Marine Surveys undertaken in the Elizabeth and Middleton Reefs Marine National Nature Reserve, December 2003

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Cover Image: Preparing to dive, Elizabeth Reef December 2003.
(*Courtesy of DEH Photographer Phil Domaschenz*)

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EXECUTIVE SUMMARY

The Elizabeth and Middleton Reefs Marine National Nature Reserve is located some 600 kilometres east of Coffs Harbour, New South Wales. The Australian Institute of Marine Science (AIMS) conducted fish, benthic, and bêche-de-mer surveys on Elizabeth Reef in the Reserve, 2–6 December 2003.

A total of 111 species of coral were identified during this survey compared with the 122 identified by Done and Veron in 1981. The coral community at Elizabeth Reef was similar to that observed during previous surveys. The percent cover of hard coral was at a moderate level and consistent with a reef recovering from disturbance. At the time of survey no bleaching and very little crown-of-thorns starfish (COTS) activity was observed. The percent cover of *Acropora* seen during this survey was lower than seen by Done in 1981, however the high disturbance regime, in combination with the distance from other reef systems, and the historic presence of COTS, suggests that a high abundance of *Acropora* is likely to be a rare event.

A total of 181 fish species were recorded during this survey: 61 of these species are new records for Elizabeth Reef, raising the number of species recorded on the reef to 311. Forty-five species represent new records for the Reserve. Comparisons between the most species rich fish genera at Elizabeth Reef in 1987 and 2003 showed that the species richness and species complement of dominant genera differed little after a 16-year gap in surveys. Black cod (*Epinephelus daemelii*) abundance was estimated at 4 cod/hectare during these surveys with no evidence that cod numbers had either increased or decreased since last surveyed in 1987, although direct abundance comparisons were not possible. The maximum black cod length recorded at Elizabeth Reef during 2003 surveys was 1.5m and this is around the maximum length recorded in Australia.

High numbers of Galapagos sharks (*Carcharhinus galapagensis*) were observed at Elizabeth Reef, especially in the lagoon. Their size suggests the reef lagoon is an important nursery area for Galapagos sharks. The presence and behaviour of these sharks in the Reserve is very significant as this species is unlikely to be present at other Australian governed reef systems (excluding Lord Howe Island).

This report represents the first published bêche-de-mer surveys in the Reserve. The outstanding observation was that the densities of *H. whitmaei* (*nobilis*) observed at Elizabeth Reef in two areas (133.3 ind ha^{-1}) were higher than have been previously reported in other areas in Australia. *Holothuria atra* were also found in high densities, though in densities similar to many other areas in the Indo Pacific.

The authors consider that the unique nature of the reserve provides compelling reasons why a high level of protection should be afforded to the biological communities of both reefs.

1 INTRODUCTION

The Elizabeth and Middleton Reefs Marine National Nature Reserve (the Reserve) is one of two protected areas in the Tasman Sea region. The Reserve is located approximately 600 km east of Coffs Harbour and 200 km north of Lord Howe Island (Figure 1). The Reserve covers an area of 188,000 hectares, and includes the southern-most open-ocean platform reefs in the world: Elizabeth Reef (~5,100 ha) and Middleton Reef (~3,700 ha). Formed on volcanic seamounts in the northern Tasman Sea, these isolated reef systems lie close to the boundary between the Coral Sea and the Tasman Sea and are exposed to both tropical and temperate ocean currents. The Reserve is one of 12 Marine Protected Areas (MPAs) managed by the Marine Environment and Policy Branch of the Department of the Environment and Heritage (DEH), nine of which contain coral reef ecosystems.

The Reserve was proclaimed on 23 December 1987. The Reserve management plan (ANCA 1993) makes clear that the reefs are to be managed as strict nature reserves - World Conservation Union (IUCN) category Ia. Such reserves are primarily for scientific research to ensure habitats, ecosystems, and native species are preserved in as undisturbed state as possible. The Reserve also forms part of the National Representative System of Marine Protected Areas (NRSMPA).

The management plan states that "the primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of marine protected areas, to contribute to the long term ecological viability of marine systems, to maintain ecological processes, and to protect Australia's biological diversity at all levels". The importance of this was highlighted in Australia's Oceans Policy where accelerated development of the NRSMPA was a specific action (Commonwealth of Australia 1998).

Performance Assessment forms a key role in the implementation of world best management practice and determining the effectiveness of these MPAs. Rigorous environmental research and monitoring programs are a core element of performance assessment (ANZECC 1999).

This document describes the fish, benthic, and bêche-de-mer surveys conducted by the Australian Institute of Marine Science (AIMS) in the Elizabeth and Middleton Reefs Marine National Nature Reserve in December 2003. A similar survey was conducted by AIMS in the Coringa-Herald National Nature Reserve in March 2003 (Oxley *et al.* 2003). A summary of the results is presented along with a discussion of their significance and comparison with other coral reef ecosystems including the Coringa-Herald National Nature Reserve, the Solitary Islands Marine Park and the coral reefs of the Capricorn Bunker Group of the Great Barrier Reef (GBR).

The Australian Customs Service provided the vessel ACV Hervey Bay and her crew for this survey: support that was critical to allowing work to be conducted in this remote area, where only one detailed survey of fish and benthic communities has been conducted since the Reserve was proclaimed (Australian Museum 1992).

2 METHODS

2.1 Sampling design

Fish and benthic communities were surveyed on 10 sites on Elizabeth Reef within the Elizabeth and Middleton Reefs Marine National Nature Reserve (Figures 1 and 2). These surveys encompassed three major habitat areas with different levels of exposure to oceanic conditions; sheltered lagoon (site 1), reef channel or near reef channel (sites 2 and 8) and exposed reef slopes (other seven sites). Reef slope sites were distributed evenly around the perimeter of Elizabeth Reef to encompass any local variation in reef communities due to reef orientation. The abundance of bêche-de-mer and clams were also assessed at all sites.

Weather conditions were not ideal for working on these exposed reefs, with a large swell (4-5m) on most days and winds in excess of 25 knots during the last four days of the patrol. It was initially intended to survey both Elizabeth and Middleton Reefs, however poor weather conditions only allowed Elizabeth Reef to be surveyed. The remoteness of the Reserve meant that SCUBA diving profiles were necessarily conservative to stay within safe diving guidelines (dictated by distance to a recompression chamber) and allow maximum spatial coverage of reef habitats. To achieve these goals, daily diving was restricted to 4 dives (max. duration 45 min.) to a depth of around 9 m. As sampling of deeper habitats was precluded, all results and discussion pertain to shallow water communities only.

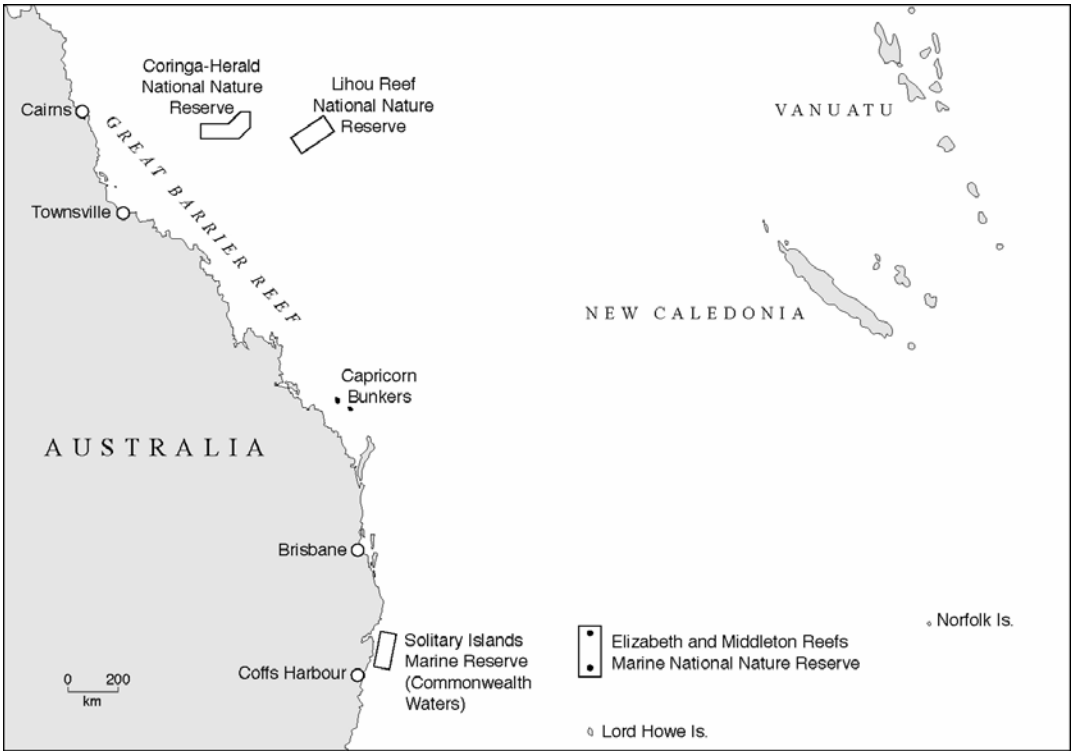

Figure 1. Location of Elizabeth and Middleton Reefs Marine National Nature Reserve and reefs surveyed. The GBR reefs and other Commonwealth marine reserves are also shown.

