall has irregular surface with the small holes crevices and ledges. Lots of sponges, algae, and 5% coral cover.

Reef top just below surface at 2m depth, with near vertical drop to 20-25 m and slope below that. Reef top with v. high coral mortality and overgrown by brown filamentous/turf algae. At depth (20m), close to 100% mortality of hard corals.

straight wall, from 3 to 35 m. rubble slope below and wall below that. Low coral cover, simple CCA/turf cover, some soft corals. High coral mortality all depths, tops (Acr, Poc) almost 100% dead w. turf/CCA. V. low remnant colonies in shallows - Poc, Pla

Site	Type	Date
NAR Patch reef NAR South Lagoon	Lagoon patch reefs	2 May 2001

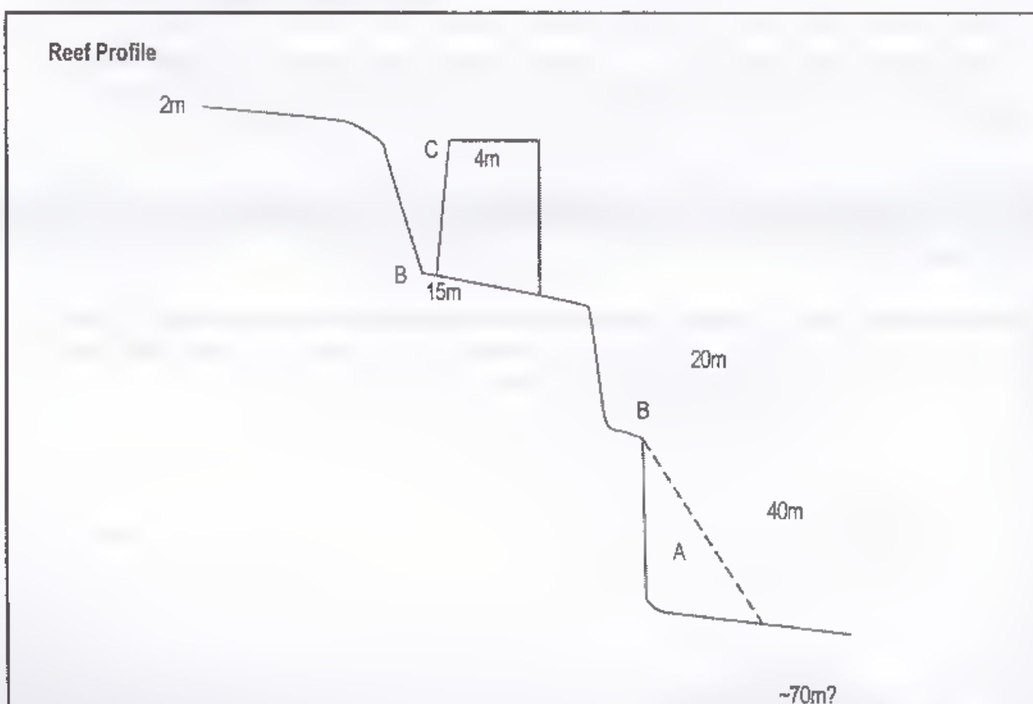


Bommie and associated patches are located within the North Astrolabe lagoon on the sandy bottom behind the barrier reef. These are small reef patches and are surrounded by a sand bottom with the little relief. Several holothurians seen. The reef mounds are characterised by such genera as *Goniopora, Pocillopora, Fungia* and *Symphyllia*. Most of the *Acropora* has died due to the bleaching. The mound substrates are a broken rubble surface. Bleaching death evident of *Acropora grandis* evident. Lots of regrowth from the branch tips is occurring. *Pocillopora verrucosa* also regrowing extensively.

Sandy bottom, increasing depth from edge, bommies and staghorn thickets, mostly dead.

1 COTs seen at NAR South Lagoon

Site -	Type	Date
GAR Windward NW windward front NAR	Windward reef fronts with bommies	2 May 2001 3 May 2001



Similar areas surveyed is on the northwest margins of the GAR and NAR. A steep slope descends from the reef crest to a shelf on which there are several bommies. The reef slope varies from 20%, around the bommies, to 100% down their vertical front faces. A wide (8m) rubble spillway coming off the reef flat and descending to the talus slope was present. The bommies are conical with vertical sides. The reef top is at 4m. The seaward face of the bommies has a minus slope and is undercut at the base.

Lots of dead standing coral (15%) was seen between 15- 20m, though as high as 40% in some areas and presumed killed by the 2000 bleaching event. Abundant live coral present (30%) indicating a healthy reef environment. Small amount of *Acropora* was present, being relatively abundant at GAR windward. Vetical walls of bommies very heavily grown with corals, with an estimated 15% coral cover on the faces.

COT's evident on the NAR, though not in the abundance as observed on the southeast exposed faces of the
NAR. Feeding scares were mainly on the *Pocillopora verrucosa* and some on *Porites.*

NAR Windward

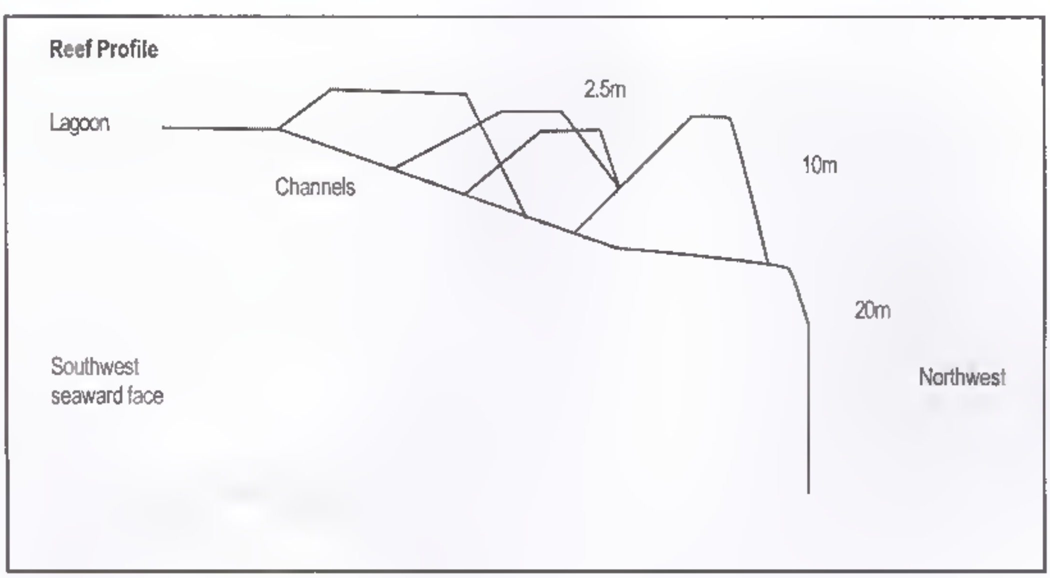
Started just W of rock point. Wall, breaking down to complex bommies/pillars, wall and reef top as on Drav. Windward. Coral mortality high. Fish life quite abundant, possibly from windward tip furthe west.

Site	Type	Date
Solo Lighthouse	Lagoon patch reefs	3 May 2001

Surveyed patch reefs to east and south of Solo Lighthouse, these extended from 5 – 15 m depth. On east side, HS patches and *Acropora* thickets (dead) on sand, changing on the south side to larger expanses of hard substrate with medium size Porites heads and other massive corals. Coral mortality high, but on southern side, relatively high cover of Porites remaining.

Sandy bottom around lighthouse, w. coral bommies, staghorn thickets, Por assemblages. Mostly dead (except Por).

Site	Type	Date
NAR North Channels NAR Outer-Northwest Outer	Windward Barrier with channels	3 May 2001



This area has a similar profile to the other outer barrier sites with bommies, though at his site the bommies and spacing between them are larger. Additionaly, the luxuriance of coral growth in the shallow area (<15m) is greater than at other sites. Channels extend through the barrier reef with coral mounds or bommies evident. The seascape is very irregular <15m. Seaward face descends vertically from 20m and drops away to depth >? 70m. The channels are characterised by sandy rubble. Bleaching death from 2000 is evident on the bommie tops (2.5m) and sides (30%). Little current bleaching but some large Acropora plates showing signs of bleaching. Acropora plates and branching colonies showing healthy growth. (40%). Complex topography of bommies/ pillars, wall and more open areas than East RockFive clams sighted 4 x T. squamosa, 1 x T. derasa.

Appendix 3: Benthic Marine Algae Collected during the Nai'a Cruises Expedition to the kadavu and Lomaiviti Group in the Fiji Islands.

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Introduction

Following is a preliminary report on the benthic marine macro-algae collected by the NAI'A Cruises from 21 April – 3 May 2001, from the Lomaiviti and Kadavu groups in Fiji. The collections were coordinated by Ms Sangeeta Mangubhai, formerly of the World Wide Fund for Nature (WWF) Fiji office, assisted by Dr David Obura, Mr Ed Lovell and Mr Rupeni Etika.

Materials & Methods

Specimens were initially preserved in 4% formal in seawater, and later transferred to 70% ethanol.

Identifications were made using standard light microscopy, with an Olympus SZ40 dissecting microscope, and a BH2 compound microscope. Where required hand sections were made to confirm anatomical details. Sections and small specimens (<2.mm in size) were preserved as microscope slides mounted in 30% corn syrup solution and stained with 1% aqueous aniline blue. Larger specimens (> 2.0 mm in size) were pressed and mounted on herbarium sheets. Specimens are housed at the Phycological Herbarium, South Pacific Regional Herbarium (SUVA-A), and will be accessioned in the Marine Studies Programme Collections database.

Images were taken with a Nikon Coolpix 990 digital camera, and are stored on Zip Discs or CD-ROM. Manipulation of the images was carried out using Adobe Photoshop Version 5.5.

Library resources were provided from G.R. South's collection of phycological books and reprints.

Results

Algae are arranged alphabetically under the four main groups: Cyanophyta, Rhodophyta, Phaeophyta and Chlorophyta. Collection data are provided, where known, and notes on some interesting species are provided. A total of 76 taxa are reported, consisting of 6 Cyanophyta, 36 Rhodophyta, 8 Phaeophyta and 26 Chlorophyta. Of these, three green algae and one red alga are newly reported for the Fiji Islands.

We thank Sangeeta Mangubhai for coordinating the collections, and the staff of the NAI'A Cruises Fiji for facilitating the field work.

Cyanophyta (Blue-green)

Lyngbya confervoides *C. Agardh*

Kawakawa Reef, Buliya, *E. Lovell* 30.iv.2001, Fj 127; Undeniable, Eastern Bligh Water *S. Mangubhai* 23.iv.2001, Fj 145. Herald Passage, Kadavu, *S. Mangubhai* 01.v.2001, Fj 161. A common alga found on recently dead *Acropora* corals or entangled with other macroalgae;

Lyngbya majuscula *(Dillwyn) Harvey*

North Save-a-Tack, Namena Barrier Reef, *S. Mangubhai*, 24.iv.2001. Fj 35.

Lyngbya semiplena *(C. Agardh) J. Agardh*

Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001 Fj 73, Fj 71

***Lyngbya* sp.**

Samu Reef, *S. Mangubhai* 23.iv.2001. Fj 36.

***Schizothrix* sp.**

Cat's Meow, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001. Fj 67.

Symploca hydnoides *(Harvey) Kützing*

Yanuyanu-i-sau fringing reef, Dravuni. *S. Mangubhai* 1.v.2001. Fj 83; Fj 130; Cat's Meow, Eastern Bligh Water. *S. Mangubhai* 23.iv.2001, Fj 94; Site unknown Fj 130.

Unidentified Cyanophytes

FJ 76. Lion's Den, Wakaya, *S. Mangubhai* 26.iv.2001. Fj 91; Yanuyanu-i-sau fringing reef, Dravuni. *S. Mangubhai* 1.v.2001. Fj 86; Cat's Meow, Eastern Bligh Water, *S Mangubhai* 23.iv.2001, Fj 95, Fj 151; Naigoro inside reef, *S. Mangubhai* 29.iv.2001, Fj 115; Teton, Namena Barrier Reef, *S. Mangubhai* 25.v.2001, Fj 120; Site not known Fj 131; Narikoso (north), *S. Mangubhai* 29.iv.2001, Fj 157;

Rhodophyta

Actinotrichia fragilis (Forsskål) Børgesen

Humann Nature, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001. Fj 79. Naigoro Passage, Kadavu Island. *S. Mangubhai* 129.iv.2001. FJ 56; Site unknown *S. Mangubhai* Fj 166.

Amphiroa foliacea Lamouroux

Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001. Fj 75; Fj 89; Naigoro inside reef, *S. Mangubhai* 29.iv.2001, Fj 112; Teton, Namena Barrier Reef, *S. Mangubhai* 25.v.2001, Fj 121.

***Amphiroa* sp.**

Yanuyanu-i-sau fringing reef, Dravuni. *S. Mangubhai* 1.v.2001. Fj 84.

***Antithamnionella* sp.**

Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001. Fj 87; Site not known Fj 140 (epiphytic on Fj 133).

Baliella repens Huisman & Kraft

Site not know. *S. Mangubhai* Fj 167 (living on tube-worm).

Balliella subcorticata (Itono) Itono & T. Tanaka

North Dravuni, Dravuni, *S. Mangubhai* 01.v.2001. Fj 44.

***Carpopeltis* sp.**

North Dravuni, Dravuni. *S. Mangubhai.* 1.v.2001. Fj 47.

Ceramium flaccidum (Kützing) Ardissone

Herald Passage (south), Kadavu. *S. Mangubhai* 01.v.2001, Fj 160 (entangled with *Lynbgya confervoides*.

Ceramium krameri South & Skelton

North Astrolabe Reef Lighthouse, Kadavu. *S. Mangubhai* 02.v.2001, Fj 172 (epiphytic on *Coelothrix irregularis*.

Ceramium macilentum J. Agardh

Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001 Fj 77. epiphytic on *Rhipilia orientalis*; North Astrolabe Reef, Kadavu. *S. Mangubhai* 2.v.2001, Fj 109, Fj 175 (epiphytic on *Coelothrix irregularis*); Teton, Namena Barrier Reef, *S. Mangubhai* 25.iv.2001, Fj 99; Site not known Fj 141 (epiphytic on Fj 133/136);

Ceramium marshallense Dawson
Kawakawa Reef, Buliya Island. *E. Lovell* 30.iv.2001, Fj 128.
Champia compressa Harvey
Teton, Namena Barrier Reef, *S. Mangubhai* 25.v.2001, Fj 123, Fj 101.
Champia parvula (C. Agardh) Harvey
Narikoso (north), *S. Mangubhai* 29.iv.2001, Fj 152.
Chondria dangeradii Dawson
North Astrolabe Reef, Kadavu. *S. Mangubhai* 2.v.2001, Fj 108.
***Chondria* sp.**
Teton, Namena Barrier Reef, *S. Mangubhai* 25.iv.2001, Fj 98.
Coelothrix irregularis (Harvey) Børgesen
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 176 (growing on rock, tetrasporic).
Corallophila apiculata
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 173 (epiphytic on *Coelothrix irregularis*).
***Cruoriella* sp.**
North Dravuni, Dravuni, *S. Mangubhai* 01.v.2001. Fj 45.
***Dasya* sp.**
Naigoro Passage, Kadavu Island. *S. Mangubhai* 29.iv.2001. Fj 55; Teton, Namena Barrier Reef, *S. Mangubhai* 25.iv.2001, Fj 104.
Galaxaura sp.
Cat's Meow, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001. Fj 38.
Ganonema farinosa (Lamouroux) Fan & Wang
Herald Passage south, Kadavu. *S. Mangubhai* 01.v.2001, Fj 163.
Gibsmithia hawaiiensis Doty
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 2.v.2001 Fj 51.
***Griffithsia* sp.**
Site unknown Fj 129. (epiphytic on *Symploca hydnoides*); Site unknown Fj 139.
Hydrolithon farinosum (Lamouroux) Penrose & Chamberlain
Herald Passage south, Kadavu. *S. Mangubhai* 1.v.2001, Fj 158.
Hypoglossum caloglossoides Wynne & Kraft
Teton, Namena Barrier Reef, *S. Mangubhai* 25.iv.2001, Fj 100.
***Hypoglossum* sp.**
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001 (epiphytic on *Coelothrix irregularis*). Fj 174; Site unknown Fj 137.
***Liagora* sp.**
Buliya Passage, *D. Obura* 30.iv.2001, Fj 116.
***Lomentaria* sp.**
Teton, Namena Barrier Reef, *S. Mangubhai* 25.v.2001. Fj 122.
Mesophyllum erubescens
Undeniable, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001, Fj 143; Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.iv.2001, Fj 186
Neogoniolithon frutescens
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 2.v.2001. Fj 182.
Peyssonnelia bornetii
Teton, Namena Barrier Reef, *S. Mangubhai* 25.v.2001, Fj 125.
Pleonosporium caribaeum (Børgesen) R. Norris
Lion's Den, Wakaya Islands. *S. Mangubhai* 26.iv.2001.Fj 78. epiphytic on *Rhipilia orientalis*; Site not known Fj 138 (⊕@&B&); Undeniable, Eastern Bligh Water, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001 (epiphytic on *Polysiphonia* sp) Fj 146.
***Polysiphonia* sp.**
Undeniable, Eastern Bligh Water, Eastern Bligh Water, *S. Mangubhai* epiphytic on 135, Fj 142. Undeniable, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001, Fj 147 (growing on rubble, abundant turf).

Predaea weldii Kraft & Abbott
North Astrolabe Reef, Kadavu. *S. Mangubhai* 2.v.2001, Fj 110.
****Predaea laciniosa*** Kraft
Site not known *S. Mangubhai* Fj 168.
Tolypiocladia glomerulata (C. Agardh) Schmitz
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001. Fj 181 (epiphytic on *Dictyota bartayresiana*).

Phaeophyta

Dictyopteris repens *(Okamura) Børgesen*
Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001, Fj 92; site not known *S. Mangubhai* Fj 170 (epiphytic and epizoic).
Dictyota bartayresiana *Lamouroux*
Naigoro inside reef, *S. Mangubhai* 29.iv.2001, Fj 113; Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 183; Site unknown Fj 136.
Dictyota crispata *Lamouroux*
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 2.v.2001. Fj 48; Lion's Den, Wakaya Island. *S. Mangubhai* 23.iv.2001, Fj 93.
Dictyota friabilis *Setchell*
Undeniable, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001, Fj 144.
Dictyota **sp.**
Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001. Fj 72; Teton, Namena Barrier Reef, *S. Mangubhai* 25.v.2001, Fj 124.
Lobophora variegata *(Lamouroux) Womersley ex Oliveira*
Buliya Island. *S. Mangubhai* 30.iv.2001. Fj 63; Samu Reef. *S. Mangubhai* 21.iv.2001. Fj 66; Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001. Fj 74; Cat's Meow, Eastern Bligh Water, *S. Mangubhai* 25.iv.2001, Fj 96; Site unknown Fj 134, Fj 171.
Padina australis *Hauck*
Teton, Namena Barrier Reef, *S. Mangubhai* 25.v.2001, Fj 117.
Sphacelaria novae-hollandiae *Sonder*
Site unknown Fj 135.

Chlorophyta

Avrainvillea **sp.**
North Dravuni, Dravuni Island. *S. Mangubhai* 1.v.2001. Fj 46.
Caulerpa biserrulata *Sonder*
Narikoso (north), *S. Mangubhai* 29.iv.2001, Fj 154.
Caulerpa brachypus *Harvey*
North Astrolabe Reef, Kadavu. *S. Mangubhai* 02.v.2001, Fj 106.
Caulerpa cupressoides *(Vahl) C. Agardh*
Naigoro Passage, 29.iv.2001. Fj 40.
Caulerpa microphysa *(Weber van Bosse) J. Feldmann*
Naigoro Passage, Kadavu Island. *S. Mangubhai* 29.iv.2001. Fj 57; Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 184, Fj 107; Teton, Namena Barrier Reef, *S. Mangubhai* 25.iv.2001, Fj 105.
Caulerpa nummularia *Harvey ex J. Agardh*
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 177; Teton, Namena Barrier Reef, *S. Mangubhai* 25.iv.2001, Fj 103.
Caulerpa peltata *Lamouroux*
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 2.v.2001. Fj 50, Fj 180; Herald Passage (south), Kadavu. *S. Mangubhai* 01.v.2001, Fj 162.

Caulpera racemosa (Forsskål) J. Agardh var. ***turbinata*** (J. Agardh) Eubank
Naigoro Passage, *S Mangubhai* 29.iv.2001. Fj 39. Solo Lighthouse, North Astrolabe Reef. *S Mangubhai* 2.v.2001. Fj 49.

Caulerpa serrulata *(Forsskål) J. Agardh*
Naigoro inside reef, *S. Mangubhai* 29.iv.2001, Fj 114; Narikoso (north), *S. Mangubhai* 29.iv.2001, Fj 153.

Caulerpa taxifolia *(Vahl) C. Agardh*
Great Astrolabe, Kadavu Island. *S Mangubhai* 2.v.2001. Fj 59; Buliya Island. *S. Mangubhai* 30.iv.2001, Fj 60; Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 185.

****Caulerpa webbiana*** Montagne var ***disticha*** Vickers
Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001. Fj 88.

Caulerpella ambigua *(Okamura) Prud'homme van Reine & Lokhorst*
Site unknown *S. Mangubhai* Fj 165.

Chlorodesmis fastigiata *(C. Agardh) Ducker*
Naigoro Passage, Kadavu Island. *S. Mangubhai* 29.iv.2001. Fj 58; Cat's Meow, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001, Fj 150; Site unknown *S Mangubhai* Fj 169, Fj 132.

***Cladophora ryukyuensis** *Sakai & Yoshida*
Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001. Fj 90; Undeniable, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001, Fj 148.

Dictyosphaeria versluysii *Weber van Bosse*
FanTSea, Namena Barrier Reef, *S. Mangubhai* 24.iv.2001. Fj 81; Yanuyanu-i-sau fringing reef, Dravuni. *S. Mangubhai* 1.v.2001. Fj 85; Teton, Namena Barrier Reef, *S. Mangubhai* 25.iv.2001, Fj 97; Herald Passage (south), Kadavu. *S. Mangubhai* 01.v.2001, Fj 159.

Halimeda cuneata *Hering*
Buliya Island. *S. Mangubhai* 30.iv.2001. Fj 61;

Halimeda cylindracea *Decaisne*
Kawakawa reef, Buliya Island. *E. Lovell* 30.iv.2001, Fj 126, fairly common; Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 179.

Halimeda macrophysa *Askenasy*
Humann Nature, Eastern Bligh Water. *S. Mangubhai* 23.iv.2001. Fj 80; Cat's Meow, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001. Fj 69.

Halimeda opuntia *(Linnaeus) Lamouroux*
Cat's Meow, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001. Fj 37, Fj 68; FanTSea, Namena Barrier Reef, *S. Mangubhai* 24.iv.2001. Fj 82; Naigoro (inside reef) Kadavu Island. *E. Rupeni* 29.iv.2001. Fj 54; Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 02.v.2001, Fj 178; Narikoso (north), *S. Mangubhai* 29.iv.2001, Fj 155.

Halimeda **sp.**
Naigoro Passage, *S. Mangubhai* 01.v.2001. Fj 41; Buliya Island. *S. Mangubhai* 30.iv.2001. Fj 62; Teton, Namena Barrier Reef, *S Mangubhai* 25.iv.2001, Fj 102.

Rhipidosiphon javensis *Montagne*
Undeniable, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001, Fj 149.

Rhipilia orientalis *A Gepp & E. Gepp*
Lion's Den, Wakaya Island. *S. Mangubhai* 26.iv.2001. Fj 70; Site unknown *S. Mangubhai* Fj 164.

Rhipilia **sp.**
Site Unknown Fj 133.

Tydemania expeditionis *Weber van Bosse*
Naigoro (inside reef), Kadavu Island. *E. Rupeni* 29.iv.2001. Fj 53, *S. Mangubhai* Fj 111; Cat's Meow, Eastern Bligh Water, *E. Rupeni* 23.iv.2001. Fj 64;

Udotea orientalis *A. Gepp & E. Gepp*
Solo Lighthouse, North Astrolabe Reef. *S. Mangubhai* 2.v.2001. Fj 52; Cat's Meow, Eastern Bligh Water, *S. Mangubhai* 23.iv.2001. Fj 65; Narikoso (north), *S. Mangubhai* 29.iv.2001, Fj 156.

Valonia macrophysa *Kützing*
North Dravuni, Dravuni, *S. Mangubhai* 01.v.2001. Fj 42.

Photographic Plates

Listed below, though images are excluded. Contact authors to obtain higher quality original images for inclusion in this Appendix.

Plate 1
A. *Champia compressa* B. *Champia parvula* C & D. *Predaea laciniosa*

Plate 2
A. *Ceramium flaccidum* B. *Ceramium krameri* C. *Corallophila apiculata* D, E & F. *Pleonosporium caribeaum.*

Plate 3
A. *Neogoniolithon frutescens* B. *Griffithsia* sp. C. *Tolypiocladia glomerulata* D. *Hypoglossum* sp.

Plate 4
A. *Sphacelaria novae-hollandiae* B. *Dictyota crispata* C. *Lobophora variegata* D & E. *Lyngbya confervoides.*

Plate 5
A & C. *Caulerpa peltata* B. *Caulerpa cupressoides* D. *Caulerpa racemosa* var. *turbinata* E & F. *Caulerpa brachypus* G *Caulerpa serrulata* H.*Caulerpa microphysa* I. *Caulerpa taxifolia.*

Plate 6
A. *Halimeda cylindrica* B. *Halimeda cuneata* C. *Halimeda opuntia* D. *Caulerpella ambigua*

Plate 7
A. *Valonia macrophysa* B. *Rhipilia orientalis* C. *Udotea orientalis* D. *Tydemania expeditionis*

Appendix 4: Coral Species List From The Great And North Astrolabe Reefs

Compiled By Ed Lovell.

Genus/species	Kadavu (148)		Fiji
	confirmed 126	tentative 22	166
Class ANTHOZOA			
Subclass ZOOANTHERIA			
Order SCLERACTINIA			
Family ASTROCOENIIDAE			
Stylocoeniella armata (Ehrenberg, 1834)			X
Stylocoeniella guentheri (Bassett-Smith, 1890)			X
Family THAMNASTERIIDAE			
Psammocora contigua (Esper, 1797)	X		X
Psammocora digitata Edward & Haime, 1851			
Psammocora nierstraszi van der Horst, 1921		X	X
Psammocora superficiales Gardiner, 1898	X		X
Family POCILLOPORIDAE			
Pocillopora damicornis (Linnaeus, 1758)	X		X
Pocillopora eydouxi Edwards & Haime, 1860	X		X
Pocillopora verrucosa (Ellis & Solander, 1786)	X		X
Seriatopora hystrix Dana, 1846	X		X
Stylophora pistillata Esper, 1797	X		X
Family ACROPORIDAE			
Acropora (A.) abrotanoides (Lamarck, 1816)	X		X
Acropora (A.) aculeus (Dana, 1846)	X		X
Acropora (A.) aspera (Dana, 1846)			X
Acropora (A.) austera (Dana, 1846)	X		
Acropora (A.) carduus (Dana, 1846)	X		X
Acropora (A.) cerealis (Dana, 1846)	X		X
Acropora (A.) clathrata (Brook, 1891)	X		X
Acropora cuneata			
Acropora (A.) cytherea (Dana, 1846)	X		
Acropora (A.) digitifera (Dana, 1846)	X		X
Acropora (A.) divaricata (Dana, 1846)	X		X
Acropora (A.) echinata (Dana, 1846)	X		X
Acropora (A) elseyi (Brook, 1892)	X		X
Acropora (A.) florida (Dana, 1846)	X		X
Acropora (A.) gemmifera (Brook, 1892)	X		
Acropora (A.) grandis (Brook, 1892)	X		
Acropora (A.) horrida (Dana, 1846)	X		
Acropora (A.) humilis (Dana, 1846)	X		X
Acropora (A.) hyacinthus (Dana, 1846)	X		X
Acropora (A.) intermedia (Dana, 1846)	X		X
Acropora (A.) latistella (Brook, 1892)	X		
Acropora (A.) longicyathus (Edwards & Haime, 1860)	X		
Acropora (A.) loripes		X	
Acropora loripes			

Genus/species	Kadavu (148)		Fiji
	confirmed 126	tentative 22	166
Acropora lovelli			
Acropora (A.) microphthalma (Verrill, 1869)	X		
Acropora (A.) millepora (Ehrenberg, 1834)	X		X
Acropora (A.) monticulosa (Bruggemanni, 1879)	X		
Acropora (A.) muricata (Dana, 1846)	X		X
Acropora (A.) nana (Studer, 1878)	X		
Acropora (A.) nasuta (Dana, 1846)	X		X
Acropora (A.) paniculata Verrill, 1902	X		X
Acropora (A.) prostrata		X	
Acropora (A.) pulchra (Brook, 1891)			X
Acropora (A.) robusta (Dana, 1846)	X		X
Acropora (A.) samoensis (Brook, 1891)	X		
Acropora (A.) secale (Studer, 1878)	X		X
Acropora (A.) selago (Studer, 1878)	X		X
Acropora (A.) subulata (Brook, 1893)	X		
Acropora (A.) subglabra (Brook, 1891)	X		X
Acropora (A.) tenuis (Dana, 1846)	X		X
Acropora (A.) valenciennesi (Edwards & Haime, 1860)	X		X
Acropora (A.) valida (Dana, 1846)	X		X
Acropora (A.) vaughani Wells, 1954			X
Acropora (A.) verweyi Veron and Wallace, 1984	X		
Acropora (A) willisae Veron and Wallace, 1984	X		
Acropora (I.) crateriformis (Gardiner, 1898)			X
Acropora (I.) cuneata (Dana, 1846)			X
Acropora (I.) palifera (Lamarck, 1816)		X	X
Anacropora sp.1			X
Anacropora sp. 2			X
Astreopora listeri Bernard, 1896	X		
Astreopora myriophthalma (Lamarck, 1816)	X		X
Montipora aequituberculata Bernard, 1897	X		
Montipora danae Edwards & Haime, 1851	X		
Montipora foliosa (Pallas, 1766)			X (group)
Montipora foveolata (Dana, 1846)			X
Montipora spumosa		X	
Montipora tuberculosa (Lamarck, 1816)		X	X
Montipora verrucosa (Lamarck, 1816)	X		X
Family AGARICIIDAE			
Gardineroseris planulata (Dana, 1846)	X		X
Leptoseris explanata Yabe & Sugiyama, 1941			X
Leptoseris gardineri Van der Horst, 1921			X
Leptoseris hawaiiensis Vaughan, 1907			X
Leptoseris incrustans		X	
Leptoseris mycetoseroides Wells, 1954	X		X
Leptoseris scabra Vaughan, 1907	X		X
Pachyseris speciosa (Dana, 1846)	X		X
Pachyseris rugosa (Lamarck, 1801)	X		
Pavona cactus (Forskal, 1775)			X
Pavona clavus (Dana, 1846)	X		X
Pavona decussata (Dana, 1846)			X
Pavona divaricata (Lamarck, 1816)			X

Genus/species	Kadavu (148)		Fiji
	confirmed 126	tentative 22	166
Pavona explanulata (Lamarck, 1816)			X
Pavona maldivensis (Gardiner, 1905)	X		X
Pavona minuta Wells, 1954	X		X
Pavona varians Verrill, 1864	X		X
Pavona (P.) venosa (Ehrenberg, 1834)	X		
Family SIDERASTREIDAE			
Coscinaraea columna (Dana, 1846)	X		
Coscinaraea exesa		X	
Family FUNGIIDAE			
Cycloseris costulata (Ortmann, 1889)			X
Cycloseris cyclolites (Lamarck, 1801)			X
Cycloseris patelliformis Boschma, 1923			X
Cycloseris vaughani (Boschma, 1923)			X
Diaseris distorta Michelin, 1842			X
Fungia (D.) danai Edwards & Haime, 1851	X		X
Fungia (D.) scruposa Kluzinger, 1879			X
Fungia (D.) horrida Dana, 1846			X
Fungia (C.) echinata (Pallas, 1766)	X		
Fungia (F.) fungites (Linnaeus, 1758)			X
Fungia (P.) mollucensis Van der Horst, 1919			X
Fungia (P.) paumotensis Stutchbury, 1833			X
Fungia (P.) scutaria Lamarck, 1801	X		X
Fungia (V.) concinna Verrill, 1864	X		X
Fungia (V.) granulosa Klunzinger, 1879			X
Fungia (V.) repanda Dana, 1846			X
Fungia (V.) scabra Doderlein, 1901			X
Fungia (C.) simplex (Gardiner, 1905)	X		
Halomitra pileus (Linnaeus, 1758)	X		
Herpolitha limax (Houttuyn, 1772)	X		
Lithophyllon edwardsi Rousseau, 1854			Cf. X
Podabacia crustacea Edwards and Haime, 1849	X		X
Polyphyllia talpina (Lamarck, 1801)	X		
Sandalolitha robusta (Quelch, 1886)	X		
Zoopilus echinatus Dana, 1846	X		X
Family PORITIDAE			
Alveopora sp. 1		X	X
Goniopora columna Dana, 1846	X		
Goniopora sp. 1			X
Goniopora sp. 2			X
Goniopora sp. 3			X
Porites (P.) annae Crossland, 1952			X
Porites (P.) australiensis Vaughan, 1918			X
Porites (P.) cylindrica Dana, 1846	X		
Porites (P.) lichen Dana, 1846			X
Porites (P.) lobata Dana, 1846	X		X
Porites (P.) lutea Edwards & Haime, 1860	X		
Porites (P.) murrayensis Vaughan, 1918			X
Porites (P.) nigrescens Dana, 1848			X
Porites (S.) rus (Forskal, 1775)	X		X

Genus/species	Kadavu (148)		Fiji
	confirmed 126	tentative 22	166
Family FAVIIDAE			
Caulastrea furcata Dana, 1846	X		X
Cyphastrea chalcidicum (Forskal, 1775)		X	X
Cyphastrea decadia		X	
Cyphastrea microphthalma (Lamarck, 1816)			X
Cyphastrea serailia (Forskal, 1775)			X
Cyphastrea japonica Yabe & Sugiyama, 1932	X		X
Diploastrea heliopora (Lamarck, 1816)	X		X
Echinopora gemmacea Lamarck, 1816			X
Echinopora horrida Dana, 1846	X		X
Echinopora lamellosa (Esper, 1795)	X		X
Barabattoia amicorum (Edwards and Haime, 1850)			Cf. X
Favia favus (Forskal, 1775)			X
Favia matthaii Vaughan, 1918	X		X
Favia maximai Veron, Pichon and Wijsman-Best, 1977	X		
Favia pallida (Dana, 1846)	X		X
Favia rotumana (Gardiner, 1899)			X
Favia rotundata (Veron, Pichon &Best, 1977)	X		X
Favia stelligera (Dana, 1846)	X		X
Favia veroni		X	
Favites abdita (Ellis & Solander, 1786)	X		X
Favites chinensis (Verrill, 1866)			X
Favites flexuosa (Dana, 1846)	X		X
Favites halicora (Ehrenberg, 1834)	X		X
Favites pentagona (Esper, 1794)			X
Favites vasta			
Goniastrea aspera	X		
Goniastrea australensis (Edwards & Haime, 1857)			X
Goniastrea edwardsi Chevalier, 1971			X
Goniastrea pectinata (Ehrenberg, 1834)			X
Goniastrea retiformis (Lamarck, 1816)	X		X
Leptastrea bewickensis (Veron, Pichon and Wijsman-best, 1977)			X
Leptastrea purpurea (Dana, 1846)	X		X
Leptastrea transversa Klunzinger, 1979		X	X
Leptoria phrygia (Ellis & Solander, 1786)	X		X
Leptoria irregularis		X	
Montastrea annuligera		X	
Montastrea curta (Dana, 1846)	X		X
Montastrea magnistellata Chevalier, 1971	X		X
Oulophyllia crispa (Lamarck, 1816)	X		X
Platygyra daedalea (Ellis & Solander, 1786)	X		X
Platygyra lamellina (Ehrenberg, 1834)	X		
Platygyra pini Chevalier, 1975	X		X
Platygyra sinensis (Edwards & Haime, 1849)	X		X
Plesiastrea versipora (Lamarck, 1816)	X		
Family TRACHYPHYLLIIDAE			
Trachyphyllia geoffroyi			X
Family OCULINIDAE			
Acrhelia horrescens (Dana, 1846)			X