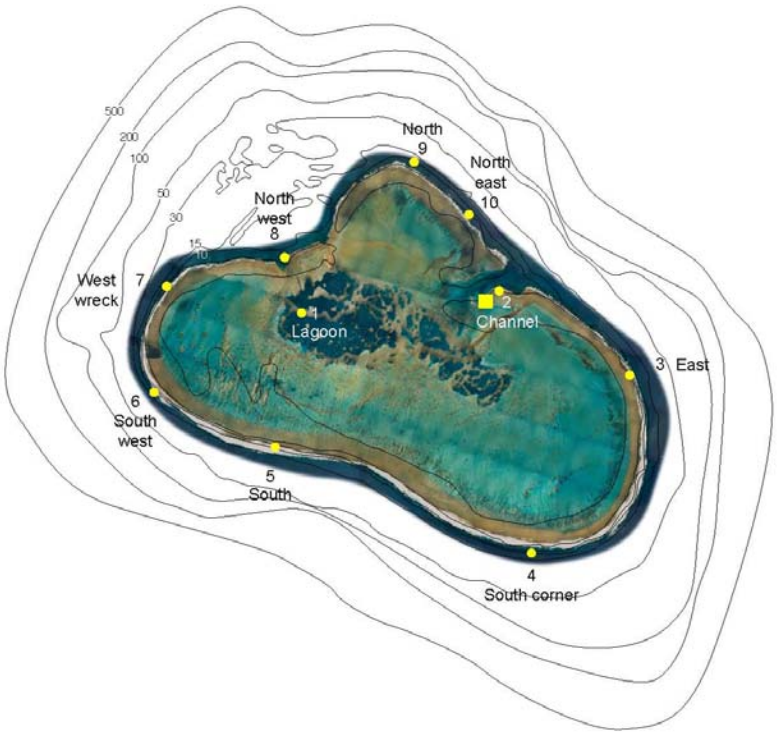

Figure 2. Location of survey sites on Elizabeth Reef. The square symbol shows the location of the snorkel swim in the lagoon. (See Appendix 6 for GPS positions of sites)

2.2 Fish and benthic communities

2.2.1 BENTHIC RAPID ASSESSMENT PROTOCOL (RAP)

A rapid visual assessment method for reef benthic abundance and diversity developed by DeVantier (see DeVantier *et al.* 1998) was used to assess the communities of Elizabeth Reef.

At all of the sites surveyed, the reef slope was gentle and broad such that at most sites the swim surveys essentially covered only one habitat. Sites on the outside of the reef were exposed to large swells and the reef crest and flat were not accessible. The distance swum during each survey was 200-400 metres. At the lagoon site the swim was conducted on snorkel due to an equipment malfunction.

The overall abundance of combined hard corals, all soft corals, all sponges and all thallous algae was estimated on a five point scale for each site (Table 1). There were two subdivisions within each ranking e.g. 1- indicates 1-5% cover, 1+ 5-10% cover. A record was kept of all hard and soft coral species seen and an estimate made using the same five point scale (*without* subdivisions) of the percentage of total hard or soft coral that each species accounted for. For example an abundance scale of 1 for a particular hard coral species indicated that that species accounted for 1-10% of the total hard coral percentage cover.

Table 1. Abundance scale used during these surveys.

Abundance scale	Percentage cover	Abundance scale	Percentage cover
1-	>0-5%	3+	>40-50%
1+	>5-10%	4-	>50-62.5%
2-	>10-20%	4+	>62.5-75%
2+	>20-30%	5-	>75-87.5%
3-	>30-40%	5+	>87.5-100%

For each species an estimate was also made of the proportion of colonies in three size classes:

1. <10 cm across;
2. 10-50 cm across;
3. >50 cm across.

All data were entered into a Microsoft® Access database and lodged at AIMS. A summary table showing relative abundance of all species recorded at each site as well as overall abundance of major benthic groups at each site is included in Appendix 1.

2.2.2 VIDEO TRANSECT SURVEYS

These surveys were used to obtain rigorous abundance estimates of biota at a coarser taxonomic resolution. They were carried out following a standard operational procedure currently used in long term monitoring surveys of the GBR. The method has received wide acceptance, both nationally and internationally, and is described fully in Page *et al.* (2001) and Osborne and Oxley (1997). Use of this method allows direct comparisons to be made with existing data from the GBR and provides a solid baseline against which future change can be measured.

Benthic organisms were sampled on three consecutive haphazard 50m transects (separated by at least 5m) within each site. A 30 cm wide swathe was recorded along each 50 m transect using a MiniDV video camera held 25-30 cm above the substrate. At the completion of the field surveys, percent cover of corals and other benthic categories were estimated using a point sampling technique, in which approximately 200 systematically-dispersed points were sampled from each video transect. Corals were identified to the greatest taxonomic detail achievable, but aggregated for analysis. Analysis of the video data focussed on four major components of the benthic community: hard corals, soft corals, algae and sponges. Species level information on coral communities was obtained using the RAP described above.

At each site 360° panoramic shots were also filmed over a 30-60 second time period before transects were sampled. These panoramas provide a contextual view of the topography and habitat in which the transects were laid. High resolution clips can be viewed on the electronic version of this report and low resolution clips can be viewed through the AIMS Reef Monitoring web page (www.aims.gov.au/reef-monitoring).

2.2.3 FISH RAPID VISUAL CENSUS METHOD

The rapid visual census method used was a timed swim count modified from that used by Williams (1982). This method provided species composition data and crude abundance estimates of the fish communities. A diver searched the reef slope from a depth of 12m (or the reef base, whichever was less) to the reef flat for a period of 45 min. Typically the diver searched the deeper habitats first then gradually worked up onto the reef flat by the end of the dive. A distance of 200-400m was covered on each dive. Divers concentrated on searching as great a variety of microhabitats as possible within the depth range. All species sighted were recorded. It should be noted that highly cryptic and nocturnal species are under represented when using this style of survey. Crude abundance estimates of each species observed within a 10m wide belt centred around the divers swim path were recorded on a log base five abundance scale as detailed in Table 2. The complete list of species found at each site is listed in Appendix 2.

Table 2. Abundance scale used for reef fish timed swim surveys.

Abundance category	Number of individuals
1	1
2	2-5
3	6-25
4	26-125
5	126-625
6	>626

2.2.4 FISH VISUAL CENSUS TRANSECTS

Visual census transects provided more rigorous density estimates of a select group of species and a solid baseline for future monitoring surveys. These surveys were carried out using a standard operational procedure currently used in long term monitoring surveys of the GBR. The method is described fully in Halford and Thompson (1994) and English *et al.* (1997). Use of this method in these surveys allowed for unbiased biogeographic comparisons of fish assemblage diversity between Elizabeth Reef, Coringa-Herald Reserve reefs and the Capricorn Bunker reefs on the GBR.

Fishes from a list of over 200 species, representing 10 families, were counted on three 50 m transects within each site. (The tapes used in laying out these transects formed the left edge of the benthic video transects described above.) Some extra, relatively abundant fish species at Elizabeth Reef, which were either not present or not targetted on the GBR, were also included in the target fish list for future comparison (See Appendix 3). All species in the list were largely non-cryptic, easily identified underwater, and included both commercial and non-commercial taxa. Age 0+ individuals were excluded from counts. These were distinguished from adults by their small size and, in some cases, distinctive colouration. Large mobile fishes and damselfishes were counted separately on transects 5m and 1m wide, respectively. The general survey procedure at each site involved an experienced observer swimming along counting large mobile fishes to 2.5m either side. Absolute numbers of target fish species were recorded using a pencil and underwater paper (attached to a

slate). The observer trailed a tape measure to determine distance covered. On completion of the three transects in which large mobile fishes were counted, the observer returned along the same transects (now marked with a tape along the centre line) recording numbers of smaller damselfishes (Pomacentridae). Observer swimming speeds averaged 10 metres per minute. In order to reduce sampling error, at the end of each transect the observer identified an object estimated to lie at the outer edge of each transect. The perpendicular distance between this object and the transect centre line was then measured, thus providing the observer with a frequent reference to the desired transect boundaries.

2.3 Comparison with GBR, Coringa-Herald National Nature Reserve and Solitary Islands Marine Park communities

Fish and benthic communities of the GBR are structured along latitudinal and exposure based environmental gradients. It was therefore considered most appropriate to compare the Reserve communities with those showing similar environmental conditions on the GBR. For this reason we chose four reefs from the Capricorn Bunker Group of the GBR, which are the southern most reefs that share similar levels of exposure to wave energy as Elizabeth Reef (Figure 1). These reefs have been surveyed annually since 1992 as part of the AIMS long term monitoring program (Sweatman *et al.* 2001).

On each GBR reef 15 transects are surveyed over three sites (5/site) in one zone (NE Flank), whilst in this study, 3 transects were surveyed at each site. The seven exposed reef slope sites surveyed at Elizabeth Reef were considered to be similar to the Capricorn Bunker reef habitat and these sites were used for the comparison. The other three sites were more sheltered with sand occupying a significant proportion of the substrate.

The fish and benthic communities of the Reserve were also compared with those in the Coringa-Herald National Nature Reserve (surveyed in March 2003 using the same methods; Oxley *et al.* 2003) and (for fish only) with available data from the Solitary Islands Marine Park (SIMP) in mid NSW (courtesy of Hamish Malcolm, NSW Marine Parks Authority) (Figure 1).

As species richness varies with area surveyed some manipulation of the fish data was required to allow direct comparisons across regions. Numbers of species from the GBR data set were summed across three randomly selected consecutive transects at each site. The average of the three values was then plotted against the mean of reef slope site species richness values at Elizabeth Reef. The mean of pooled site species richness values across all NE flank sites in the Coringa-Herald reefs was plotted against the Elizabeth Reef mean value. Comparisons of fish abundance from the different regions are based on mean density of individuals per hectare. In both species richness and abundance comparisons, the greater sampling effort on the GBR made for more precise estimates.

2.4 Multivariate techniques

Community structure of the reef fish and coral communities were investigated by use of ordination plots of principal coordinates analysis. In each ordination, the Manhattan distance matrix was used. For comparisons between the Elizabeth Middleton Reserve and the Coringa-Herald Reserve coral species level presence/absence data and fish timed swim data were used. Within Elizabeth Reef comparisons were also made using the fish timed swim data. For comparisons between the Elizabeth Middleton Reserve and the GBR reefs, species level fish transect data were used. Transect data were fourth root transformed to stabilise the distribution of the data and to downweight the influence of the most abundant species on the analysis.