Genus/species	Kadavu (148)		Fiji
	confirmed 126	tentative 22	166
Galaxea cf. astreata (Lamarck, 1816)	X		X
Galaxea fascicularis (Linnaeus, 1767)	X		X
Family MERULINIDAE			
Clavarina triangularis Veron & Pichon, 1979			Cf. X
Hydnophora exesa (Pallas, 1766)	X		X
Hydnophora microconos (Lamarck, 1816)	X		X
Hydnophora rigida (Dana, 1846)	X		
Merulina ampliata (Ellis & Solander, 1786)	X		X
Merulina scabricula (Dana, 1846)		X	X
Scapophyllia cylindrica (Edwards and Haime, 1848)	X		X
Family MUSSIDAE			
Acanthastrea brevis		X	
Acanthastrea echinata (Dana, 1846)	X		
Acanthastrea ishigakiensis		X	
Lobophyllia corymbosa (Forskal, 1775)	X		X
Lobophyllia hataii Yabe, Sugiyama & Eguchi, 1936		X	X
Lobophyllia hemprichii (Ehrenberg, 1834)	X		X
Lobophyllia pachysepta Chevalier, 1975	X		
Symphyllia agaricia Edwards and Haime, 1849			X
Symphyllia radians (Edwards & Haime, 1849)	X		
Symphyllia recta (Dana, 1846)	X		X
Scolymia vitiensis Bruggemann, 1877	X		
Family PECTINIIDAE			
Echinomorpha nishihirai		X	
Echinophyllia aspera (Ellis & Solander, 1786)	X		X
Echinophyllia echinata (Saville-Kent, 1871)	X		X
Mycedium elephantotus (Pallas, 1766)	X		X
Mycedium mancaoi		X	
Oxypora glabra Nemenzo, 1959	X		X
Oxypora lacera (Verrill, 1864)	X		X
Pectinia paeonia (Dana, 1846)			X
Family CARYOPHYLLIIDAE			
Catalophyllia jardinei (Saville-Kent, 1893)			X
Euphyllia cristata Chevalier, 1971			X
Euphyllia glabrescens (Chamisso & Eysenhardt, 1821)			X
Physogyra lichensteini Edwards and Haime, 1851			X
Plerogyra simplex Rehberg, 1892	X		
Plerogyra sinuosa (Dana, 1846)	X		X
Family DENDROPHYLLIIDAE			
Tubastrea aurea (Quoy & Gaimard)			X
Tubastraea micrantha Ehrenberg, 1834	X		X
Turbinaria frondens (Dana, 1846)			X
Turbinaria mesenterina			X
Turbinaria peltata (Esper, 1794)	X		X
Turbinaria radicalis Bernard, 1896			X
Turbinaria reniformis Bernard, 1896	X		Cf. X
Turbinaria stellulata (Lamarck, 1816)			X
Order STOLONIFERA			
Family TUBIPORIDAE			
Tubipora musica Linnaeus, 1758	X		

Genus/species	Kadavu (148)		Fiji
	confirmed 126	tentative 22	166
Class HYDROZOA			
Order MILLEPORINA			
Family MILLEPORIDAE			
Millepora exaesa Forskal, 1775			X
Millepora platyphylla Hemprich & Ehrenberg, 1834		X	X
Millepora tenella Boschma, 1949			X
Millepora tuberosa Boschma, 1966			

Appendix 5: Fish Species Checklist for Sites in the Lomaiviti Group, February – April 2001.

Family	Species
Acanthuridae	*Acanthurus achilles*
	Acanthurus bariene
	Acanthurus blochii
	Acanthurus dussumieri
	Acanthurus lineatus
	Acanthurus lituratus
	Acanthurus nigricans
	Acanthurus nigricauda
	Acanthurus olivaceous
	Acanthurus pyroferus
	Acanthurus sp.
	Acanthurus strigosus
	Acanthurus thompsoni
	Acanthurus triostegus
	Acanthurus xanthopterus
	Ctenochaetus binotatus
	Ctenochaetus striatus
	Ctenochaetus strigosus
	Naso annulatus
	Naso brevirostris
	Naso brevistroris
	Naso caesios
	Naso caesius
	Naso hexacanthus
	Naso lituratus
	Naso minor
	Naso tuberosus
	Naso unicornis
	Naso vlamingi
	Zanclus cornutus
	Zanclus veliferum
	Zebrasoma scopas
	Zebrasoma vagabandus
	Zebrasoma veliferum
Balistidae	*Amanses scopas*
	Balistapus undulatus
	Balistapus viridescens
	Balistoides conspicillum
	Balistoides viridescens
	Canthidermis maculatus?
	Melichthys vidua
	Pseudobalistes flavimarginatus
	Sufflamen bursa
	Sufflamen caudimaculatum
	Sufflamen chrysopterus
	Chaetodon kleinii
	Chaetodon lineolatus
	Chaetodon lunula
	Chaetodon melannotus
	Chaetodon mertensii
	Chaetodon ornatus
	Chaetodon oxycephalus
	Chaetodon pelewensis
	Chaetodon plebeius
	Chaetodon punctatofasciatus
	Chaetodon rafflesi
	Chaetodon reticulatus
	Chaetodon speculum
	Chaetodon trifascialis
	Chaetodon trifasciatus
	Chaetodon ulietensis
	Chaetodon unimaculatus
	Chaetodon vagabundus
	Forcipiger flavissimus
	Forcipiger longirostris
	Hemitaurichthys polylepsis
	Heniochus acuminatus
	Heniochus chrysopterus
	Heniochus chrysostomus
	Heniochus monoceros
	Heniochus singularis
	Heniochus striatus
	Heniochus varius
Ephippidae	*Platax pinnatus*
Fistularidae	*Aulostomus chinensis*
	Fistularia commersonii
Haemulidae	*Plectorhinchus chaetodontoides*
Holocentridae	*Myripristis murdjan*
	Myripristis violacea
	Neoniphon brevistroris
	Neoniphon sammara
	Priacanthus hamur
	Sargocentron caudimaculatum
	Sargocentron spiniferum
Kyphosidae	*Kyphosus cinerascens*
	Kyphosus vaigiensis
Labridae	*Anampses meleagrides*
	Anampses twisti
	Bodianus anthioides
	Bodianus axillaris
	Bodianus diana
	Bodianus loxozonus
	Bodianus mesothorax
	Cheilinus chlorourus
	Cheilinus fasciatus
	Cheilinus trilobatus
	Cheilinus undulatus
	Choerodon jordani
	Cirrhilabrus temminckii
	Coris aygula
	Coris gaimard
	Epibulus insidiator
	Gomphosus varius
	Halichoeres chrysus
	Halichoeres hortulanus
	Halichoeres ornatissimus
	Halichoeres prosopeion
	Halichoeres trimaculatus
	Hemigymnus fasciatus
	Hemigymnus melapterus
	Labrichthys unilineatus
	Labroides bicolor

Family	Species	Family	Species
	Labroides dimidiatus		*Centropyge sp.*
	Labropsis micronesica		*Genicanthus melanospilos*
	Macropharyngodon negrosensis		*Pomacanthus diacanthus*
	Novaculichthys taeniourus		*Pomacanthus imperator*
	Oxycheilinus diagrammus		*Pomacanthus semicirculatus*
	Pseudocheilinus hexataenia		*Pygoplites diacanthus*
	Pseudojuloides cerasinus	Priacanthidae	*Priacanthus hamur*
	Thalassoma hardwicke	Scaridae	*Cetoscarus bicolor*
	Thalassoma lunare		*Hipposcarus longiceps*
	Thalassoma lutescens		*Scarus bleekeri*
Lethrinidae	*Gnathodentex aurolineatus*		*Scarus chameleon*
	Gymnocranius sp.		*Scarus dimidiatus*
	Lethrinus atkinsoni		*Scarus forsteni*
	Lethrinus gibbus		*Scarus ghobban*
	Lethrinus obsoletus		*Scarus globiceps*
	Lethrinus olivaceous		*Scarus microrhinos*
	Lethrinus sp.		*Scarus niger*
	Lethrinus xanthochilus		*Scarus oviceps*
	Monotaxis grandoculis		*Scarus rubroviolaceus*
	Monotaxis trifasciatus		*Scarus scaber*
	Scolopsis bilineatus		*Scarus schlegeli*
Lutjanidae	*Aphareus furca*		*Scarus sordidus*
	Aprion virescens		*Scarus sp.*
	Lutjanus biguttatus		*Scarus spinus*
	Lutjanus bohar	Scombridae	*Gymnosarda unicolor*
	Lutjanus ehrenbergi		*Rastrelliger kanagurta*
	Lutjanus fulviflamma	Scorpaenidae	*aaScorpionfish ??*
	Lutjanus fulvus	Serranidae	*Cephalopholis argus*
	Lutjanus gibbus		*Cephalopholis miniata*
	Lutjanus kasmira		*Cephalopholis urodeta*
	Lutjanus monostigma		*Epinephelus corallicola*
	Lutjanus quinquilineatus		*Epinephelus merra*
	Lutjanus russelli		*Epinephelus ongus*
	Lutjanus semicinctus		*Epinephelus polyphedion*
	Lutjanus sp.		*Epinephelus sp.*
	Macolor macularis		*Plectropomus areolatus*
	Macolor niger		*Plectropomus laevis*
	Pristipomoides auricilla		*Plectropomus leopardus*
Malacanthidae	*Malacanthus brevirostris*		*Pseudanthias pascalus*
	Malacanthus latovittatus		*Psuedanthias squamipinnus*
Mullidae	*Mulloides vanicolensis*		*Serranocirrhitus latus*
	Parupeneus barberinoides		*Variola louti*
	Parupeneus barberinus	Siganidae	*Siganus argenteus*
	Parupeneus bifasciatus		*Siganus doliatus*
	Parupeneus cyclostomus		*Siganus punctatus*
	Parupeneus flavolineatus		*Siganus spinus*
	Parupeneus indicus		*Siganus uspi*
	Parupeneus multifasciatus		*Siganus vermiculatus*
	Parupeneus pleurostigma	Sphyreanidae	*Sphyraena qenie*
	Parupeneus spirulus	Synodontidae	*Synodus variegatus*
Nemipteridae	*Scolopsis bilineatus*	Tetraodontidae	*Arothron nigropunctatus*
Ostraciidae	*Ostracion cubicus*		*Arothron sp.*
	Ostracion solorensis		*Arothron stellatus*
Pinguipedidae	*Parapercis hexophtalma*	ELASMOBRANCHS	
	Parapercis millepunctata	Rays	*Aetobatus narinari*
Pomacanthidae	*Apolemichthys trimaculatus*		*Manta birostris*
	Centropyge bicolor	Sharks	*Carcharhinus amblyrhynchos*
	Centropyge bispinosus		*Carcharhinus longimanus*
	Centropyge flavissimus		*Nebrius ferrugineus*
	Centropyge heraldi		*Triaenodon obesus*

Appendix 6 – Abundance Of Fish Families In Kadavu (Mean And Standard Deviation)

Site	Total density	Acanthuridae		Balistidae		Caesionidae		Carangidae		Chaetodontidae	
		m	sd	m	sd	m	sd	m	sd	m	sd
GAR-cha-Buliya Passage	67.5	2.9	3.7	1.0	0.0	48.3	48.9			1.6	0.9
GAR-cha-Herald South	108.8	2.8	2.6	1.0	0.0	61.4	53.9			1.9	0.9
GAR-cha-Naigoro Passage	28.1	3.3	2.4	1.2	0.4	8.0	2.8			2.4	2.0
GAR-cha-Usborne South	45.4	4.0	4.3	1.0	0.0	18.0				2.1	1.5
GAR-lag-Buliya Patch Reef	35.3	3.3	2 6			17.7	2.5			2.1	1 3
GAR-lag-Dravuni Patach Reef	32.1	5.7	2.5	3.0	1.8	7.5	3.5			1.8	0.9
GAR-lag-Kawakawa	20.8	3.8	2.7	1.0	0.0					1.7	0.9
GAR-lag-Naigoro Inner	26 2	4.1	3.1	1.7	0.6	1.5	0.7			2.4	1.5
GAR-lag-Nakoro	18.1	2.1	1.1	1.7	0.8					1.6	0.8
GAR-lag-Narikoso North	28.3	2.9	2.4	1.0	0.0	6.0				2.3	1.9
GAR-lag-Narikoso South	89.1	67.8	212.7	3.0	2.2					1.7	1.0
GAR-lag-Wais1unprotected	34.1	3.9	3.1	2.0						1.8	1.2
GAR-lag-Wais2unprotected	26.4	3.1	1.3	2.1	1.6					2.1	1.6
GAR-lag-Wais3unprotected	18.3	5.0		2.7	2.9					1.8	0 5
GAR-lag-Wais4unprotected	13.7	2.4	1.5	2.7	2.0					1.3	0.5
GAR-lag-Yamotubalavu	53.3	4.7	5.3	1.0	0.0					1.9	0.9
GAR-lag-Yanuyanu-I-Sau	84.0	4 8	6.7	1.2	0.4					1.6	0.9
GAR-lee-Buliya Bommies	94.6	2 4	1.4	1.3	0.5	35.9	20.2			2.1	1.8
GAR-lee-Herald North	26.9	3.5	2.7							3.8	3.2
GAR-lee-Outer Bommies	44.2	2.8	2.7	1.3	0.5	20.0	7.1			2.3	2.3
GAR-lee-Usborne North	23.0	4.5	6.4	2.0						1.8	1.0
GAR-lee-Vanuakula	57.4	42.7	205.1	1.0						2.0	1.1
GAR-lee-Western Barrier	54.8	37.1	181.2	1.0						2.3	2.2
GAR-MPA-Wais5MPA	53.3	3.7	3.9	1.2	0.4			24.0		1.9	1.2
GAR-MPA-Wais6MPA	16.4	3.4	5.3	1.5	0.7					1.9	1.5
GAR-MPA-Wais7MPA	13.8	3.5	2.3	1.0	0.0					1.5	0.6
GAR-MPA-Wais8MPA	19.9	2.6	1.9	1.5	0.7			1.0		1.5	0.6
GAR-MPA-Wais9MPA	19.9	2.8	2.1	1.6	0.9					1.3	0.6
GAR-wind-GAR North	31.9	5.9	4.7	1.0		15.0				2.0	1.1
GAR-wind-GAR Windward	98.3	3.8	4.5	1.0	0.0	56.6	40.0			1.8	0.8
NAR-cha-Channel-west	30.7	3.7	2.6	1.7	1.5	6.0				2.1	1.4
NAR-cha-North Channels	43.3	3.6	3.7	1.0	0.0	14 0	10.4			2.5	2.0
NAR-lag-Lighthouse Reef	162.0	3 3	2.5	1.0	0.0	126.7	112 4			2.3	1.4
NAR-lag-Patch Reef	21.1	3.1	2 3	2.0	2.0					1.2	0.4
NAR-lag-South Lagoon	30.5	2.8	2 6	1.3	0.6					2.5	1.9
NAR-lee- Lee	148.1	3.2	2.6	1.0	0.0	88.5	55.4	1.5	0.7	1.7	0 9
NAR-lee-Lee - North	24.1	2.0	1.2	1.0	0.0			1 0		1.9	1.5
NAR-wind-Eastern Point	76.6	5.7	5.6	1.6	0.8	46.7	44 5			1.8	0 8
NAR-wind-Northwest	19.6	3.7	3.4	1.0	0.0					2.4	1.3
NAR-wind-Outer-North	27.7	3.3	3.1	1 0		8 0	0.0			1.7	1.0
NAR-wind-Southern Point	98.2	9.1	14.4	4 6	9.0	60 0	38.1			2.5	3.6
NAR-wind-Windward	66.1	43.1	207.2	1.92	1.08	7	1.414			3.12	2.16

Site	Haemulidae		Labridae		Lethrinidae		Lutjanidae		Mullidae	
	m	sd	m	sd	m	sd	m	sd	m	sd
GAR-cha-Buliya Passage			1.2	0.6	2.6	1.1	1.0	0.0	1.0	0.0
GAR-cha-Herald South		1.5	0.6	1.5	0.6	2.3	2.5	1.0	0.0	
GAR-cha-Naigoro Passage			1.2	0.5	1.4	0.7	1.0	0.0	1.7	1.1
GAR-cha-Usborne South					1.7	1.3	3.5	3.2	4.2	4.2
GAR-lag-Buliya Patch Reef	1.5	0.7	2.0	0.0	1.2	0.4	1.4	0.7	1.0	0.0
GAR-lag-Dravuni Patach Reef					3.7	3.2	4.6	4.4	1.5	0.8
GAR-lag-Kawakawa	1.0		1.4	0.5	1.3	0.5	2.3	2.2	1.3	0.8
GAR-lag-Naigoro Inner			1.3	0.6	1.5	0.9	2.0	1.7	2.4	1.5
GAR-lag-Nakoro			2.2	2.7	1.5	1.0			1.3	0.7
GAR-lag-Narikoso North			1.4	0.6	1.8	1.0			2.3	1.6
GAR-lag-Narikoso South					2.0	1.2	3.3	4.5	3.3	3.3
GAR-lag-Wais1unprotected					7.6	6.7	5.3	5.3	2.9	2.6
GAR-lag-Wais2unprotected									3.5	2.1
GAR-lag-Wais3unprotected			1.0						3.0	
GAR-lag-Wais4unprotected							1.0	0.0	3.2	1.3
GAR-lag-Yamotubalavu			5.5	11.9	10.7	14.4	1.3	0.6	1.4	1.3
GAR-lag-Yanuyanu-I-Sau			1.7	1.8	1.5	1.2	1.0	0.0	2.2	1.7
GAR-lee-Buliya Bommies			1.0	0.0	1.0		1.0	0.0	1.0	
GAR-lee-Herald North					2.0		2.3	2.5	3.3	4.1
GAR-lee-Outer Bommies			1.3	0.6	2.4	2.1	2.8	3.4	1.7	0.6
GAR-lee-Usborne North			1.0	0.0	2.0		2.0	1.4	1.0	
GAR-lee-Vanuakula					1.8	1.1	1.0	0.0	2.0	0.0
GAR-lee-Western Barrier			1.0		2.0	1.7	1.9	2.3	3.9	3.2
GAR-MPA-Wais5MPA					5.1	5.1	5.7	7.1	5.9	9.1
GAR-MPA-Wais6MPA			1.0	0.0	1.0				1.6	0.9
GAR-MPA-Wais7MPA			1.0	0.0	1.8	1.5	1.0		1.0	0.0
GAR-MPA-Wais8MPA					2.4	1.8	3.9	5.2	2.0	2.4
GAR-MPA-Wais9MPA			1.0		1.0		1.0		2.5	1.8
GAR-wind-GAR North				1.3	0.5	1.6	1.7	2.2	1.6	
GAR-wind-GAR Windward	1.0		1.2	0.4	1.0	0.0	1.2	0.4	1.0	0.0
NAR-cha-Channel-west					2.0	1.4	1.0		1.6	1.0
NAR-cha-North Channels			1.2	0.4	2.0	1.8	2.6	2.3	6.0	14.6
NAR-lag-Lighthouse Reef			1.4	0.7	2.0	1.2	2.7	2.1	3.8	2.9
NAR-lag-Patch Reef					6.3	6.1	3.7	4.0	2.5	1.7
NAR-lag-South Lagoon			2.5	2.1	2.5	2.8	1.0	0.0	4.1	4.6
NAR-lee- Lee	1.7	0.6	1.4	0.6	3.0	2.0	3.5	3.4	11.5	18.0
NAR-lee-Lee - North			1.0		3.0	2.4	1.6	1.1	3.3	3.6
NAR-wind-Eastern Point	1.0		1.3	0.9	1.4	0.8	1.3	0.5	1.3	0.6
NAR-wind-Northwest			1.0	0.0	2.1	1.5	1.0	0.0	2.3	1.5
NAR-wind-Outer-North					2.3	1.4	1.2	0.4	1.0	0.0
NAR-wind-Southern Point			1.7	1.7	3.5	3.5	1.3	0.6	1.0	0.0
NAR-wind-Windward					3.5	4.36	1		2.5	0.71