2.5 Holothuria (bêche-de-mer), crown of thorns starfish (COTS), *Drupella*, giant clam (*Tridacna derasa*) and coral bleaching survey methods

Thirteen species of holothuria were chosen for survey (Table 3). COTS were counted during the timed swims and SCUBA searches. Any incidental sightings were also noted. Only two clam species (*Tridacna gigas* and *T. derasa*) were specifically targeted during this series of surveys for DEH. Two habitats were selected for surveys of bêche-de-mer and clams: the lagoon and the reef perimeter at a depth of 6-12m. The reef perimeter was sampled using SCUBA searches and the lagoon was sampled using SCUBA searches and snorkel swims. The reef perimeter sites were also classified on the presence of sediment. These methods are described in more detail below. In each case densities per hectare were calculated from the data.

2.5.1 SNORKEL SWIMS

Snorkel swims were used to survey the shallow water of the Elizabeth Reef lagoon. Each observer censused a 500 m by 5 m belt transect, covering 2500 m^2 of substrate. The four observers swam side-by-side, approximately 10m apart. Observers recorded numbers of bêche-de-mer, COTS and clams. The transect length was determined by marking a waypoint on entry and then having the tender proceed 500m from this waypoint (judged by the GPS distance from the original waypoint), drop a buoy and standby. The snorkellers were able to observe the tender and swim towards it. Water depths ranged from 2-6m. The latitude and longitude of the start and end point transect were recorded (using a GPS) to assist in future surveys of the same area.

Table 3. List of bêche-de-mer species sampled and rationale for their selection.

Species	Common name	Rationale for inclusion
Holothuria whitmai (nobilis)	Black Teatfish	Key commercial species. Recorded from reserve 1987. widespread Indo-west Pacific, Lord Howe, northern Australia.
Actinopyga mauritania	Surf Redfish	For comparison: observed in other MPAS, GBR.
Actinopyga other	Blackfish	For comparison: observed in other MPAS, GBR.
Holothuria atra	Lollyfish	Recorded from reserve 1987. widespread Indo-west Pacific, Lord Howe, northern Australia.
Stichopus chloronotus	Greenfish	For comparison: observed in other MPAS, GBR.
Thelenota ananas	Prickly Redfish	Recorded from Middleton Reef in 1987. widespread Indo-west Pacific, Lord Howe, northern Australia.
Holothuria fuscogilva	White Teatfish	For comparison: observed in other MPAS, GBR.
Holothuria scabra	Sandfish	Key Commercial species. Observed in other MPAS, GBR.
Stichopus hermani (variegates)	Curryfish	For comparison: observed in other MPAS, GBR.
Bohadschia argus	Leopardfish	For comparison: observed in other MPAS, GBR.
Holothuria edulis	Pinkfish	Recorded as common in reserve in 1987. widespread Indo-west Pacific, northern Australia.
Thelenota anax	Amberfish	For comparison: observed in other MPAS, GBR.
Holothuria leucospilota/ coluber	None /Snakefish	For comparison: observed in other MPAS, GBR.
Holothuria impatiens	Tiger Tail	Recorded in reserve in 1987. Widespread Indo- Pacific, northern Australia.

2.5.2 SCUBA SEARCH

SCUBA searches provided information on numbers of Holothuria, crown-of-thorns starfish (COTS) and *Drupella* (a coral eating snail) and other sources of coral mortality (especially coral bleaching) to assist in interpreting benthic cover estimates. SCUBA searches provided a more detailed picture of the causes and relative scale of coral mortality than was possible with either the manta tow or video techniques. A 5m belt (2.5m either side of the central tape measure) was visually searched along each 50m transect for holothurians. Along the same transects, data were recorded for the other categories shown in Table 4, from a 2m wide belt (1m either side of the central tape measure).

Table 4. Data collected using SCUBA search method.

Holothurians	Total count by species
Crown of thorns starfish	Total count in 3 size classes
Crown of thorns starfish scars	Total count
Drupella spp	Total count
Drupella scars	Total count
White syndrome disease scars	Total count
Blackband disease scars	Total count
Unknown scars	Total count
Coral bleaching	Estimate of bleaching as a percentage of live coral cover.

2.6 Data storage

All data resulting from these surveys reside in the Reef Monitoring Database, which is maintained at the Australian Institute of Marine Science (AIMS) (Baker and Coleman 2000). Interactive access to parts of these data is available via the AIMS web site (www.aims.gov.au). Videotapes resulting from these surveys are stored at AIMS and copies will be archived with the National Archives office in Canberra.

2.7 Historical Sea Surface Temperature (SST) data

SST data were obtained from DEH for the Coral Sea Region from March 1985 to February 2003 (Figure 3). Data points are based on 8 day composites, and were compiled from NOAA AVHRR data by CSIRO Marine Research, Marine Pelagic Ecosystems Spatial Dynamics Group

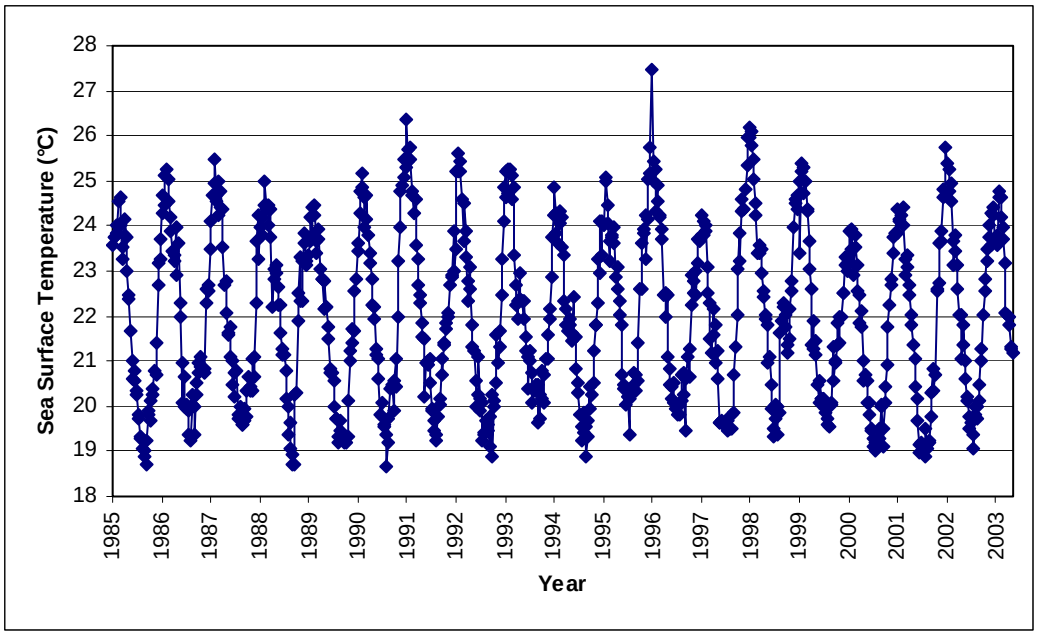

Figure 3. Average sea surface temperature for the waters around Elizabeth and Middleton Reefs. (*graph provided by DEH).*

3 RESULTS

3.1 Fish and benthic communities

The fish and benthic communities are considered in three ways. Firstly, the data are set into a broad spatial context using comparisons with similar data collected from southern GBR reefs and the Coringa-Herald National Nature Reserve. Fish data are also compared to data from the Solitary Islands Marine Park in NSW. Secondly, spatial differences in assemblage structure and diversity within Elizabeth Reef are compared. Data on black cod (*Epinephelus daemelii*) and the Galapagos shark (*Carcharhinus galapagensis*) are investigated in greater detail at the reef level. Finally, the current "status" of the fish and benthic communities are investigated by comparison with historical data sets.

Note that estimates of benthic cover have been derived from both the RAP and the video transect methods. There are slight differences in the data obtained from each method so in each case "like with like" data have been used to make comparisons.

3.1.1 BROAD SPATIAL COMPARISONS

3.1.1.1 Benthos

One hundred and eleven hard coral species were recorded in the Reserve compared to 99 at the Coringa-Herald Reserve (Oxley *et al.* 2003). Both these counts are relatively low compared with species numbers found on the GBR (Table 5). On the most recent data available, there continues to be a higher diversity of hard coral species at Elizabeth Reef than at Lord Howe Island, Nonetheless, comparison with the comprehensive species list collected by Harriott *et al.* (1995) suggests the hard coral community type is similar in the two locations.

In all locations Faviidae, Acroporidae, Poritidae and Pocilloporidae made up the top four coral families, by percentage cover, however, the relative cover of these hard coral families differed (Figure 4). On Elizabeth Reef, Faviidae (50.7% of cover of top six families) were the most abundant followed by Acroporidae (24.4%), Poritidae (13.6%) and Pocilloporidae (5.8%). At Coringa-Herald, Poritidae corals had the highest relative cover (51% of cover of top six families) while at the Capricorn Bunker group the Acroporidae corals dominated the top six families (95.4% of cover of top six families).

Species level composition data collected during the timed swims clearly separates Elizabeth Reef from the Coringa-Herald Reserve reefs (Figure 5). *Leptoria phrygia, Cyphastrea* sp*, Favia rotumana* and *Acanthastrea hemprichii* were four key species whose abundance at Elizabeth Reef distinguished this reef from Coringa-Herald. The numbers of species within each coral genus is shown in Appendix 5.

Table 5. Number of hard coral species found in different locations.