Site	Pomacanthidae		Scombridae		Serranidae		Siganidae		Sphyreanidae	
	m	sd	m	sd	m	sd	m	sd	m	sd
GAR-cha-Buliya Passage	1.7	2.0			1.0	0.0	1.3	0.6		
GAR-cha-Herald South	1.3	0.6	15.0		12.4	21.9	2.0			
GAR-cha-Naigoro Passage	1.8	1.1			1.0	0.0				
GAR-cha-Usborne South	1.5	0.7					7.7	10.7		
GAR-lag-Buliya Patch Reef	1.0	0.0		1.1	0.4	2.0	0.0			
GAR-lag-Dravuni Patach Reef	2.5	2.4								
GAR-lag-Kawakawa	1.5	0.8		1.0	0.0	3.5	2.2			
GAR-lag-Naigoro Inner	1.5	0.8		1.0		1.5	0.7			
GAR-lag-Nakoro	1.4	0.5		1.1	0.4					
GAR-lag-Narikoso North	1.5	0.7		1.0	0.0	2.0				
GAR-lag-Narikoso South	3.4	2.3		2.0	2.0	1.7	1.2			
GAR-lag-Wais1unprotected	2.3	1.5		1.0	0.0					
GAR-lag-Wais2unprotected	3.2	2.6		1.7	1.2	6.0				
GAR-lag-Wais3unprotected	2.3	1.5		1.0						
GAR-lag-Wais4unprotected	1.1	0.4		1.0						
GAR-lag-Yamotubalavu	4.7	4.4		1.0		13.0	17.0			
GAR-lag-Yanuyanu-I-Sau	1.4	0.6	51.0	69.3	2.0		11.0	12.7		
GAR-lee-Buliya Bommies	1.3	0.5	30.0		11.5	15.0	2.2	1.0		
GAR-lee-Herald North	2.0	1.4		1.3	0.5	1.0	0.0			
GAR-lee-Outer Bommies	2.0	1.4		1.0	0.0	2.8	1.5			
GAR-lee-Usborne North	1.0	0.0		4.0						
GAR-lee-Vanuakula	2.0			1.0	0.0	1.5	0.5			
GAR-lee-Western Barrier	2.0	0.6		1.0	0.0	1.0				
GAR-MPA-Wais5MPA	1.5	0.5		1.0	0.0	2.0	1.4			
GAR-MPA-Wais6MPA	1.5	0.5		1.2	0.7					
GAR-MPA-Wais7MPA	1.6	0.5								
GAR-MPA-Wais8MPA	1.6	1.1		1.0	0.0					
GAR-MPA-Wais9MPA	1.9	0.9		1.0	0.0	3.0				
GAR-wind-GAR North	1.0	0.0		1.0	0.0					
GAR-wind-GAR Windward	1.6	1.0		14.6	18.6	2.5	0.7			
NAR-cha-Channel-west	1.4	0.5		1.2	0.4	1.0				
NAR-cha-North Channels	1.6	1.0		1.0	0.0	2.0	0.0			
NAR-lag-Lighthouse Reef	1.8	0.9		1.0	0.0	10.3	9.5			
NAR-lag-Patch Reef	1.4	0.5				1.0				
NAR-lag-South Lagoon	2.3	1.0		1.0	0.0					
NAR-lee- Lee	1.6	0.9		20.4	22.8	1.0				
NAR-lee-Lee - North	1.0	0.0		1.0	0.0					
NAR-wind-Eastern Point	3.6	2.7	1.0		3.1	6.0				
NAR-wind-Northwest	1.7	1.2		1.3	0.8					
NAR-wind-Outer-North	1.0	0.0		1.5	0.5				1.0	
NAR-wind-Southern Point	2.7	2.5		3.9	6.0	2.0				
NAR-wind-Windward				1.3	0.67				1	

Site	Tetraodontidae		Rays		Sharks		Other
	m	sd	m	sd	m	sd	
GAR-cha-Buliya Passage							3.9
GAR-cha-Herald South			1.0		3.7		
GAR-cha-Naigoro Passage	1.0	0.0					4.1
GAR-cha-Usborne South							1.7
GAR-lag-Buliya Patch Reef							1.0
GAR-lag-Dravuni Patach Reef							1.7
GAR-lag-Kawakawa							1.0
GAR-lag-Naigoro Inner							5.5
GAR-lag-Nakoro							5.4
GAR-lag-Narikoso North							6.2
GAR-lag-Narikoso South							1.0
GAR-lag-Wais1unprotected	1.0						6.3
GAR-lag-Wais2unprotected							4.8
GAR-lag-Wais3unprotected							1.5
GAR-lag-Wais4unprotected							1.0
GAR-lag-Yamotubalavu							8.1
GAR-lag-Yanuyanu-I-Sau			1.0				3.7
GAR-lee-Buliya Bommies							3.9
GAR-lee-Herald North							7.8
GAR-lee-Outer Bommies							4.0
GAR-lee-Usborne North					1.0	0.0	2.8
GAR-lee-Vanuakula					1.0		1.5
GAR-lee-Western Barrier							1.8
GAR-MPA-Wais5MPA							1.3
GAR-MPA-Wais6MPA							3.3
GAR-MPA-Wais7MPA							1.6
GAR-MPA-Wais8MPA							2.5
GAR-MPA-Wais9MPA							2.7
GAR-wind-GAR North							1.0
GAR-wind-GAR Windward			2.0		1.0		8.1
NAR-cha-Channel-west					1.0		8.0
NAR-cha-North Channels							5.9
NAR-lag-Lighthouse Reef			1.0				4.9
NAR-lag-Patch Reef							0.0
NAR-lag-South Lagoon					1.0		9.5
NAR-lee- Lee	1.0						7.3
NAR-lee-Lee - North							7.3
NAR-wind-Eastern Point	1.0	0.0			1.0	0.0	4.8
NAR-wind-Northwest					1.0		2.2
NAR-wind-Outer-North					1.0		4.8
NAR-wind-Southern Point					1.0		4.8
NAR-wind-Windward							1.7

Figures

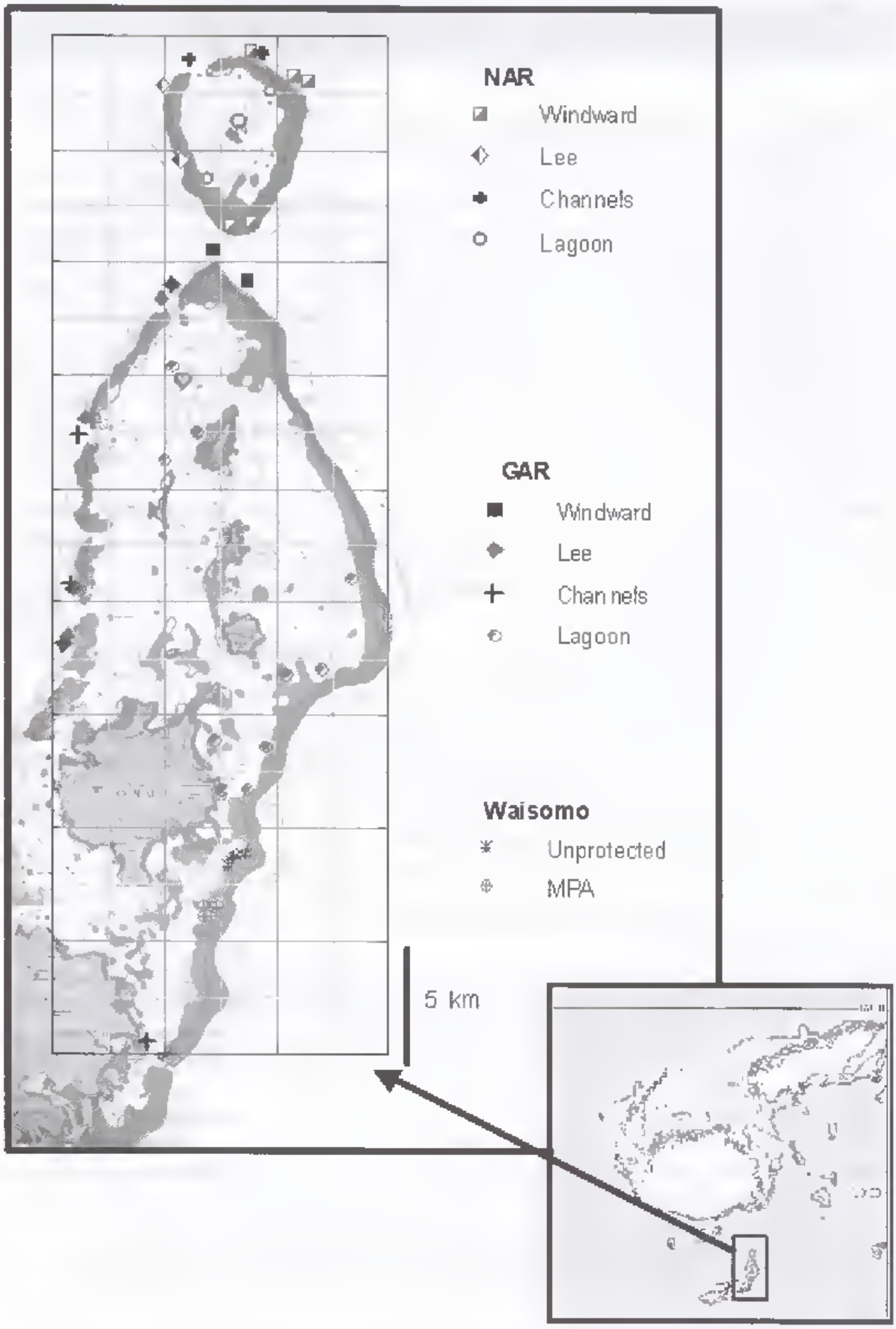

Figure 1. Map of the Great and North Astrolabe Reefs, Kadavu Island, Fiji. The inlay (bottom right) shows the location of the GAR and NAR in Fiji. The grid overlay on the main map is in 5km squares and shows study sites grouped by reef and zone.

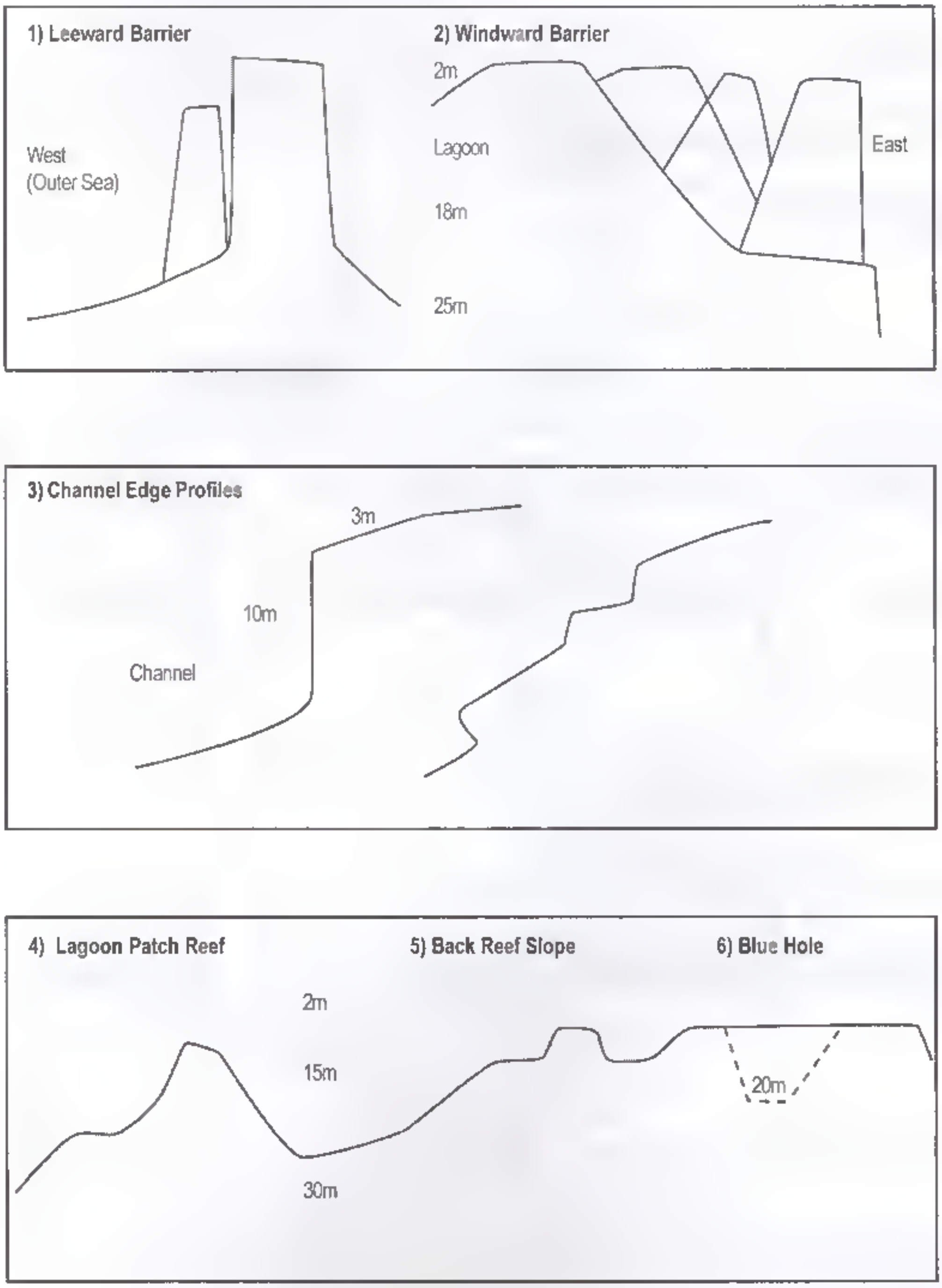

Figure 2. Sketches of the primary reef types surveyed on the Great and North Astrolabe Reefs, in the Kadavu, Fiji: 1) Leeward Barrier; 2) Windward Barrier; 3) Channel edge profiles; 4) Lagoon patch reefs; 5) Back reef slopes; and 6) blue holes. Habitats 1-4 were surveyed in this study, and 5-6 in Sauni (2001). See Appendix 2 for detailed structure of individual survey sites.

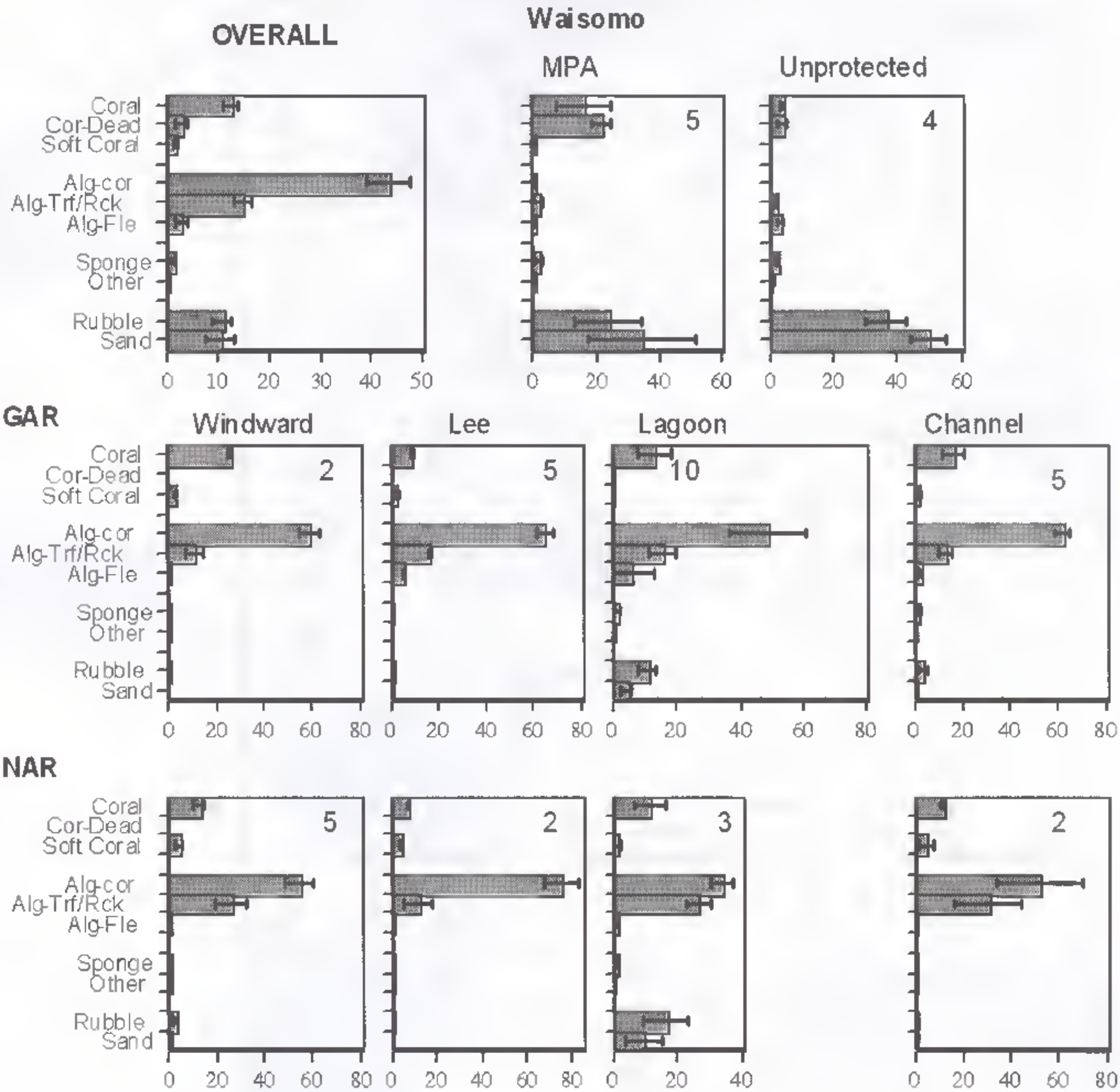

Figure 3. Percent cover (mean ± standard error) of benthic categories in the Great Astrolabe Reef (GAR) and North Astrolabe Reef (NAR), Kadavu, Fiji. Groups are assigned according to Table 3. Numbers indicate number of sites. Codes used in the figure (and see Table 2): Cor-Dead – dead coral; Alg-cor – coralline algae; Alg-Trf/Rck – low algal turf and rock surfaces; Alg-Fle – fleshy and large algal fronds; Other – miscellaneous invertebrates and unknown cover types.