LOCATION	NUMBER OF HARD CORAL SPECIES	SOURCE
Coringa-Herald Reserve	99	Oxley *et al.* (2003)
Northern GBR	324	Veron (1993)
Capricorn Bunkers (Southern GBR)	244	Veron (1993)
Elizabeth/Middleton	122	Done and Veron, in Aust. Museum (1992)
Elizabeth	114	(this report)
Lord Howe Island	65	Veron (1993)
Lord Howe Island	83	Harriott *et al.* (1995)

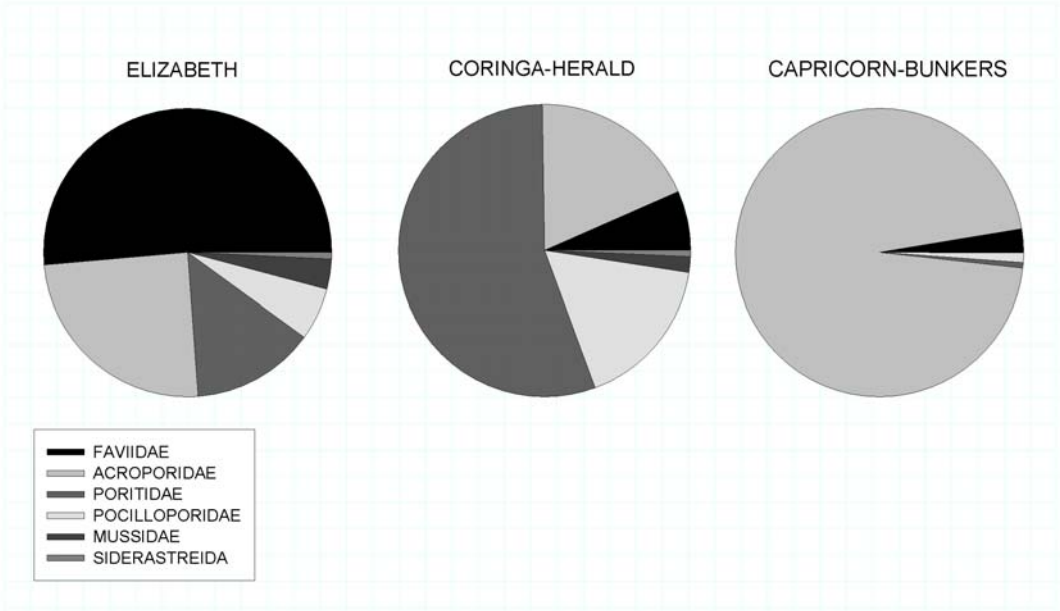

Figure 4. Pie Charts showing the top six coral families at Elizabeth Reef (by % cover) compared with the cover of these families at the Coringa-Herald Reserve (CHNNR) and the Capricorn Bunker group of reefs on the GBR. Pie slices are the percentage of the total cover of the six families at each of the locations. The other coral families are excluded as they mostly covered less than 1% with a maximum of 3% of total cover in any location. For interpretation, note that the first pie slice starts at 0° (3 o'clock) and additional slices are added in a counter-clockwise direction.

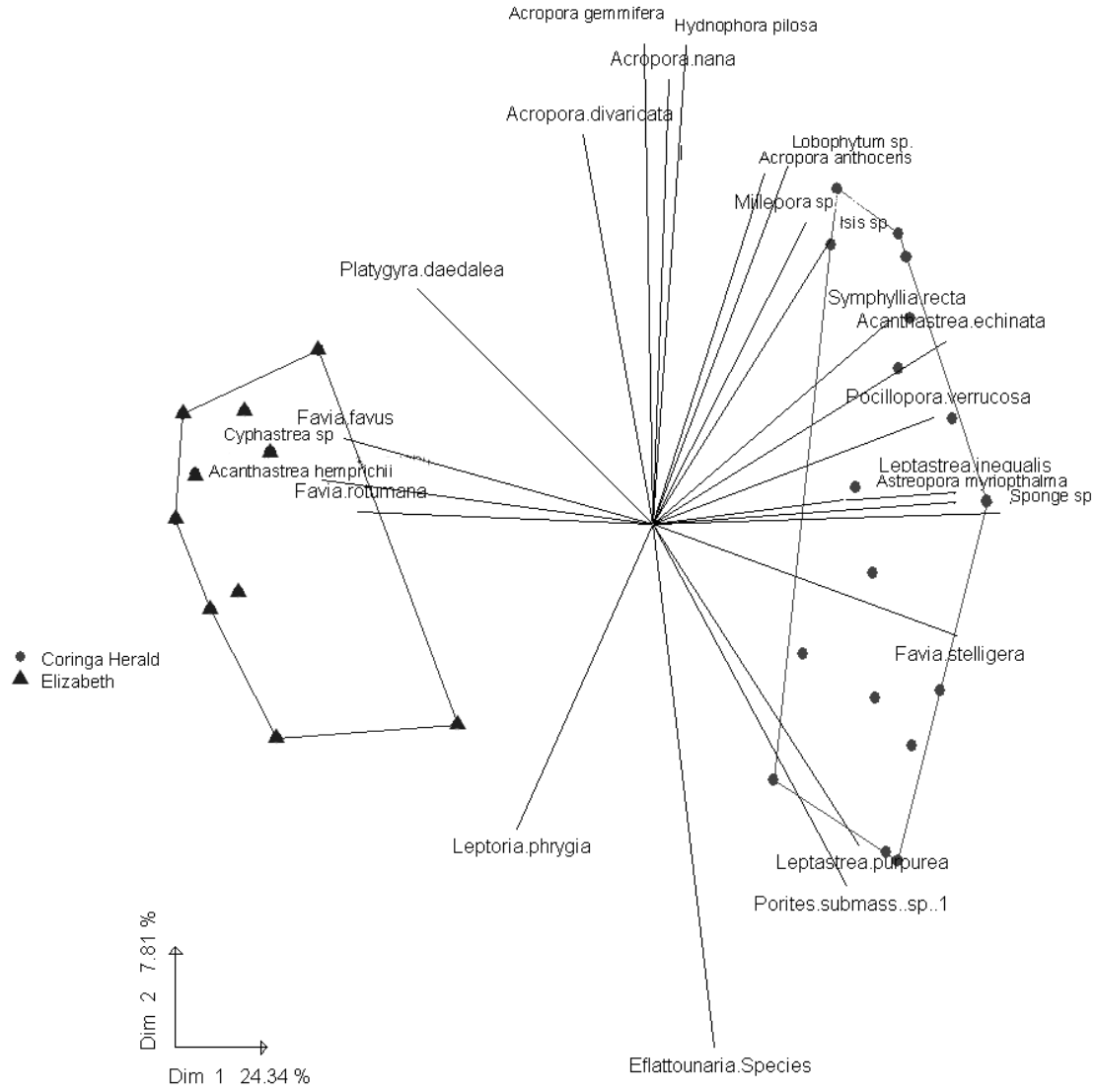

Figure 5. Multivariate plot showing separation of coral communities between Elizabeth Reef sites and the Coringa-Herald Reef sites. Vectors represent species that characterise the differences among the samples.

INTERPRETATION OF MULTIVARIATE ANALYSES: BIPLOTS

In this report both the presence/absence of many coral species and the abundance of many fish species from multiple sites are analysed. Multivariate analyses are required to examine the multidimensional relationships among these coral or fish species. The following is provided to facilitate understanding and interpretation of these analyses.

- Biplots graphically display the multivariate relationships of the rows (individual 'sites' or 'samples') and columns (species) of a data matrix on a single two-dimensional plot. The term 'biplot' therefore indicates that both sets of relationships (i.e. among sites and among species) are displayed in a single plot.
- The biplots represent each site by a point on the plot with different symbols used to identify each reef (or reef group). These points are grouped to identify their reef (or reef group) membership.
- The individual species are represented on the biplot as vectors (i.e. lines). The vectors are labelled with the species names.
- Of the total variation in presence/absence or abundance of all species, the percentage explained by each dimension of the biplot is shown in the lower left corner of the plot. The first dimension explains the greatest percentage of the total species variance and is shown on the x-axis. The second dimension explains the next largest percentage of the total species variance and is shown on the y-axis.

Ordination methods that represent high-dimensional data in low-dimensional space are used for the analysis of the multivariate coral and fish species data. These unconstrained ordination analyses reduce the multivariate data to a set of uncorrelated derived variables which are linear combinations of the original variables, and which have been calculated to account for the maximum amount of variability in the data. In this report the biplots represent the first two dimensions (or derived variables) from these analyses thus displaying the most informative 2-dimensional view of a multidimensional distribution. The biplots show the relationships of the original variables (i.e. species) to each other and indicates their role in explaining the observed spatial (i.e. among sites) patterns. This is achieved by super-imposing vectors for the original variables (i.e. species) over the plot of points, which represent the spatial (i.e. among sites) patterns.

In the biplots for fish abundance in this report the species vectors generally form an arc defining the gradient (direction) of greatest abundance. The length of a vector approximates the variability (standard deviation) of the associated species. Thus short vectors mean that the species is consistent in abundance among sites and a long vector means that the species is highly variable among reefs. If a reef has a high abundance of a particular species, the site point and species vector are far away from the origin and in the same direction. If a site has a low abundance of a particular species, the site point and species vector are in opposite directions and far apart. Site points close to the origin represent sites that have typical abundances of all species. Sites that are close together on the biplot have similar proportions of most species. The angle between two vectors represents the correlation between the two species that the vectors represent. Thus if the angle between them is small (0°) the species are highly correlated, if large (180°) the species are negatively correlated and if at right angles (90°) the species are uncorrelated. For ease of interpretation of the biplots only the vectors of those species that correlated highly with the derived dimensions of variability were shown on the plots. Therefore only a small proportion of the species included in each analysis are displayed on the plots.