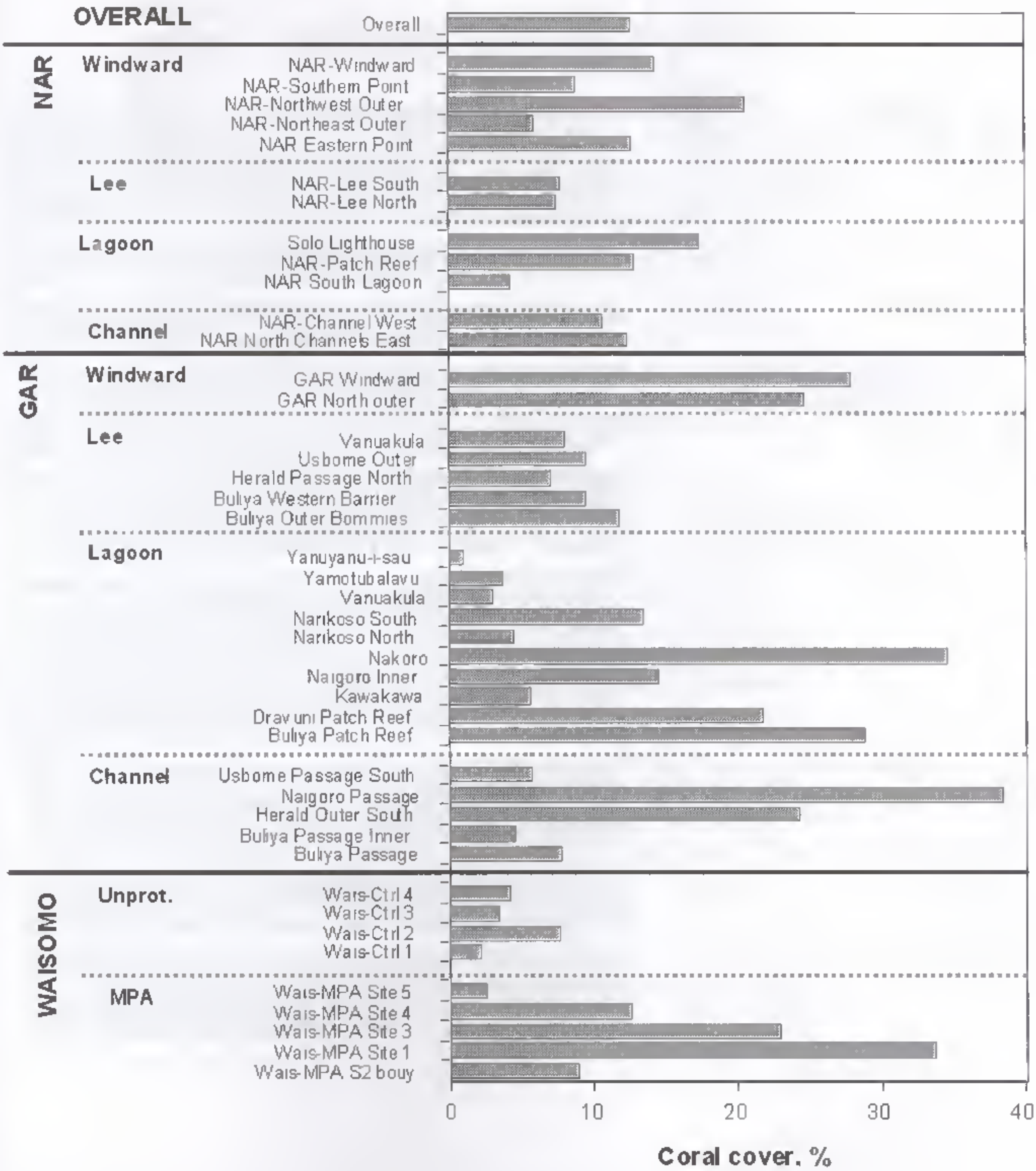

Figure 4. Coral cover (in percent) at all surveyed sites in Kadavu. Sites are grouped according to Table 3.

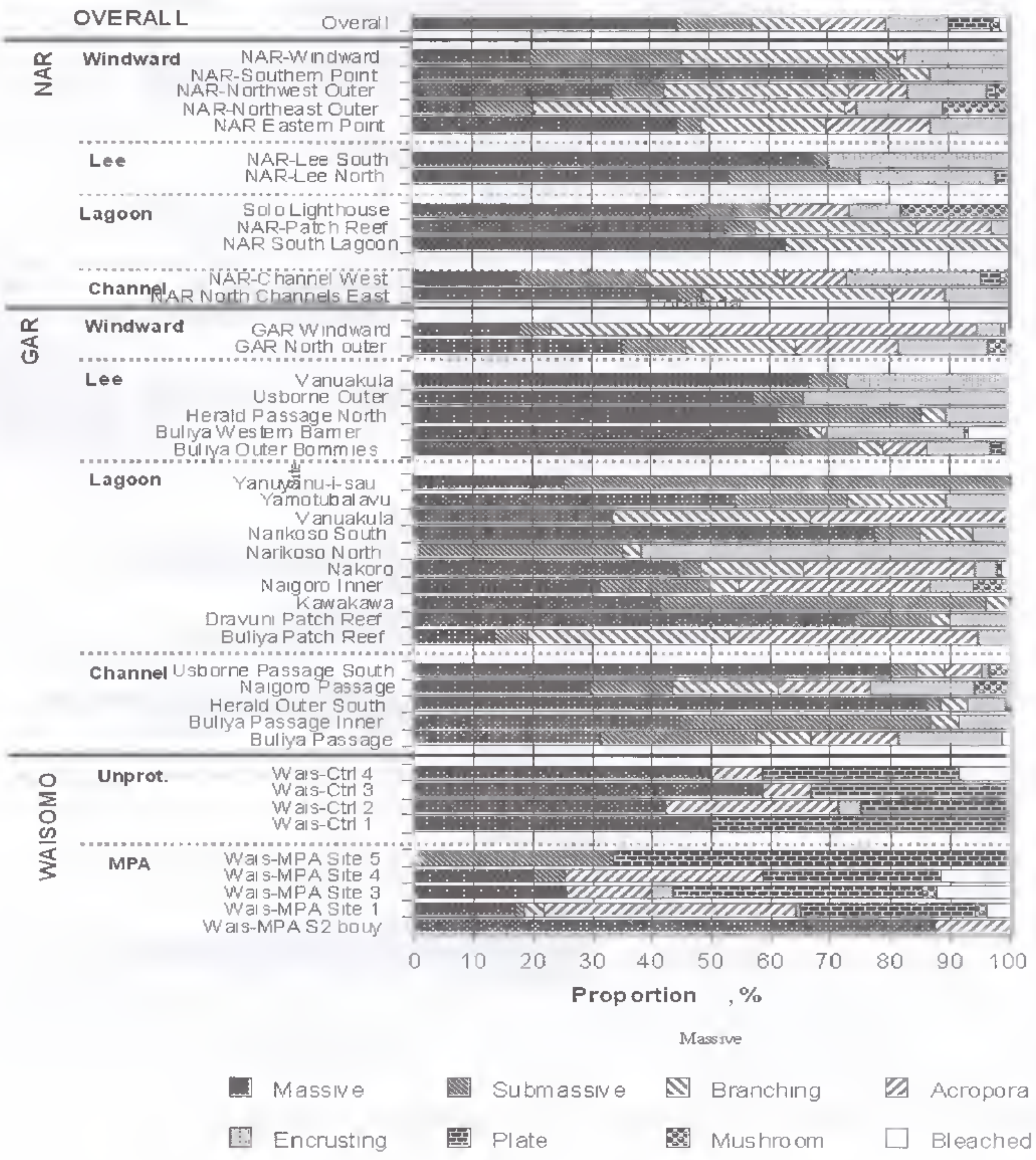

Figure 5. Percentage composition of coral colony morphologies. Sites are grouped according to Table 3.

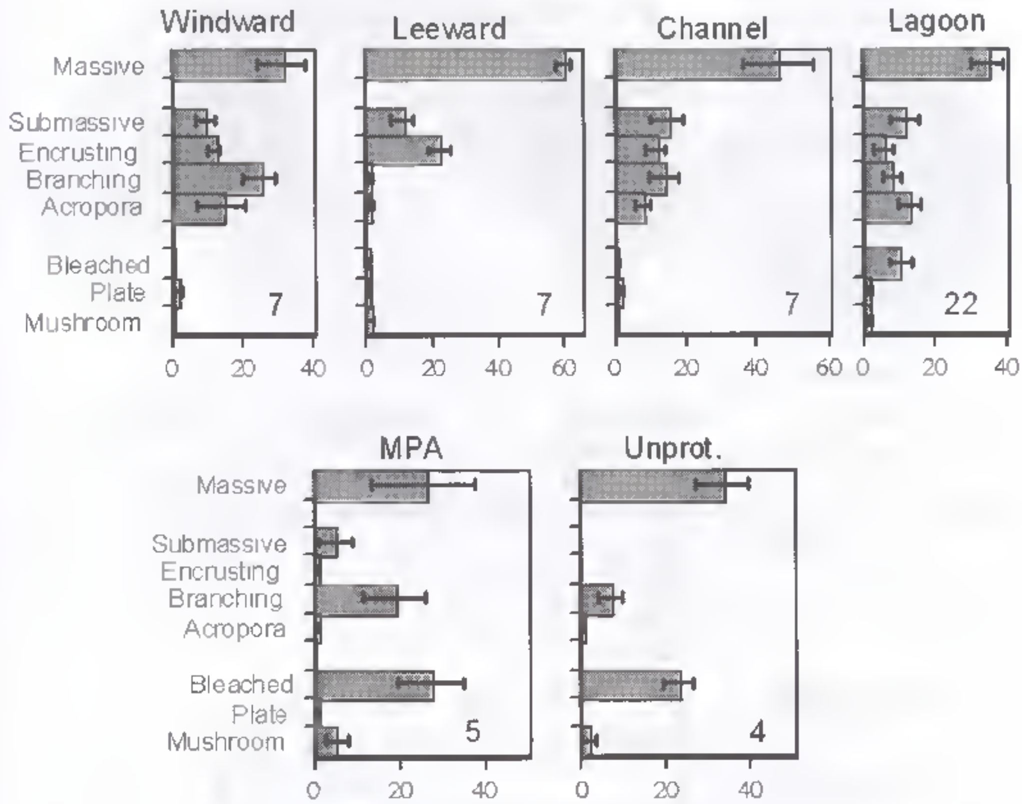

Figure 6. Percent abundance of coral morphologies by reef habitat and for MPA and unprotected sites in Waisomo. Number shows number of sites sampled on the Great and North Astrolabe Reefs, Kadavu, Fiji.

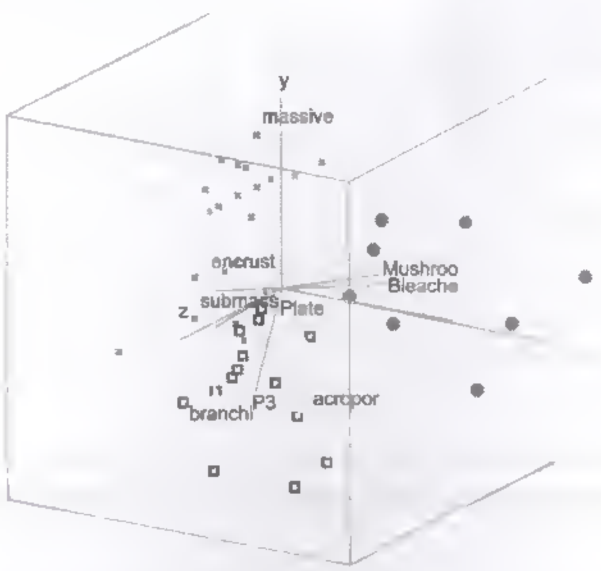

Figure 7. Three-dimensional representation of a Principal Components Analysis of the abundance of different coral morphologies at reef sites, showing segregation of 3 groups of sites. Rays show the weighting of coral morphologies in the cluster analysis and aid interpretation of the characteristics of the nearby sites. Diamonds– reefs with high bleaching and mushroom corals; Squares– reefs with high branching corals and Acropora; Crosses– reefs with mix of massive, encrusting and submassive corals.

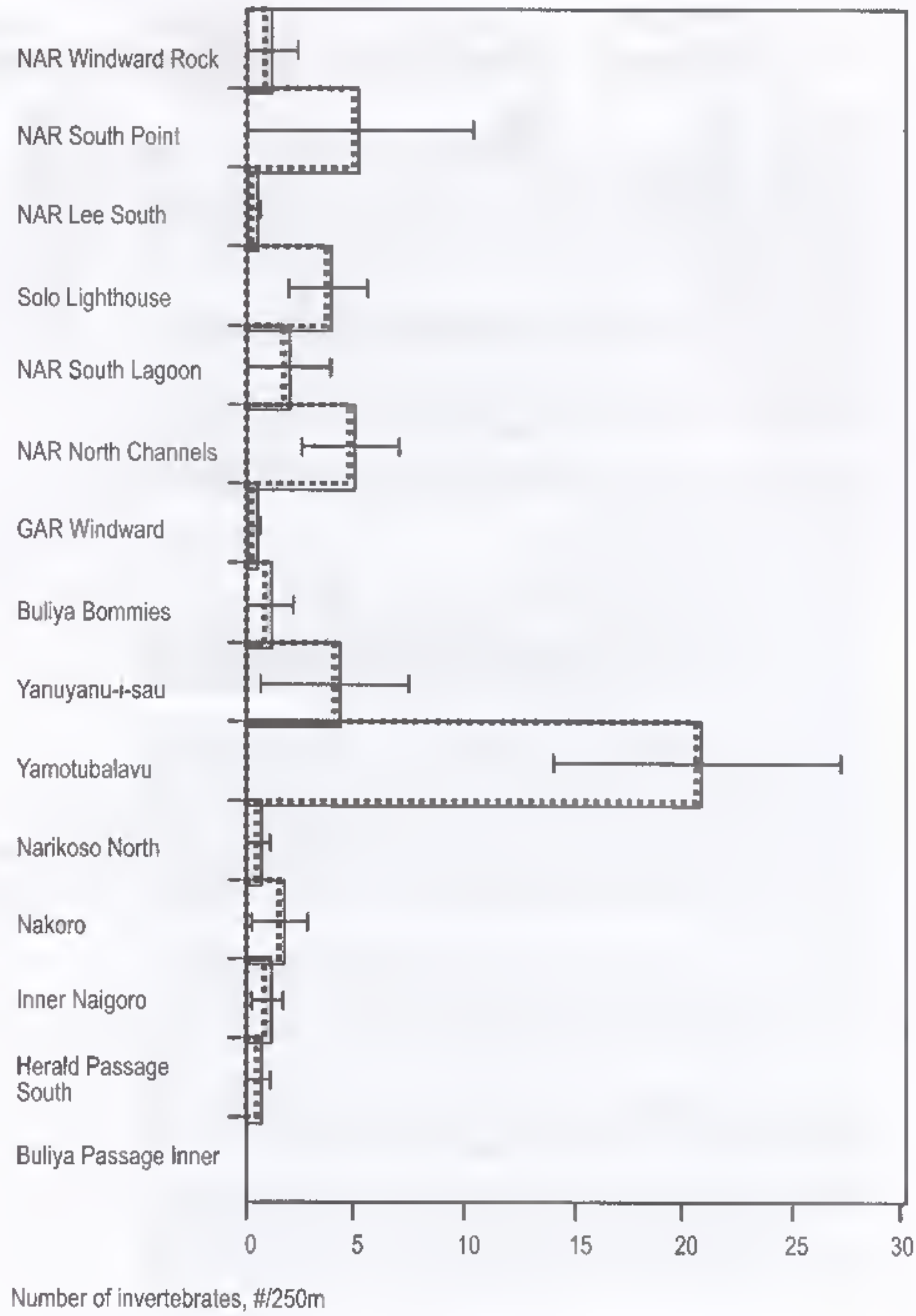

Figure 8: Condition of 3 commonly observed coral genera showing dotted line, bleaching or recent mortality. Numbers indicate number of colonies recorded.