At the time of this survey, average hard coral cover at Elizabeth Reef was 25% compared with 2.9% at Coringa-Herald (recorded during the 2003 survey) (Figure 6). Both Reserve areas (Coringa-Herald and Elizabeth) had a high cover of macroalgae compared to the Capricorn Bunker outer shelf GBR reefs (Figure 6). A clear distinction between Coringa-Herald and Elizabeth Reef (apart from the coral cover) was that foliose and encrusting sponges were common at Coringa-Herald whereas at Elizabeth Reef only very low numbers of cryptic encrusting species were seen. The algal community at Elizabeth Reef is distinct from the GBR reefs in having a higher percent cover of thallous algae. *Halimeda*, a dominant algal genus at Coringa-Herald, was not abundant at Elizabeth Reef.

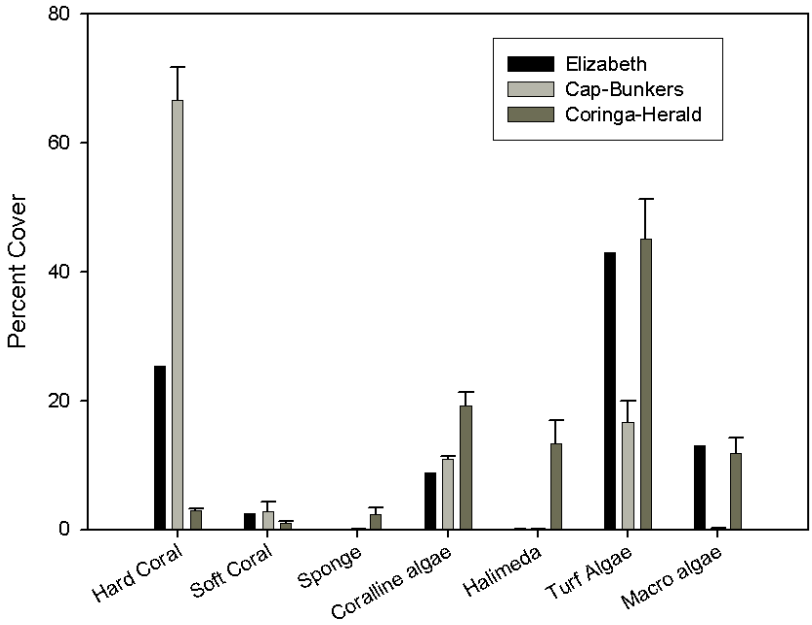

Figure 6. Comparison of Benthic Groups between Elizabeth Reef, Capricorn Bunker Group reefs and reefs in the Coringa-Herald Reserve. Error bars are standard errors at the reef level. Consequently there are no error bars for Elizabeth Reef.

The average percent cover of hard coral observed at Elizabeth Reef (25%) was close to the average coral cover for all AIMS Long Term Monitoring Program (LTMP) survey reefs for 2003 (29%) (AIMS unpublished data). The Capricorn Bunkers, which are the southern most reefs surveyed by the LTMP, are strongly dominated by *Acropora* spp. at this time and have had very high coral cover in recent years.(66.6% in 2003.- Figure 6).

3.1.1.2 Comparison of fish communities with other reef systems.

Reef fish assemblages recorded during transect surveys at Elizabeth Reef differed greatly from those on reefs of the far southern GBR (Figure 7), based on a modified species list that allowed valid comparisons with GBR methods (Appendix. 3). While all large fish species recorded from transects at Elizabeth Reef were also present on the GBR reefs (with the exception of *Chaetodon tricinctus*, *Chlorurus frontalis* and *Coris bulbifrons*), a number of damselfish species were locally abundant in one region and either absent or in very low numbers at the other. Damselfish characterizing Elizabeth Reef and absent from the GBR included two sub-tropical species (*Chromis hypsilepis* and *Chrysiptera notialis*), while *Pomacentrus* spp. that often dominate GBR fish assemblages were represented by only one species (*P. coelestis*) at Elizabeth Reef.

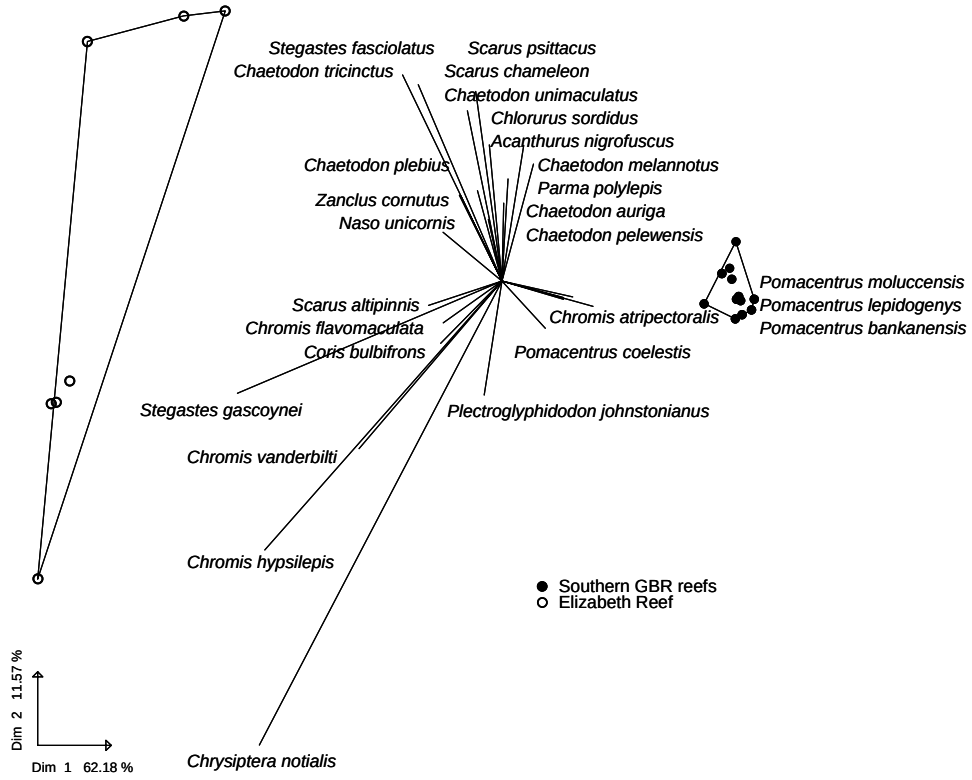

Figure 7. Multivariate plot showing separation of fish assemblages between the southern GBR and Elizabeth Reef. Vectors represent species that characterise the differences between the samples.

Reef fish assemblages recorded during timed swim surveys at Elizabeth Reef (Appendix 2) also differed greatly from those at the Coringa-Herald Reserve, surveyed using identical methods in March 2003 (Figure 8). The major difference between the two regions was the relative abundance of sub-tropical and temperate species at Elizabeth Reef (i.e. *Pseudolabrus luculentus*, *Chrysiptera notialis* and *Stegastes gascoynei*) most of which were absent from CHNNR reefs. Conversely, a number of tropical species that were abundant at the CHNNR (i.e. *Pomacentrus vaiuli*, *Halichoeres margaritcaeous* and *Pomachromis richardsoni*) were absent from Elizabeth Reef (Figure 8).

The abundance and species richness of large reef fish was low on transects at Elizabeth Reef, compared to southern GBR and CHNNR reefs (Figures 9 and 10). However, there was high variation among the CHNNR reefs, with Coringa Islet and Chilcott Islet having abundance and species richness values similar to those at Elizabeth Reef, while values at the two Herald Cay reefs were much higher (Oxley *et al.* 2003). It should also be noted that one large surgeonfish species (*Prionurus maculatus*) was locally abundant on transects at Elizabeth Reef (Appendix 3) but was not included in geographic comparisons as it was not in the GBR target fish list. Numbers of damselfish did not differ greatly across the three systems even though the mean number of species on GBR sites was double that at Elizabeth Reef (Figure 10). This is due to the ubiquitous distribution of a small number of abundant damselfish species at Elizabeth Reef, namely *Chrysiptera notialis*, *Chromis hypsilepis* and *Stegastes gascoynei* (Appendix 3).

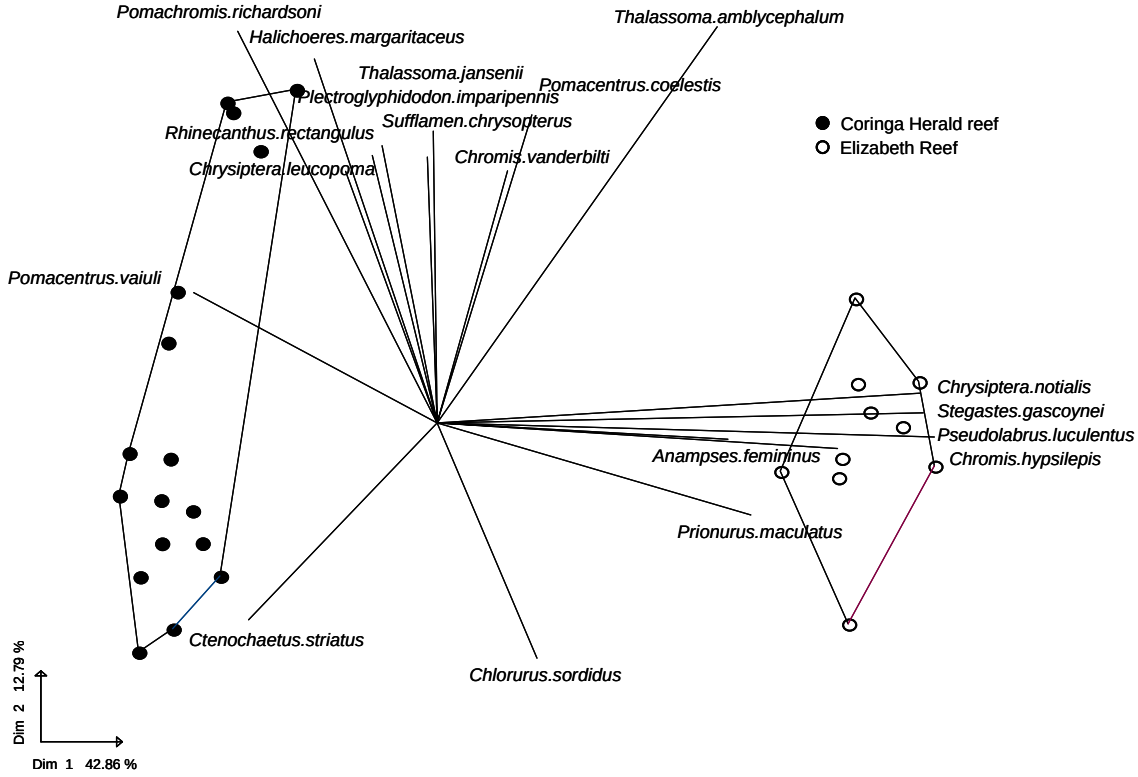

Figure 8. Multivariate plot showing separation of fish assemblages between the CHNNR reefs and Elizabeth Reef. Vectors represent species that characterise the differences between the samples.