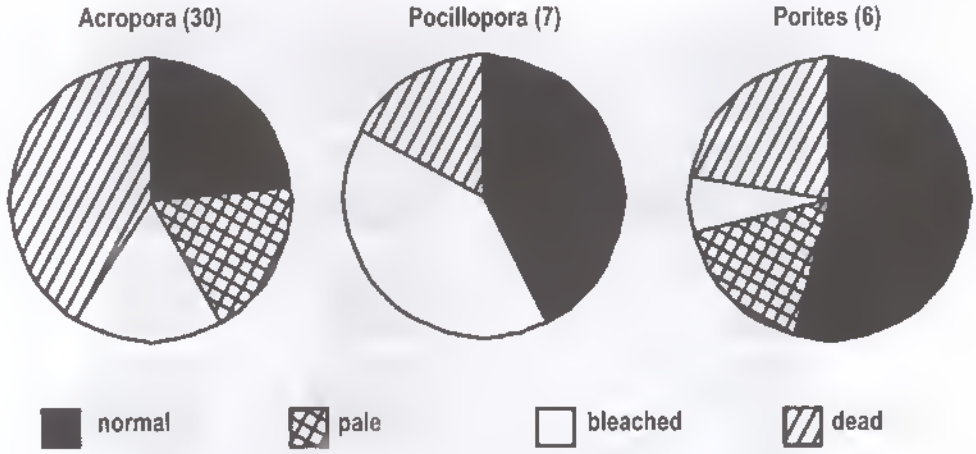

Figure 9. Invertebrate density per transect (250m²) sampled on the Great and North Astrolabe Reefs, Kadavu, Fiji.

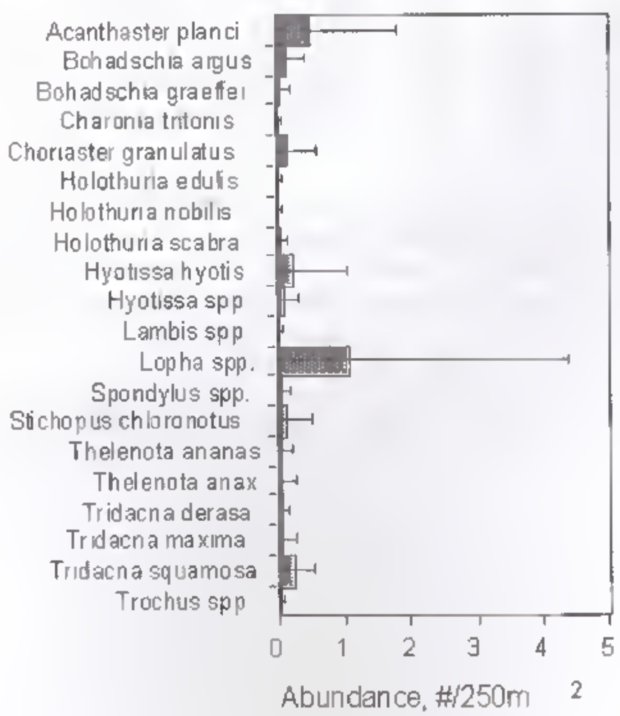

Figure 10. Average density of invertebrate species (per $250m^2$) on the Great and North Astrolabe Reefs, Kadavu, Fiji.

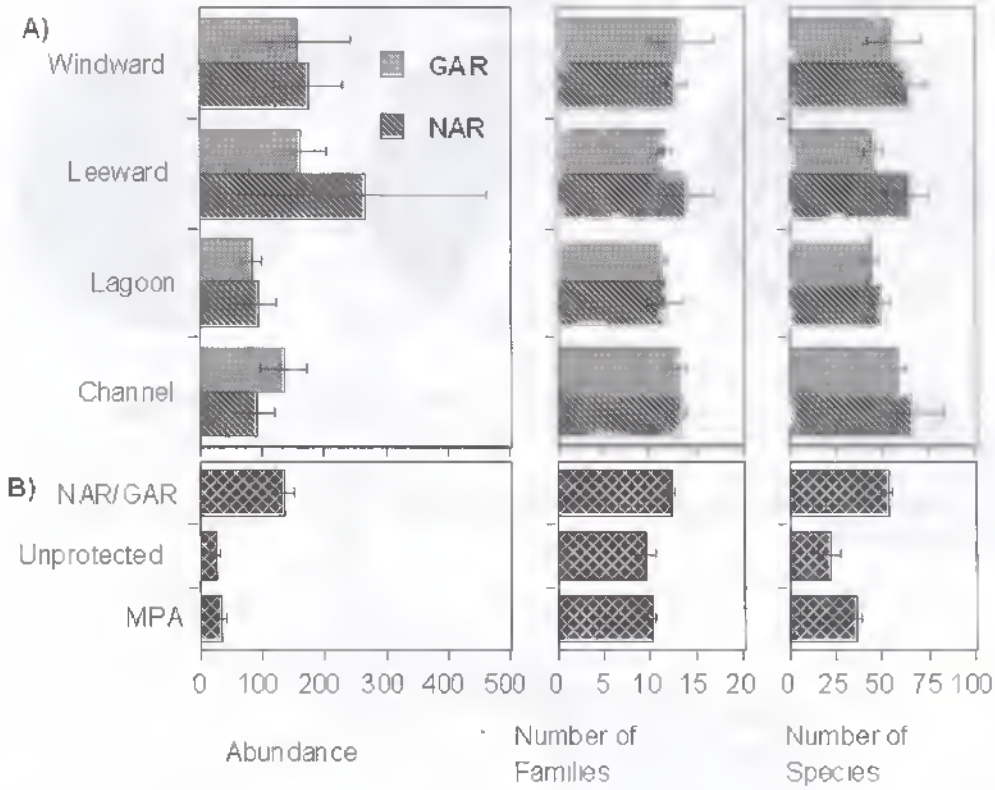

Figure 11. A) Fish abundance by habitat for Great Astrolabe Reef (GAR) and North Astrolabe Reef (NAR), Kadavu, Fiji, per 250 m^2 transect (mean and standard error). B) Comparison of fish abundance, at the Waisomo Marine Protected Area and adjacent control (unprotected sites), with other reef zones combined for the Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji.

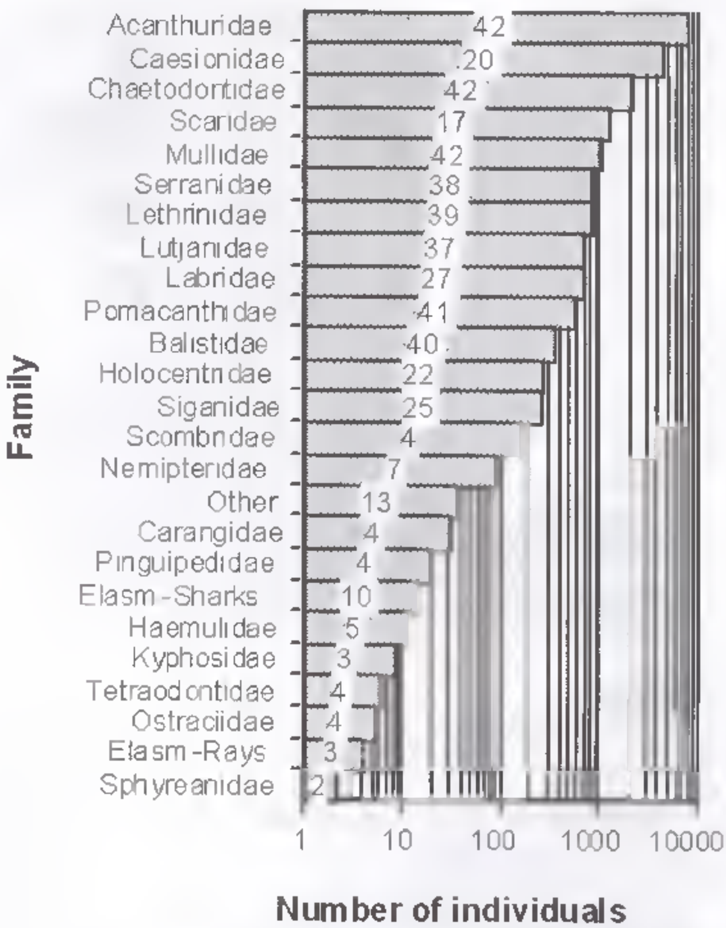

Figure 12. Dominance of fish families censused in Kadavu, showing overall abundance and the number of sites in which the family was recorded.

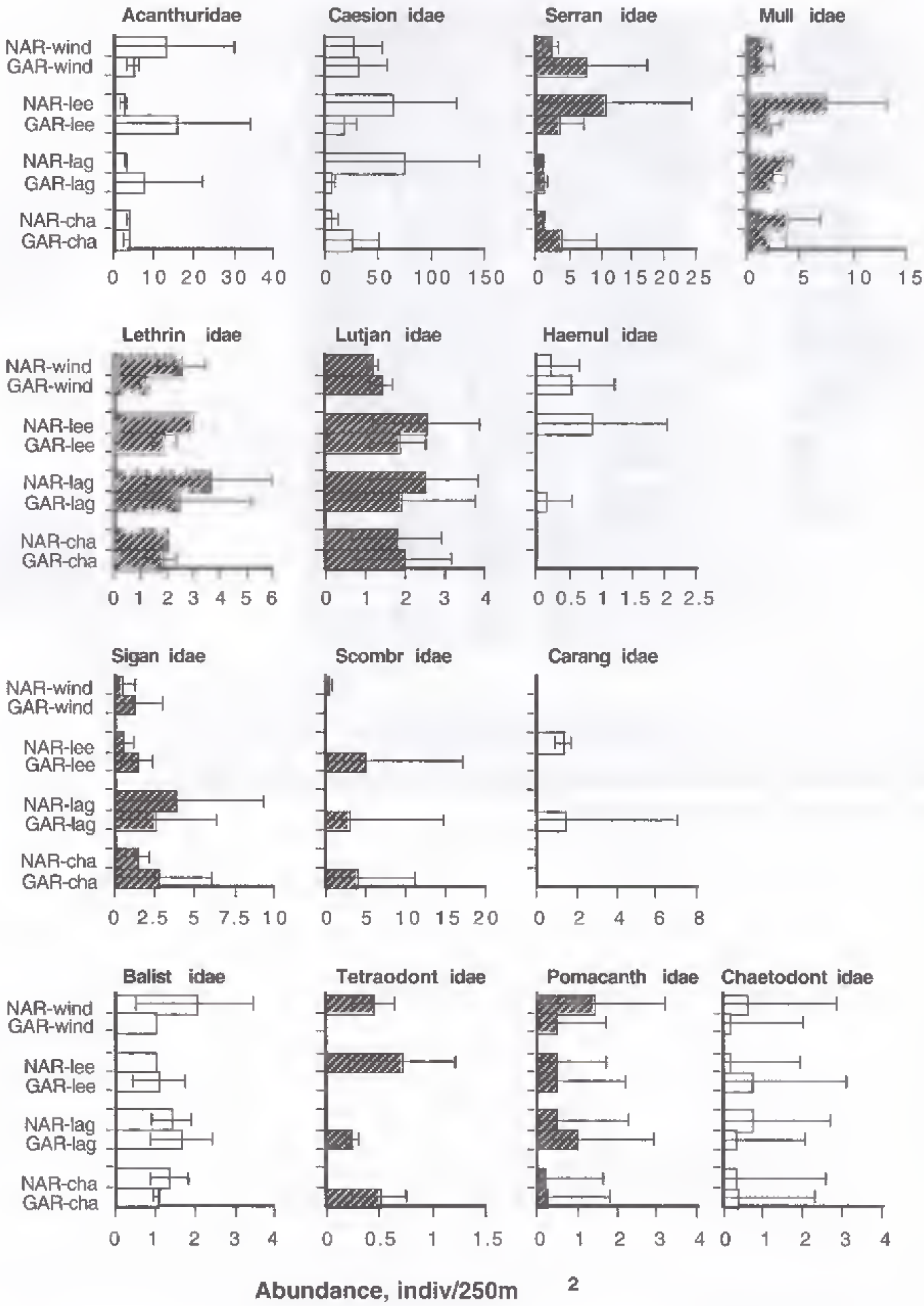

Figure 13. Abundance (mean and standard error) of fish families by reef and zone, per 250m^2, Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji.

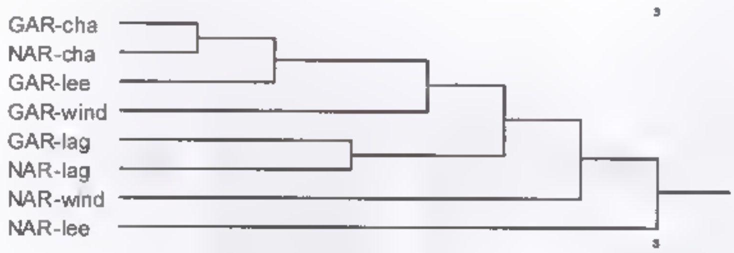

Figure 14. Cluster analysis of fish abundance by family, by habitat and reef.

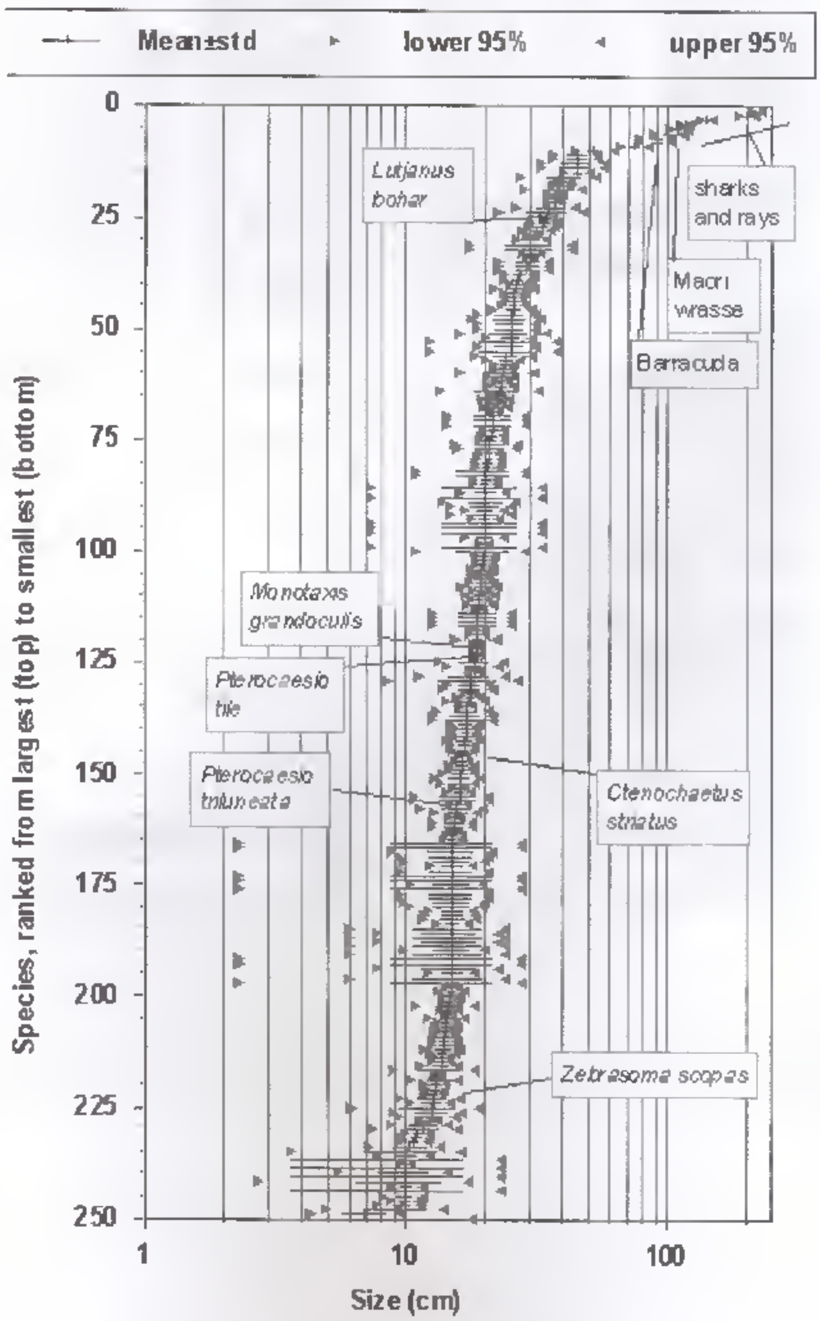

Figure 15. Size distributions of 250 species of fish, ordered from largest to smallest, censused on the GAR and NAR, Kadavu, Fiji (mean, standard deviation and lower and upper 95% confidence limits). Labelled fish are discussed in the text, and in Figures 16 and 17. Note logarithmic x axis.