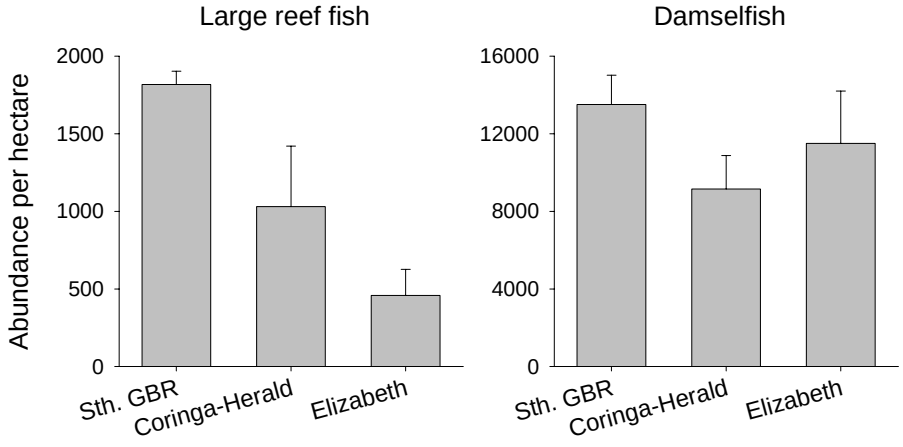

Figure 9. Comparisons of mean reef fish abundance (+ one standard error) between the southern GBR NE flanks, CHNNR NE flanks and reef slope sites at Elizabeth Reef based on transect data using comparable species (see Appendix 3).

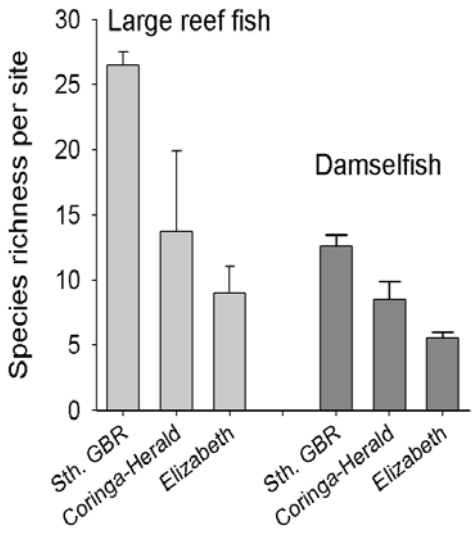

Figure 10. Comparisons of mean fish species richness (with one standard error) between southern GBR NE flanks, CHNNR NE flanks and reef slope sites at Elizabeth Reef based on data from sites comprising three consecutive transects.

Using timed swim data, comparisons of total species richness between the Coringa-Herald reefs and Elizabeth Reef revealed that the number of species recorded at sites around Elizabeth Reef (181 species) was less than that recorded per reef in the Herald group (NE and SW Herald Islands, mean of 240 species). Species numbers at Elizabeth Reef were comparable to those recorded from the Coringa group (Chilcott and Coringa Islets, mean of 185 species). However, given that the number of species recorded during surveys increases with the area searched, and that more than double the surveys were conducted at Elizabeth Reef compared with the individual Coringa-Herald reefs, the total species richness at Elizabeth Reef is clearly less than at the Coringa group (see also Table 6).

Species richness of major fish families was often lower at Elizabeth Reef when compared to the southern GBR, Coringa-Herald and the Solitary Islands Marine Park (SIMP) in NSW (Table 6). Numbers of damselfish species (Pomacentridae) were particularly low, with 21 species less than at the SIMP, which is at similar latitude on the Australian coast. While a greater number of surveys have been conducted on the GBR and in the SIMP, most of the fishes in Table 6 are visually obvious and it is likely that the patterns of diversity in this table are a reasonable reflection of the true status of these families. The species richness of major fish families at Elizabeth Reef were closer to those recorded at the SIMP, although there was great variation amongst taxa. Surgeonfishes (Acanthuridae) and parrotfishes (Scaridae) were relatively under-represented at SIMP while richness of damselfishes and wrasse (Labridae) were far lower at Elizabeth Reef (Table 6). It is noteworthy that the range of fish species recorded at the SIMP included a number of sub-tropical and temperate species common at Elizabeth Reef but not recorded on the GBR or CHNNR (i.e. *Chaetodon tricinctus*, *Chromis hypsilepis*, *Chrysiptera notialis*, *Coris bulbifrons* and *Epinephelus daemelii*; information courtesy of Hamish Malcolm, NSW Marine Parks Authority).

The relative proportion of broad taxonomic groups comprising fish assemblages on Elizabeth Reef (based on transect data) differed substantially from that on southern GBR and CHNNR reefs (Figure 11). The large mobile fish assemblages at Elizabeth Reef had a lower proportion of surgeonfishes (Acanthuridae) and a higher proportion of butterflyfishes (Chaetodontidae). The proportional representation of damselfish genera differed markedly between the three reef systems (Figure 11) with *Chromis* being the only genus present in substantial proportions across the three regions. The genus *Pomacentrus* was barely represented at Elizabeth Reef although this genus dominated GBR damselfish assemblages. Aside from *Chromis*, the two genera, *Chrysiptera* and *Stegastes,* dominated the Elizabeth Reef damselfishes yet were only represented by one and two species respectively. These two genera only made up a very low proportion of damselfish assemblages on transects on the southern GBR and CHNNR.

Table 6. Species richness of major fish families recorded in the; Capricorn Bunker group of the southern GBR (Russell 1983), Coringa-Herald National Nature Reserve (Byron *et al.* 2001, Oxley *et al*. 2003), Solitary Islands Marine Park (Data courtesy of Hamish Malcolm, NSW Marine Parks Authority) and Elizabeth and Middleton Reef (Australian Museum 1992, AIMS this study). Bolded numbers indicate the region with lowest species richness for each family.

Family	Common name	Capricorn-Bunker	CHNNR	SIMP	Elizabeth-Middleton
Acanthuridae	Surgeonfish	25	31	**12**	16
Chaetodontidae	Butterflyfish	32	29	24	**20**
Labridae	Wrasse	69	62	73	**56**
Lethrinidae	Emperors	9	9	5	**3**
Lutjanidae	Snappers	14	10	9	**5**
Scaridae	Parrotfish	22	18	**5**	18
Serranidae	Cod	32	**20**	21	22
Pomacentridae	Damselfish	69	53	47	**26**
Pomacanthidae	Angelfish	15	12	8	**7**
Total		287	244	204	**173**

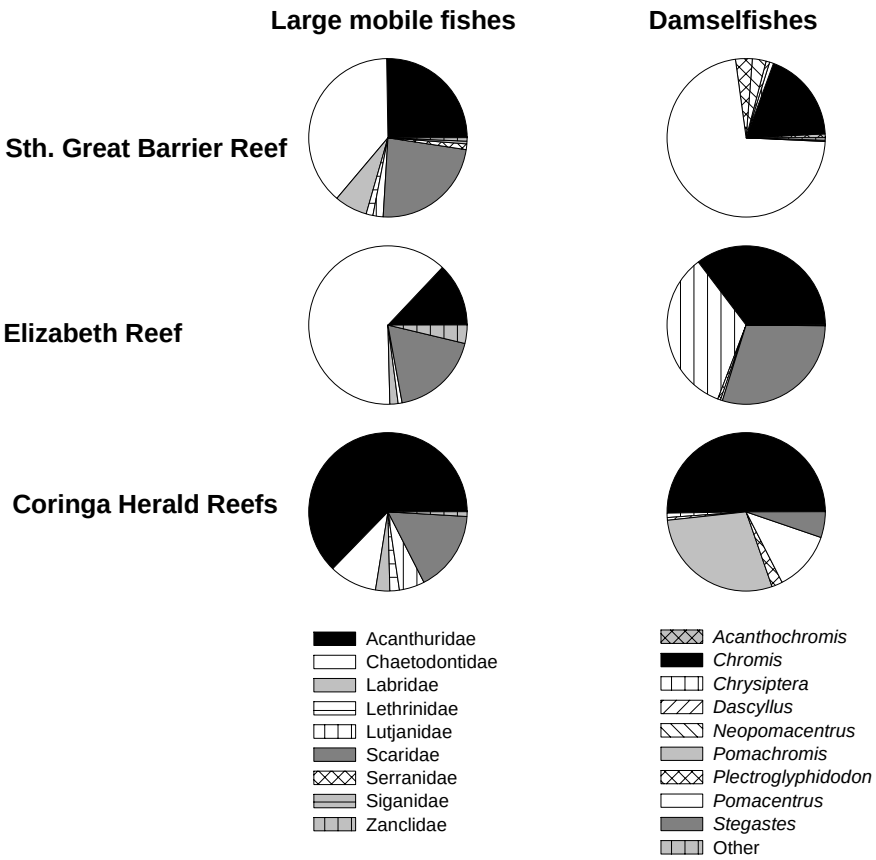

Figure 11. Differences in the proportion of higher taxonomic groupings of fishes between the GBR, CHNNR and Elizabeth Reef based on transect data.

3.1.2 ELIZABETH REEF BENTHOS

3.1.2.1 Coral cover and species richness

Hard coral cover was low to moderate at all sites visited, ranging from 10% to 35% cover. Hard coral diversity was also low, relative to the GBR, with a total of 111 species recorded (Appendix 1).

The number of species recorded per site ranged from 22 to 46 with a mean of around 37. Nine species were recorded at all of the sites (Table 7), with a further 14 species recorded at more than 50% of sites. (Note – Site 1 was not included due to anomalous data collection).

Soft coral cover was also very low in all the survey sites reaching a maximum of 7% (Table 8). Average cover of soft coral was 2.4%. Sites on the NE side of the reef had higher abundance than elsewhere. A total of 11 soft coral genera were recorded on the reef with *Sinularia, Lobophytum* and *Capnella* sp. being the most abundant.

Table 7. Hard Coral Species recorded at six or more of the 10 survey sites.

Coral species recorded at >6 of the 10 sites	
**Acanthastrea echinata*	**Leptoria phrygia*
Acropora cuneata	**Montastrea curta*
Acropora glauca	*Pavona varians*
Acropora latistella	**Platygyra daedalea*
**Coscinaraea columna*	*Pocillopora damicornis*
**Cyphastrea serailia*	*Porites lichen*
**Favia favus*	**Porites massive spp.*
Favia pallida	*Stylophora pistillata*
Favia rotumana	*Turbinaria mesentaria*
**Favia speciosa*	
Favites abdita	** Recorded at all sites*
Favites russelli	
Goniastrea australensis	
Goniastrea favulus	

Table 8. Percent Cover of Major Benthic Groups at Elizabeth Reef**.**

Site_ No	Hard Coral	SE	Soft Coral	SE	Coralline Algae	SE	Macro Algae	SE	Turf Algae	SE	All Algae	SE	Sand	SE
1	29.2	3.4	0.0	0.0	0.0	0.0	0.2	0.2	56.2	4.4	56.3	4.3	13.8	6.8
2	10.3	4.3	2.0	1.3	0.0	0.0	33.8	3.9	37.7	3.8	71.5	6.1	15.5	0.8
3	26.8	2.9	4.3	1.9	15.3	3.9	7.3	0.4	45.2	8.1	67.8	4.6	0.3	0.2
4	35.2	2.0	0.3	0.3	19.8	1.6	2.7	1.2	33.7	0.7	56.2	2.0	0.0	0.0
5	28.3	1.6	0.3	0.2	25.8	0.7	10.0	3.5	32.8	4.3	68.7	1.6	0.2	0.2
6	29.8	5.4	1.0	0.3	15.2	2.2	10.7	2.3	36.7	5.0	62.5	5.0	0.3	0.3
7	28.2	2.1	2.0	0.9	3.4	1.7	29.3	1.1	35.1	4.3	67.7	1.9	0.2	0.2
8	11.3	0.4	1.7	1.4	1.8	0.9	15.0	3.0	55.2	2.4	72.0	5.4	12.8	4.2
9	31.7	3.2	5.7	1.3	2.5	0.5	5.2	0.3	53.2	3.8	60.8	4.1	0.0	0.0
10	23.3	1.0	6.9	1.3	4.6	1.9	18.6	1.6	44.7	2.6	67.9	1.5	0.7	0.3
Reef Mean	25.4		2.4		8.8		13.3		43.0		65.1		4.4	0.0

Sponges were not abundant at any site and no large sponges were seen. The sponges observed were restricted to cryptic habitats within the habitats surveyed.

Thallous algae (macro algae) were common at all sites (Table 8), especially *Caulerpa* spp., *Codium* spp., *Chlorodesmis* sp. and small Rhodophyta. The average cover of thallous algae was 13% with a range from less than 1% in the lagoon site (site 1) to 34% in the channel (site 2).

3.1.2.2 Size of coral colonies

There were very few coral colonies greater than 1m and no massive *Porites* greater than 50cm were seen. The largest colonies were *Leptoria phrygia* (numerous colonies >50cm) and *Lobophyllia hemprichii*. Coral recruits were not numerous and often only a single colony of a species was recorded at each site.

3.1.2.3 Coral damage in the survey sites

Few signs of recent mortality were seen. There were no obviously diseased colonies. One *Acropora* colony showed symptoms similar to 'white syndrome'. Damage was not recorded in the field but the video was interrogated for *Leptoria*, digitate *Acropora* and tabulate colonies. For *Leptoria*, 12% of colonies had damage of over 10% of the colony and for *Acropora* the figure was 10%. There was no evidence of large-scale mortality in the recent past. The exception was the lagoon site (Site 1) where the dominant coral genera, *Montipora* and *Seriatopora* both showed signs of substantial mortality. Many of the *Montipora* were still intact but with dead areas of up to 90% of the colony. There was less evidence of mortality in shallow water than at depth. The mortality event was not recent and the agent was not established.

During the three-day survey period, only 3 COTS were seen. All were observed at site 3 whilst undertaking surveys. Some coral mortality resulting from COTS predation was observed at this site. No *Drupella* were observed on Elizabeth Reef.

3.1.2.4 Characteristics of the reef and sites

Only at the lagoon site was there a pronounced depth stratification in coral species. Branching *Acropora* dominated the top 3 metres while *Montipora* and *Seriatopora* were most abundant at 9m. The most pronounced difference between sites at Elizabeth Reef was in the degree of sedimentary influence. Sites 1, 2 and 8 were located in the lagoon, north-east channel and near the north-west channel respectively. The channel sites had a higher percent cover of sand but also a marked sedimentary influence over the entire substrate. Coral cover was low (around 10%) and dominated by Faviids, *Porites* and macro/turf algal assemblages. All other sites were located around the perimeter of the reef and were quite similar in their topography and slope. The majority of sites surveyed were on a broad platform at 8-10m. The reef substrate was hard and small-scale topographic features were generally absent. Medium scale topographic features included grooves in the reef that were largely devoid of benthic cover (apart from coralline/turf algae). The bottoms of the grooves were filled with round reef boulders.

The southern side of the reefs was the most exposed to swell and this made surveys difficult. The benthic community on sites 4, 5 and 6, had more coralline algae than macroalgae. *Porites*, *Acropora*, *Isopora* spp. and *Montastrea curta* were the dominant hard corals. The presence of eroded coral boulders on the reef flat is testament to the power of past storms in this area.

Table 9. New records of fish species from Elizabeth Reef. Those marked with, ✱ have been recorded previously at Middleton Reef.

Family	Species Name	Common Name	
Acanthuridae	*Acanthurus albipectoralis*	Whitefin surgeonfish	
	Acanthurus blochii	Ringtail surgeonfish	
	Ctenochaetus strigosus	Goldring bristletooth	
	Naso vlamingii	Vlaming's unicornfish	
	Zebrasoma scopas	Twotone tang	✱
	Zebrasoma veliferum	Sailfin tang	✱
Apogonidae	*Apogon cyanosoma*	Yellow striped cardinalfish	
Balistidae	*Sufflamen chrysopterus*	Halfmoon triggerfish	✱
Blenniidae	*Cirripectes castaneus*	Chestnut eyelash blenny	
Carangidae	*Carangoides orthogrammus*	Thicklip trevally	
	Seriola rivoliana	Almaco jack	✱
Chaetodontidae	*Chaetodon ephippium*	Saddle butterflyfish	✱
	Chaetodon speculum	Mirror butterflyfish	✱
Coryphaenidae	*Coryphaena hippurus*	Dolphinfish	
Dasyatidae	Species not identified	Stingray	
Echeneidae	*Echeneis naucrates*	Live sharksucker	✱
Fistulariidae	*Fistularia commersonii*	Bluespotted cornetfish	✱
Holocentridae	*Myripristis kuntee*	Shoulderbar soldierfish	✱
Kyphosidae	*Kyphosus sydneyanus*	Silver drummer	
Labridae	*Anampses caeruleopunctatus*	Bluespotted wrasse	
	Anampses geographicus	Georgraphic wrasse	
	Bodianus loxozonus	Blackfin hogfish	
	Bodianus mesothorax	Splitlevel hogfish	
	Cheilinus bimaculatus	Twospot wrasse	
	Cheilinus orientalis	Oriental maori wrasse	
	Cheilinus trilobatus	Tripletail maori wrasse	
	Coris gaimard	Yellowtail coris	
	Coris pictoides	Blackstripe coris	
	Hemigymnus fasciatus	Barred thicklip	
	Hologymnosus annulatus	Ringwrasse	
	Labropsis australis	Southern tubelip	
	Novaculichthys taeniourus	Rockmover wrasse	
	Oxycheilinus unifasciatus	Ring-tail wrasse	
	Pseudocoris yamashiroi	Redspot wrasse	
	Pseudodax moluccanus	Chiseltooth wrasse	
	Pteragogus cryptus	Cryptic wrasse	
	Stethojulis strigiventer	Three ribbon wrasse	✱
	Thalassoma quinquevittatum	Fivestripe wrasse	
	Thalassoma trilobatum	Ladder wrasse	
	Xyrichthys pavo	Peacock razorfish	
Lutjanidae	*Aphareus furca*	Smalltoothed jobfish	
Microdesmidae	*Nemateleotris magnifica*	Fire goby	
	Ptereleotris microlepis	Pale dartfish	
	Ptereleotris zebra	Zebra dartfish	
Monacanthidae	*Cantherhines fronticinctus*	Spectacled filefish	
	Cantherhines pardalis	Honeycomb filefish	
Muraenidae	*Gymnothorax meleagris*	Whitemouth moray	
Pomacentridae	*Chromis atripectoralis*	Black-axil chromis	✱
	Dascyllus trimaculatus	Threespot dascyllus	✱
	Plectroglyphidodon imparipennis	Brighteye damsel	
Scaridae	*Cetoscarus bicolor*	Bicolour parrotfish	
	Chlorurus frontalis	Tanfaced parrotfish	
	Scarus chameleon	Chameleon parrotfish	
	Scarus longipinnis	Highfin parrotfish	
	Scarus niger	Dusky parrotfish	✱
Scorpaenidae	*Dendrochirus zebra*	Zebra turkeyfish	
Serranidae	*Cephalopholis miniata*	Coral hind	✱
	Pseudanthias squamipinnis	Sea goldie	✱
	Variola louti	Yellow-edged lyretail	✱
Siganidae	*Siganus fuscescens*	Mottled spinefoot	
Synodontidae	*Synodus hoedti*	Unnamed	

The north-east and north-west sites (3, 7, 9, 10) had a higher cover of macroalgae, and the Faviids *Leptoria*, *Platygyra*, *Cyphastrea* and *Favia* were relatively more abundant. *Sinularia* soft corals were also relatively abundant.