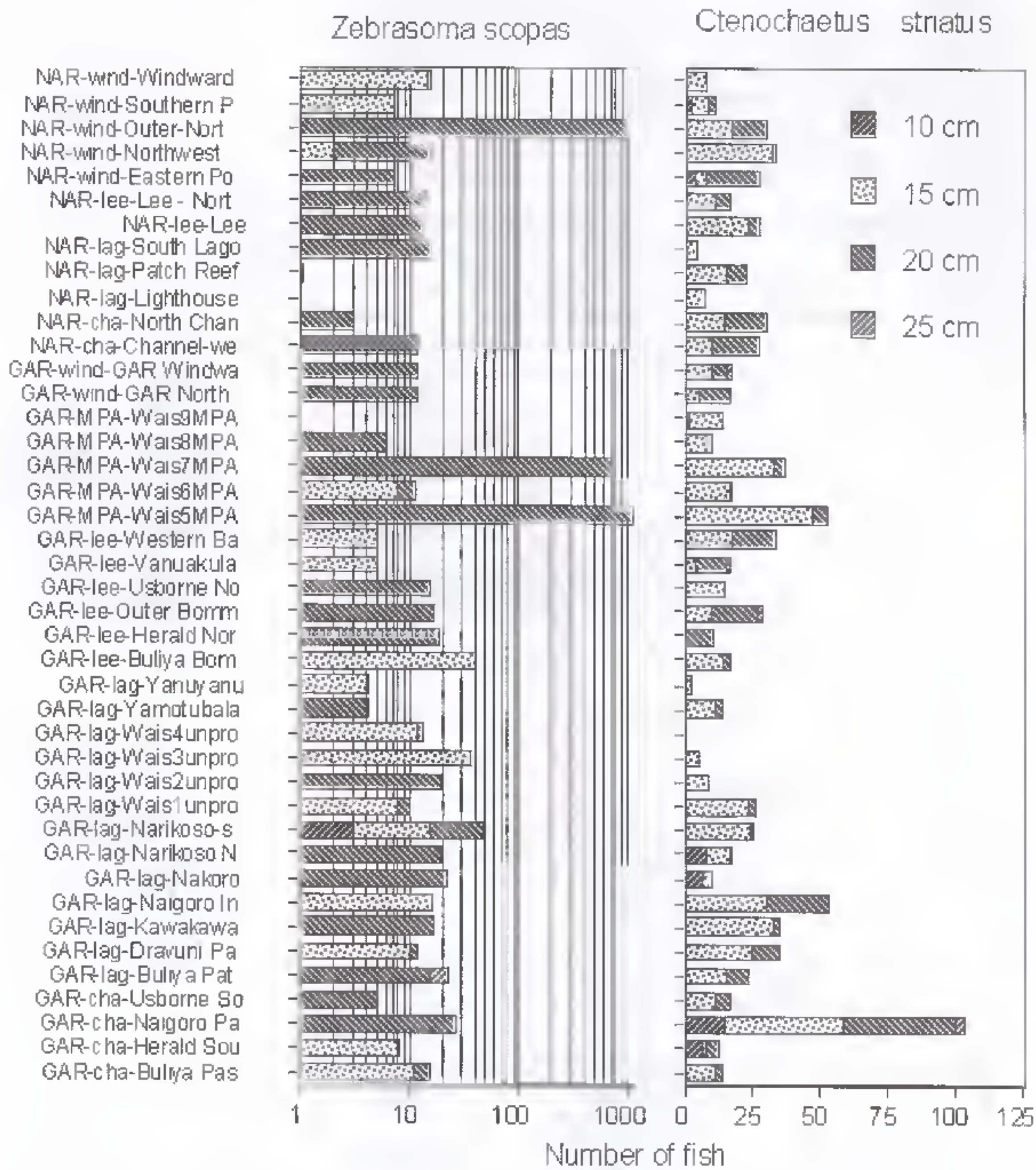

Figure 16. Size class distributions by site of the two most abundant acanthurids (surgeonfish), *Zebrasoma scopas* (left) and *Ctenochaetus striatus* (right). Note the logarithmic scale for the x axis for *Z. scopas* while *C. striatus* has a linear x axis.

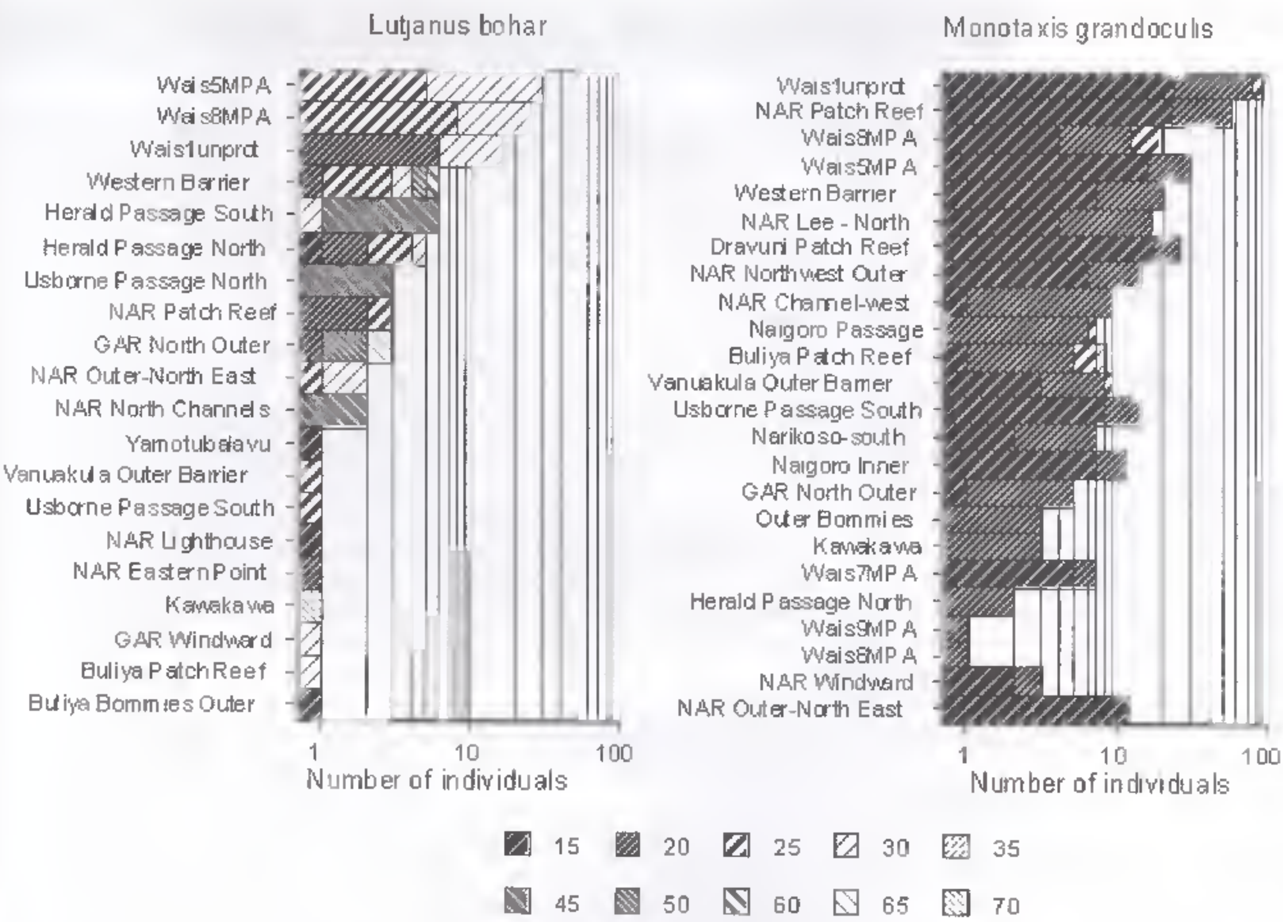

Figure 17. Size class distributions by site of the two most abundant scavengers and food fish, *Lutjanus bohar* (snapper, left) and *Monotaxis grandoculis* (emperor, right). Note the logarithmic scale for the x axes for both species.

Tables

Table 1. The names and geographical location of the sites surveyed on the Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji, April – May 2001.

Site	Longitude (E)	Latitude (S)
GAR-channels		
Buliya Passage	178°27.6'	18°50.8'
Buliya Passage-inner	178°27.8'	18°49.3'
Herald Outer South	178°27.9'	18°45.8'
Naigoro Passage	178°29.6'	19°0.47'
Usborne Passage South	178°30.2'	18°42.1'
GAR-lagoon		
Buliya Patch Reef	178°34.5'	18°49.3'
Dravuni Patch Reef	178°30.8'	18°45.7'
Kawakawa	178°32.9'	18°51.6'
Naigoro Inner	178°29.5'	19°0.49'
Nakoro	178°33.8'	18°51.4'
Narikoso Fringing	178°32.5'	18°53.3'
Narikoso North	178°32.5'	18°53.3'
Narikoso South	178°32.0'	18°54.3'
Narikoso Village	178°31.4'	18°54.3'
Vanuakula	178°30.2'	18°44.1'
Vativati Point	178°31.2'	18°53.1'
Yamotubalavu	178°27.9'	18°49.5'
Yanuyanu-i-sau	178°30.0'	18°46.4'
GAR-leeward		
Buliya Barrier	178°27.6'	18°50.8'
Buliya Outer Bommies	178°27.6'	18°50.6'
Buliya Western Barrier	178°27.8'	18°49.5'
Herald Passage North	178°28.1'	18°45.4'
Usborne Outer	178°30.2'	18°42.1'
Vanuakula-outer barrier	178°29.9'	18°42.5'
GAR-windward		
GAR North Outer	178°31.1'	18°41.3'
GAR Windward	178°32.0'	18°42.0'
NAR-channels		
NAR Channel-West	178°30.6'	18°36.7'
NAR North Channels E.	178°32.4'	18°36.5'
NAR-lagoon		
NAR Patch reef	178°32.5'	18°37.4'
NAR South Lagoon	178°31.0'	18°39.6'
Solo Lighthouse	178°31.8'	18°38.2'
NAR-leeward		
NAR Lee North	178°30.0'	18°37.3'
NAR Lee South	178°30.4'	18°39.1'
NAR-windward		
NAR Eastern Point	178°33.5'	18°37.2'
NAR Northwest Outer	178°32.1'	18°36.5'
NAR Outer North East	178°33.1'	18°37.1'
NAR Southern Point	178°31.6'	18°40.7'
NAR Windward	178°32.1'	18°40.6'
Waisomo-MPA		
Waisomo-MPA.BH1	178°31.8'	18°56.1'
Waisomo-MPA.BH2	178°29.0'	18°56.3'
Waisomo-MPA.BH3	178°31.3'	18°57.2'
Waisomo-MPA.BH4	178°30.9'	18°57.4'
Waisomo-MPA.BH5	178°31.1'	18°57.4'
Waisomo-Unprotected		
Waisomo-Unprot.BH	178°31.6'	18°56.2'
Waisomo-Unprot BR1	178°31.7'	18°55.9'
Waisomo-Unprot.BR2	178°31.6'	18°56.0'
Waisomo-Unprot.BR3	178°31.9'	18°55.9'

Table 2. Benthic categories recorded for video transects and habitat descriptions.

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

Table 3. Factorial structure for ANOVA of benthic, invertebrate and fish survey data, Ono tikina, Fiji. Factors A) and B) form a fully crossed design, with all reef zones being found on both reefs. Factor C) includes sites from a separate study (Sauni 2001) in the Waisomo MPA and adjacent unprotected reference areas.

Factor	Level 1	Level2	Level 3	Level 4
A) Reef	Great Astrolabe Reef	North Astrolabe Reef		
B) Zone	Windward	Leeward	Lagoon	Channel
C) Waisomo study (Sauni 2001)	MPA	unprotected		

Table 4. ANOVA results of benthic cover by reef (Great Astrolabe, North Astrolabe) and reef zone (windward, leeward, lagoon and channel). Waisomo results are excluded from this analysis. ns – not significant, * - p<0.05, ** - p<0.01, *** - p<0.001.

		Reef	Habitat	Reef*Habitat
	r^2	1	3	3
Coral	0.144	ns	ns	ns
Dead Coral	0.206	ns	ns	ns
Soft Coral	0.488	*	**	ns
Sponge	0.179	ns	ns	ns
Alg-Cor	0.369	ns	*	ns
Alg-Trf/Rck	0.367	**	ns	ns
Alg-Fle	0.047	ns	ns	ns
Sand	0.296	ns	ns	ns
Rubble	0.432	ns	**	ns

Table 5. Three way factorial ANOVA of coral cover by reef, habitat and coral morphology at the Great and North Astrolabe Reefs, Kadavu, Fiji. (r^2=0.590). ns – not significant, * - p<0.05, ** - p<0.01, *** - p<0.001.

Source	df	F Ratio	Prob>F	Significance
Reef	1	0.006	0.936	ns
Habitat	3	0 230	0.875	ns
Morphology	7	31.499	0.000	***
Reef*Habitat	3	0.029	0.993	ns
Reef*Morphology	7	0.974	0.450	ns
Habitat*Morphology	21	2.158	0.003	**
Reef*Habitat*Morphology	21	0 890	0.604	ns

Table 6. Scleractinian coral families and genera, and numbers of species per family and genus, recorded during surveys on the Great and North Astrolabe Reefs in Kadavu, Fiji. Total of 16 families, 52 genera and 148 species recorded.

FAMILY	# species per	
Genus	Genus	Family
ACROPORIDAE		47
Acropora	40	
Astreopora	2	
Montipora	5	
FAVIIDAE		31
Caulastrea	1	
Cyphastrea	3	
Diploastrea	1	
Echinopora	2	
Favia	6	
Favites	3	
Goniastrea	2	
Leptastrea	2	
Leptoria	2	
Montastrea	3	
Oulophyllia	1	
Platygyra	4	
Plesiastrea	1	
FUNGIIDAE		11
Fungia	5	
Halomitra	1	
Herpolitha	1	
Podabacia	1	
Polyphyllia	1	
Sandalolitha	1	
Zoopilus	1	
AGARICIIDAE		11
Gardineroseris	1	
Leptoseris	3	
Pachyseris	2	
Pavona	5	
MUSSIDAE		10
Acanthastrea	3	
Lobophyllia	4	
Scolymia	1	
Symphyllia	2	

FAMILY Genus	# species per Genus	 Family
PECTINIIDAE		7
Echinomorpha	1	
Echinophyllia	2	
Mycedium	2	
Oxypora	2	
PORITIDAE		6
Alveopora	1	
Goniopora	1	
Porites	4	
MERULINIDAE		6
Hydnophora	3	
Merulina	2	
Scapophyllia	1	
POCILLOPORIDAE		5
Pocillopora	3	
Seriatopora	1	
Stylophora	1	
THAMNASTERIIDAE		3
Psammocora	3	
DENDROPHYLLIIDAE		3
Tubastraea	1	
Turbinaria	2	
OCULINIDAE		2
Galaxea	2	
SIDERASTREIDAE	2	
Coscinaraea	2	
CARYOPHYLLIIDAE		2
Plerogyra	2	
TUBIPORIDAE		1
Tubipora	1	
MILLEPORIDAE		1
Millepora	1	

Table 7. ANOVA of *Acanthaster planci* and *Bohadschia argus* density by reef and zone, Great and North Astrolabe Reefs, Kadavu Fiji. These were the only two species for which > 10 and a significant ANOVA result. ns – not significant, + - p<0.10, * - p<0.05, ** - p<0.01, *** - p<0.001.

Species *	Total	ANOVA Reef	F	p	significance
Acanthaster planci	30	Reef	5.885	0.019	*
		Zone	1.623	0.195	ns
		Reef*Zone	1.623	0.195	ns
Bohadschia argus	10	Reef	0.487	0.488	ns
		Zone	3.077	0.036	*
		Reef*Zone	5.557	0.002	**

Table 8. The total number and species of invertebrates in general searches at 17 sites on the Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji. Sites ordered by decreasing number of species.

	Number ofIndividuals	Number of Species				
		Total	Giant clams	Cucumbers	Oysters	Starfish
Sites			3	10	6	2
Solo Lighthouse	16	7	2	3	2	0
NAR South Lagoon	16	5	2	3	0	0
Buliya Passage Inner	3	4	0	2	2	0
Naigoro Passage	6	4	0	1	3	0
NAR North Channels	9	4	0	3	0	1
Yanuyanu-i-sau	9	4	1	1	1	1
Buliya Bommies	3	0	2	1	0	
Nakoro	6	3	1	2	0	0
GAR Windward	2	2	1	1	0	0
Herald Passage South	5	2	2	0	0	0
Inner Naigoro	4	2	1	0	1	0
NAR Windward Rock	3	2	2	0	0	0
Vanuakula Outer Lee	3	2	1	1	0	0
NAR Lee South	1	1	0	0	0	1
NAR South Point	11	1	0	0	0	1
Narikoso North	2	1	0	1	0	0

Table 9. The species and number of sea-cucumbers recorded at 17 sites surveyed on the Great and North Astrolabe Reefs, Kadavu, Fiji.

Site	*Bohadschia argus*	*Stichopus chloronotus*	*Thelenota anax*	*Holothuria atra*	*Thelenota ananas*	*Holothuria scabra*	*Bohadschia graeffei*	*Holothuria edulis*	*Holothuria marmoratus*	*Holothuria nobilis*	*Actinopyga sp.*
Naigoro Passage			1								1
Narikoso North	2										
Nakoro	3		2								
Yamotubalavu		10									
Passage Inner			5		1						
Buliya Passage			1		1						
Yanuyanu-i-sau	1										
Vanuakula								1			
Windward										1	
Solo Lighthouse	3					2			1		
NAR South Lagoon	5	1		7							
NAR North Channels East		1			2		1				
Total	14	12	9	7	4	2	1	1	1	1	1

Table 10. The number of crown-of-thorns (*Acanthaster planci*) and *Choriaster granulatus* starfish recorded at 17 sites surveyed on the Great and North Astrolabe Reefs, Kadavu, Fiji.

Site	*Acanthaster planci*	*Choriaster granulatus*
Yamotubalavu	1	
Yanuyanu-i-sau		4
Narikoso South	4	
NAR-Southern Point	11	
NAR Lee South	1	
NAR North Channels East	5	
Total	22	4

Table 11. The species and number of giant clams (Tridacnidae) recorded at 17 sites surveyed on the Great and North Astrolabe Reefs, Kadavu, Fiji.

Site	*Tridacna derasa*	*Tridacna maxima*	*Tridacna squamosa*
Naigoro Inner			3
Nakoro	1		
Yanuyanu-i-sau			1
Herald Outer South	2		3
Vanuakula	2		
Windward			1
Solo Lighthouse	1		1
NAR Eastern Point		1	2
NAR South Lagoon		2	1
Total	6	3	12

Table 12. The species/genus and number of oysters recorded at 17 sites surveyed on the Great and North Astrolabe Reefs, Kadavu, Fiji.

Site	*Hyotissa hyotis*	*Hyotissa spp.*	*Lopha spp.*	*Oyster sp. A*	*Spondylus spp.*	Total
Yamotubalavu	13	4	51			68
Solo Lighthouse		1	17			18
Yanuyanu-i-sau		1	7			8
Naigoro Passage				2	2	4
Buliya Bommies					3	3
Buliya Passage Inner	1		1			2
Inner Naigoro					1	1
NAR North Channels					1	1
Total	14	6	76	2	7	105

Table 13. The numbers and size statistics (in cm, average, standard deviation, minimum and maximum) of all invertebrates observed in general searches and transects, at 17 sites on the Great and North Astrolabe Reefs, Kadavu, Fiji.

Species	Number of Individuals	Sizes (cm): Mean	Std.Dev.	Maximum	Minimum
Starfish					
Acanthaster planci	18	37.6	10.88	60	15
Choriaster granulatus	4				
Sea-cucumbers					
Bohadschia argus	14	34 8	6.58	47	22
Stichopus chloronotus	12	18.6	8.34	41	12
Thelenota anax	9	48.7	10.12	65	37
Holothuria atra	7	33.1	9.08	47	25
Thelenota ananas	4	63	9.49	74	51
Holothuria scabra	2	41.5	0.71	42	41
Bohadschia graeffei	1	47		47	47
Holothuria edulis	1	30		30	30
Holothuria marmoratus	1	29		29	29
Holothuria nobilis	1	18		18	18
Actinopyga sp.	1	32		32	32
Giant Clams					
Tridacna squamosa	12	26.9	10.26	40	8
Tridacna derasa	6	37	18.17	59	13
Tridacna maxima	3	31.3	6.11	38	26
Other Molluscs					
Lopha spp.	11	23.5	7.12	35	15
Hyotissa spp.	5	21.2	5.31	27	17
Spondylus spp.	4	24	5.23	31	20
Oyster sp. A	2	18.5	4.95	22	15
Hyotissa hyotis	1	28		28	28

Table 14. Reef fish populations censused at each study site on the GAR and NAR, Kadavu, Fiji, showing abundance (mean and standard error) and total number of families and species. Sites are ordered by decreasing abundance, and categorized by reef and zone. GAR = Great Astrolabe Reef; NAR = North Astrolabe Reef. Zone: Lee = Leeward; Wind = Windward; Cha = Channel; Lag = Lagoon; MPA = Marine Protected Area. sem = standard error of the mean.

Site	Reef	Zone	# Transects	Abundance: Mean	sem	Number of: Families	Species
NAR Lee	NAR	Lee	4	465.3	72.6	17	75
NAR Windward	NAR	Wind	4	338.0	267.8	10	46
Vanuakula Outer Barrier	GAR	Lee	4	299.3	263.3	11	42
Western Barrier	GAR	Lee	5	257.8	208.1	11	55
Herald Passage South	GAR	Cha	4	252.0	70.1	15	66
GAR Windward	GAR	Wind	4	244.5	97.3	17	72
NAR Southern Point	NAR	Wind	4	242.0	66.1	14	84
Buliya Bommies Outer	GAR	Lee	4	205.3	28.7	15	62
NAR Eastern Point	NAR	Wind	4	188.5	45.8	16	94
Narikoso-south	GAR	Lag	5	177.6	149.6	10	28
NAR Lighthouse	NAR	Lag	4	158.5	76.5	15	59
Yamotubalavu	GAR	Lag	4	150.0	16.7	12	56
NAR North Channels	NAR	Cha	4	121.8	12.7	14	84
Naigoro Passage	GAR	Cha	5	103.6	11.5	14	63
Buliya Passage Inner	GAR	Cha	4	102.3	37.5	13	56
Usborne Passage South	GAR	Cha	4	90.0	1.1	10	48
Yanuyanu	GAR	Lag	5	85.8	18.1	13	58
Herald Passage North	GAR	Lee	4	79.3	16.3	10	49
Naigoro Inner	GAR	Lag	5	73.8	5.0	13	57
GAR North Outer	GAR	Wind	4	71.0	6.2	10	42
Wais5MPA	GAR	MPA	7	67.4	11.0	11	47
Usborne Passage North	GAR	Lee	1	67.0		11	26
NAR Patch Reef	NAR	Lag	4	66.3	4.2	8	44
NAR Lee - North	NAR	Lee	4	64.8	13.8	11	52
Outer Bommies	GAR	Lee	4	62.0	9.2	12	41
Narikoso North	GAR	Lag	4	59.3	3.7	12	47
NAR Channel-west	NAR	Cha	4	58.8	10.9	13	49
NAR Outer-North East	NAR	Wind	4	57.8	3.6	13	50
Nakoro	GAR	Lag	4	57.5	15.4	10	46
NAR South Lagoon	NAR	Lag	5	55.6	8.3	12	45
Dravuni Patch Reef	GAR	Lag	4	55.5	4.1	9	25
Buliya Patch Reef	GAR	Lag	4	52.3	1.7	12	37
NAR Northwest Outer	NAR	Wind	4	51.3	7.2	11	42
Wais1unprot	GAR	Lag	7	51.1	11.0	13	36
Kawakawa	GAR	Lag	5	42.4	6.7	12	37
Wais8MPA	GAR	MPA	7	29.7	7.0	10	34
Wais9MPA	GAR	MPA	7	28.0	3.0	11	35
Wais6MPA	GAR	MPA	7	27.4	6.7	10	33
Wais2unprot	GAR	Lag	7	24.1	3.6	9	23
Wais7MPA	GAR	MPA	7	21.4	3.3	9	29
Wais4unprot	GAR	Lag	7	13.6	2.3	8	15
Wais3unprot	GAR	Lag	3	11.7	5.5	8	11

Table 15. ANOVA of fish abundance and number of families and species. Two-way ANOVA of Reef by zone (for NAR and GAR), and One-way ANOVA of protection status (MPA by unprotected Waisomo control sites by all NAR/GAR sites. ns – not significant, * - p<0.05, ** - p<0.01, *** - p<0.001.

Variable	Two-way ANOVA: Reef by Zone						One-way ANOVA: Protection	
	Reef		Zone		Reef*Zone			
	F	sign.	F	sign.	F	sign.	F	sign.
Abundance	0.2697	ns	2.0821	ns	0.5401	ns	4.4728	*
Number of Families	0.3982	ns	0.8609	ns	0.444	ns	4.5632	*
Number of species	2.3569	ns	1.5352	ns	0.2037	ns	9.4503	***

Table 16. The ten most abundant fish species sampled at the Great and North Astrolabe Reefs, Kadavu, Fiji, showing their % contribution to the total of all fish counted, and cumulative % contribution.

	Species	Family	Abundance	%	Cum%
1	*Zebrasoma scopas*	Acanthuridae	3334	16.4	16.4
2	*Pterocaesio tile*	Caesionidae	1470	7.2	23.7
3	*Zebrasoma veliferum*	Acanthuridae	1127	5.6	29.2
4	*Pterocaesio triluneata*	Caesionidae	1120	5.5	34.7
5	*Ctenochaetus striatus*	Acanthuridae	910	4.5	39.2
6	*Caesio teres*	Caesionidae	554	2.7	42.0
7	*Pseudanthias pascalus*	Serranidae	484	2.4	44.3
8	*Pterocaesio pisang*	Caesionidae	480	2.4	46.7
9	*Monotaxis grandoculis*	Lethrinidae	463	2.3	49.0
10	*Acanthurus lineatus*	Acanthuridae	319	1.6	50.6

Table 17. Number of large indicator fish species recorded in general surveys at representative sites in the Great Astrolabe and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji. Total number of species = 33.

Site	Reef	Number	Site	Reef	Number
North Channels East	NAR	22	Naigoro Inner	GAR	9
Southern Point	NAR	18	Herald Outer, South	GAR	8
Naigoro Passage	GAR	16	Nakoro	GAR	6
Eastern Point	NAR	16	Yanuyanu-i-sau	GAR	5
Buliya Passage-Inner	GAR	15	Channel West	GAR	5
Windward	GAR	15	Narikoso North	GAR	3
Solo Lighthouse	NAR	15	Yamotubalavu	GAR	2
Herald Outer, North	GAR	13			

Table 18. List of large indicator fish counted in general surveys at selected sites on the Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji. The Table shows the number of sites at which species was found, and the maximum, mean and standard deviation of abundance.

Scientific	Common Name	#sites	Max	Mean	Sd.
Sharks					
Triaenodon obesus	Whitetip Reef Shark	11	5	1.60	1.45
Carcharhinus amblyrhynchos	Grey Reef Reef Shark	5	3	0.67	1.11
Nurse shark	Nurse shark	0	1	0.07	0.26
Rastreliger kanagurta	Leopard shark	1	2	0.13	0.52
Rays					
Manta birostris	Manta Ray	1	1	0.07	0.26
Aetobatus nari nari	Eagle ray	3	2	0.27	0.59
Pelagic					
Gymnosarda unicolor	Dogtooth Tuna	3	1	0.20	0.41
Scomberomorus commersoni	Narrow Barred Spanish Mackerel	10	3	0.93	0.88
Nebruis terrugineus.	Striped mackerel	7	100	24.00	30.43
Elegatus bipinnulata	Rainbow Runner	5	100	10.60	26.16
Caranx sexfasciatus	Bigeye Trevally	3	500	37.67	128.58
Caranx melanpygus	Bluefin Trevally	5	6	1.00	1.73
Caranx ignobilis	Giant Trevally	2	1	0.13	0.35
Carangoides orthogrammus	Thicklip Trevally	3	6	0.73	1.71
Atule mate	Yellowtail Scad	1	40	2.67	10.33
Barracuda					
Sphyraena qenie	Chevron Barracuda	3	150	11.33	38.59
Spyraena jello	Pickhandle Barracuda	2	50	3.60	12.88
Sphyraena barracuda	Great Barracuda	2	1	0.13	0.35
Sphyraena helleri	Hellers Barracuda	1	200	13.33	51.64

Table 19. Abundance of sharks and rays counted in general surveys at representative sites in the Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji during a dive. See Table 18 for list of species in each group.

	Sharks			Rays		
	mean	sd	max	mean	sd	max
NAR North Channels	2.50	2.08	5	-	-	-
Solo Lighthouse	1.50	1.29	3	-	-	-
NAR Eastern Point	1.00	1.41	3	0.50	0.71	1
Narikoso North	0.75	1.50	3	-	-	-
NAR Southern Point	0.75	1.50	3	0.50	0.71	1
Windward	0.75	0.96	2	-	-	-
Naigoro Inner	0.50	1.00	2	-	-	-
Nakoro	0.50	1.00	2	-	-	-
Naigoro Passage	0.25	0.50	1	1.00	1.41	2
Yanuyanu-I-sau	0.25	0.50	1	0.50	0.71	1
Herald Outer, South	0.25	0.50	1	-	-	-
Herald Outer, North	0.25	0.50	1	-	-	-
Yamotubalavu	-	-	-	-	-	-
Buliya Passage-Inner	-	-	-	-	-	-
Channel West	-	-	-	-	-	-

Table 20. Abundance of pelagic fish and barracuda at representative sites in the Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji during a dive. See Table 18 for list of species in each group.

	Pelagic			Barracuda			Overall
	Mean	sd	max	mean	sd	max	
Buliya Passage-Inner	62.44	164.87	500	0.25	0.50	1	62.69
NAR North Channels	11.89	19.04	50	50.00	100 00	200	61.89
NAR Southern Point	7.56	12.87	30	37.50	75.00	150	45.06
Naigoro Passage	-	-	-	13.50	24 41	50	13.50
NAR Eastern Point	11.44	33.22	100	1.00	2.00	4	12.44
Yamotubalavu	11.11	33.33	100	-	-	-	11.11
Windward	3.67	7.02	17	4.00	8.00	16	7.67
Herald Outer, North	6.00	16.53	50	-	-	-	6.00
Yanuyanu-I-sau	5.67	16 63	50	-	-	-	5.67
Solo Lighthouse	4.78	13.23	40	-	-	-	4.78
Channel-West	4.44	13.33	40	-	-	-	4.44
Naigoro Inner	0.44	1.01	3	-	-	-	0.44
Nakoro	0.11	0.33	1	0.25	0.50	1	0.36
Herald Outer, South	0.33	0.71	2	-	-	-	0.33
Narikoso North	-	-	-	-	-	-	-

Table 21. Summary of key observations from surveys conducted from 29 April – 3 May 2001, on the Great Astrolabe and North Astrolabe Reefs, Kadavu, Fiji.

Reef Structure

A. The GAR and NAR have a classic barrier-reef/lagoon structure with a windward barrier reef on the east, a deep lagoon with islands and patch reefs in the middle, and a leeward barrier reef in the west.
B. The structure and orientation of the reefs show the dominant influence of high wave energy on the eastern barrier, flow of seawater through the lagoon, and outward flow through the channels in the leeward western barrier reef channels.
C. The topographic complexity of the barrier reefs and bommie systems are evidence of high coral growth in the past and good habitat for invertebrate and fish populations.
D. The lagoon patch reefs, back reef slopes and blue holes have less topographic complexity than the barrier reefs, and therefore less capacity to harbour fish and invertebrates.

Benthic community structure

E. The high cover of coralline algae (43%) and low coral cover (12%) on the GAR and NAR are due to a combination of factors, including the prevalence of coralline algae in Fijian reefs and recent mortality of corals in 2000, which caused ? 60% mortality in reefs throughout Fiji (Cummings, in review).
F. Highest coral cover on the windward eastern barrier reef is probably due to upwelling of cooler oceanic water during the bleaching in 2000, resulting in lower stress. Lagoon and leeward reefs, because they are calmer, suffer higher temperatures and sedimentation, and therefore had higher coral mortality (Salm *et al.* 2001).
G. The Waisomo MPA had higher coral cover than other sites, the high dead coral indicating how much higher the coral cover was before bleaching and mortality in 2000.
H. Benthic communities on the GAR and NAR show greater similarity within a reef system than between the two reefs.

Coral community structure

A. Coral communities on the GAR and NAR are dominated by massive corals, and vary mainly by reef zone.
B. Coral species richness of 148 species compares to previous lists of 210 (Lovell, pers.comm.) for Fiji.
C. Low coral bleaching levels are due to low coral populations after mortality in 2000.
D. Crown-of-thorns starfish feeding scars common on NAR windward and channel sites.

Invertebrates

E. Invertebrates were at low abundances, except for oysters on shallow reefs fringing islands where freshwater runoff and currents are high.
F. *Acanthaster planci*, or crown-of-thorns starfish, was the second most abundant invertebrate, though found only at windward and channel sites in the NAR.
G. Giant clams were infrequent in the NAR and GAR, with a maximum of five recorded at any one site.
H. An unknown sea cucumber species in the genus *Actinopyga* was recorded at Naigoro Passage, which may represent a range extension of a known species, or a new unidentified species.

Fish abundance

I. Fish abundance was higher at NAR than GAR.
J. Fish abundance was highest on leeward and windward reefs, and least in lagoons and channels.
K. Fish abundance is least at the Waisomo MPA and adjacent sites, reflecting historically heavy fishing at these sites, and their simple structure compared to other habitats in the GAR and NAR.
L. Fish abundance at the Waisomo MPA was marginally higher than the unprotected sites, though at too low levels to draw conclusions on the effectiveness of the MPA (Sauni 2001).
M. Two species of schooling herbivorous surgeonfish, *Zebrasoma* scopas and *Z.velliferum* dominate patterns of abundance among all sites at the NAR and GAR.

Fish family and species patterns

N. Surgeonfish and fusiliers are the most abundant fish on the GAR and NAR, comprising 8 of the 10 most abundant species.
O. Fisheries species – snappers, emperors, sweetlips and rabbitfish – are at low abundances at all sites.
P. NAR windward and leeward sites have more different fish community structures than all other sites on the NAR and GAR.
Q. Fish sizes on the GAR and NAR were small, indicative of overfishing, particularly at the heavily fished sites near Waisomo village, and illustrated by small size classes of fish recruiting to the Waisomo MPA.

Large predatory fish

R. Outer windward and high-current channel sites had the highest abundance and diversity of large predatory reef fish, while sheltered lagoon and leeward sites had the lowest.
S. NAR has higher abundance of large predatory reef fish than GAR.
T. Lagoon sites with high abundance of some fish may be due to the fish behaviour (pelagics) or low fishing pressure (Solo Lighthouse), emphasizing their potential/importance in protection.
U. Fishing is the principal threat, from local access points within the GAR.

GPS Areas Surveyed

Table 1. The names and geographical location of the sites surveyed on the Great and North Astrolabe Reefs (GAR, NAR), Kadavu, Fiji, April – May 2001.

Site	Longitude (E)	Latitude (S)	Site	Longitude (E)	Latitude (S)
GAR-channels			***NAR-channels***		
Buliya Passage	178°27.6'	18°50.8'	NAR Channel-West	178°30.6'	18°36.7'
Buliya Passage-inner	178°27.8'	18°49.3'	NAR North Channels E.	178°32.4'	18°36.5'
Herald Outer South	178°27.9'	18°45.8'	***NAR-lagoon***		
Naigoro Passage	178°29.6'	19°0.47'	NAR Patch reef	178°32.5'	18°37.4'
Usborne Passage South	178°30.2'	18°42.1'	NAR South Lagoon	178°31.0'	18°39.6'
GAR-lagoon			Solo Lighthouse	178°31.8'	18°38.2'
Buliya Patch Reef	178°34.5'	18°49.3'	***NAR-leeward***		
Dravuni Patch Reef	178°30.8'	18°45.7'	NAR Lee North	178°30.0'	18°37.3'
Kawakawa	178°32.9'	18°51.6'	NAR Lee South	178°30.4'	18°39.1'
Naigoro Inner	178°29.5'	19°0.49'	***NAR-windward***		
Nakoro	178°33.8'	18°51.4'	NAR Eastern Point	178°33.5'	18°37.2'
Narikoso Fringing	178°32.5'	18°53.3'	NAR Northwest Outer	178°32.1'	18°36.5'
Narikoso North	178°32.5'	18°53.3'	NAR Outer North East	178°33.1'	18°37.1'
Narikoso South	178°32.0'	18°54.3'	NAR Southern Point	178°31.6'	18°40.7'
Narikoso Village	178°31.4'	18°54.3'	NAR Windward	178°32.1'	18°40.6'
Vanuakula	178°30.2'	18°44.1'			
Vativati Point	178°31.2'	18°53.1'			
Yamotubalavu	178°27.9'	18°49.5'			
Yanuyanu-i-sau	178°30.0'	18°46.4'	***Waisomo-MPA***		
GAR-leeward			Waisomo-MPA.BH1	178°31.8'	18°56.1'
Buliya Barrier	178°27.6'	18°50.8'	Waisomo-MPA.BH2	178°29.0'	18°56.3'
Buliya Outer Bommies	178°27.6'	18°50.6'	Waisomo-MPA.BH3	178°31.3'	18°57.2'
Buliya Western Barrier	178°27.8'	18°49.5'	Waisomo-MPA.BH4	178°30.9'	18°57.4'
Herald Passage North	178°28.1'	18°45.4'	Waisomo-MPA.BH5	178°31.1'	18°57.4'
Usborne Outer	178°30.2'	18°42.1'	***Waisomo-Unprotected***		
Vanuakula-outer barrier	178°29.9'	18°42.5'	Waisomo-Unprot.BH	178°31.6'	18°56.2'
GAR-windward			Waisomo-Unprot.BR1	178°31.7'	18°55.9'
GAR North Outer	178°31.1'	18°41.3'	Waisomo-Unprot.BR2	178°31.6'	18°56.0'
GAR Windward	178°32.0'	18°42.0'	Waisomo-Unprot.BR3	178°31.9'	18°55.9'