3.1.3 FISH WITHIN ELIZABETH REEF

3.1.3.1 Species richness

A total of 181 fish species were recorded at Elizabeth Reef in December 2003. One hundred and sixty species were recorded during timed swim and transect surveys, and another 21 species were noted during holothurian surveys or opportunistically, when working around the reef. It should be noted that numbers of small cryptic species (such as Blennidae and Gobiidae) and nocturnal species, are always underestimated when using visual survey techniques. Therefore, actual numbers of species present in 2003 would have been considerably higher. Sixty-one of the fish species recorded in 2003 were absent from previous surveys (Australian Museum 1992) and thus represent new records for Elizabeth Reef (Table 9). Sixteen of these 61 species had previously been recorded at Middleton Reef (Australian Museum 1992). Appendix 2 provides a list of the species observed in 2003, including their abundance and distribution within the sites surveyed.

3.1.3.2 Within reef variation in fish assemblages

Ordinations of the timed swim fish data tended to group into three fish assemblage types corresponding to exposed reef slopes with moderate coral cover (sites 3, 4, 5, 6, 7, 9 and 10), reef channels with low coral cover and moderate silt component (sites 2 and 8) and the sheltered lagoon (site 1) (Figure 12).

Differences in fish assemblages within Elizabeth Reef were driven largely by the lack of overlap of some species between habitats and the relatively high abundance of two small planktivorous damselfish (*Chromis* species) and a surge living damselfish (*Stegastes fasciolatus*) on the more exposed reef slope sites (Figure 12).

The mean abundance of large mobile fishes and damselfishes recorded on transects (species list in Appendix 3) differed between sites, but there was often great variation (large standard errors) in abundance between transects on the same site (Figure 13). There was no clear trend indicating higher abundance in one habitat type compared to another. Lower abundance of damselfishes in the lagoon is hard to interpret based on samples from only one site. Species richness was also variable across sites based on timed swim data. The two channel sites had fewest species (46 and 34 species), the lagoon site had 55 species, while the numbers of species at reef slope sites varied from 51 to 80.

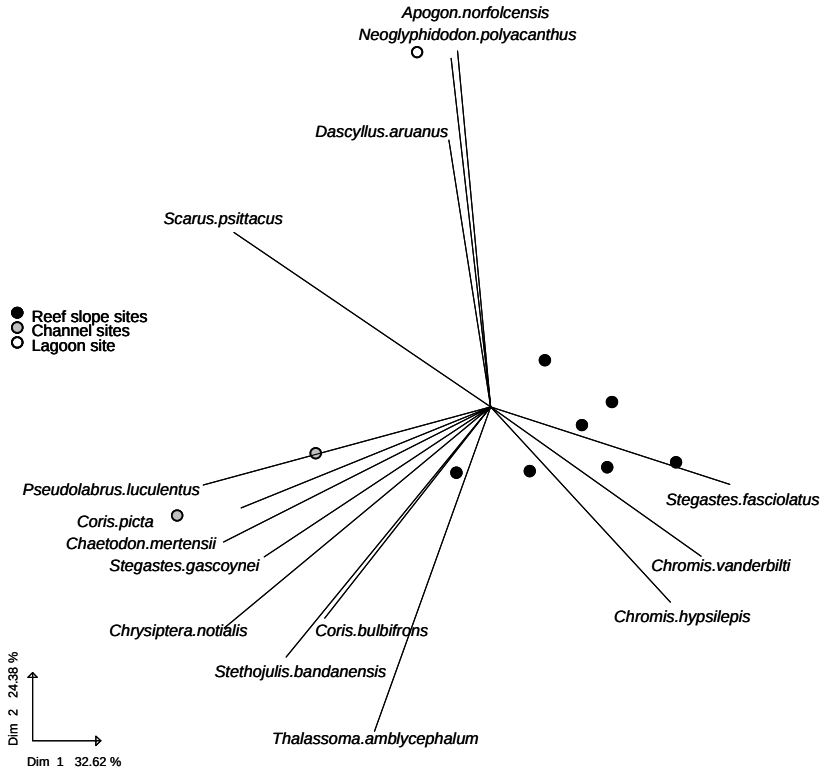

Figure 12. Multivariate plot showing separation of sites within Elizabeth Reef based on fish timed swim data. Vectors represent fish species that characterise the differences between sites.

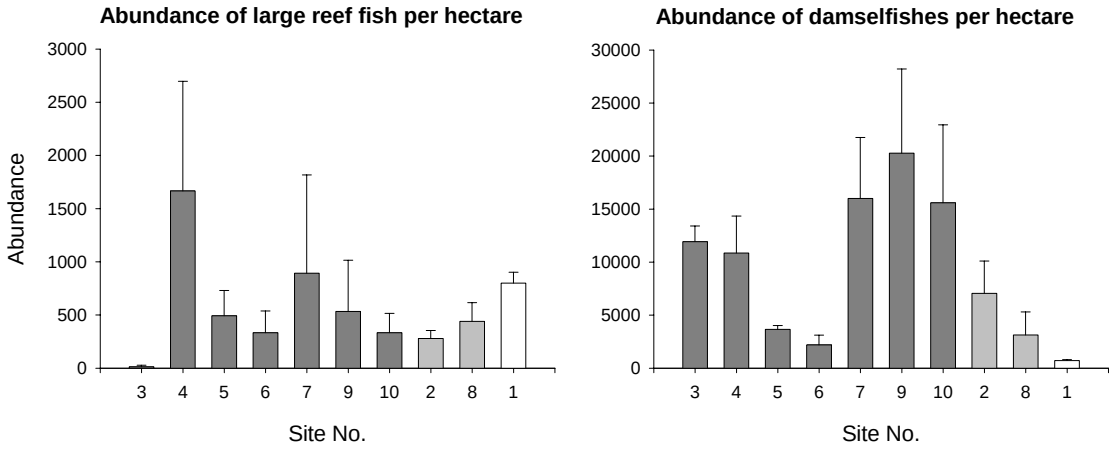

Figure 13. Fish abundance from transect surveys at all sites at Elizabeth Reef. Dark grey bars represent reef slope sites, light grey bars indicate channel sites and the lagoon site is shown in white.

*3.1.3.3 Black cod (*Epinephelus daemelii*) and other potential target finfish*

A total of 18 black cod (*Epinephelus daemelii*) were recorded at Elizabeth Reef during surveys. These cod were present at all reef zones (reef slope, channel and lagoon) at depths from 3m to 12m (Appendix 4). We derived a rough estimate of black cod numbers at Elizabeth Reef of 4 fish/ hectare, based on the estimated average distance the observer swam during timed swims. Only two black cod were recorded during transect surveys. The length of black cod ranged from 55 to 150cm (Appendix 4). Lengths of 23 black cod were also visually estimated during surveys in 1987 (Australian Museum 1992) at Elizabeth and Middleton Reef. The mean size of fish recorded in 2003 was significantly higher (t-test, t value = 2.102, P = 0.042) than that recorded in 1987 (Figure 14). Comparisons of the frequency of occurrence of different size classes (Figure 14) between 1987 and 2003 indicated that a proportionally greater number of larger fish were present in 2003 with a clear dominance of fish in the 81-100 cm length range.

Due to the different methods used in the 1987 Museum surveys (longer swims and greater depth ranges surveyed), direct comparisons of cod numbers in 1987 and 2003 are not possible. However, based on the total number of individuals collected and sighted in 1987, black cod were assessed as common (between 10 and 100 individuals). In 2003, numbers of black cod still remain in the common category. There is no clear indication of a major decline or increase in population numbers.

On the shallow (< 12m) coral reef slopes of Elizabeth Reef, there was generally a low abundance of finfish species considered to be prime targets for fishermen. Numbers and diversity of snappers (Lutjanidae), emperors (Lethrinidae) and cods (Serranidae) were appreciably lower at Elizabeth Reef compared with reefs in the far southern Great Barrier Reef (Figure 11, Table 6, AC personal observation). Species likely to be caught by fishermen in shallow areas of Elizabeth Reef include the yellowtail kingfish-amberjack (*Seriola lalandi*) and other Carangidae species, two cod species (*Epinephelus daemelii* and *Variola louti*), and the double-header wrasse (*Coris bulbifrons*). There were a large number of small colourful coral reef species that would be of interest to collectors in the aquarium trade; particularly some with restricted distributions not readily available elsewhere (Australian Museum 1992).

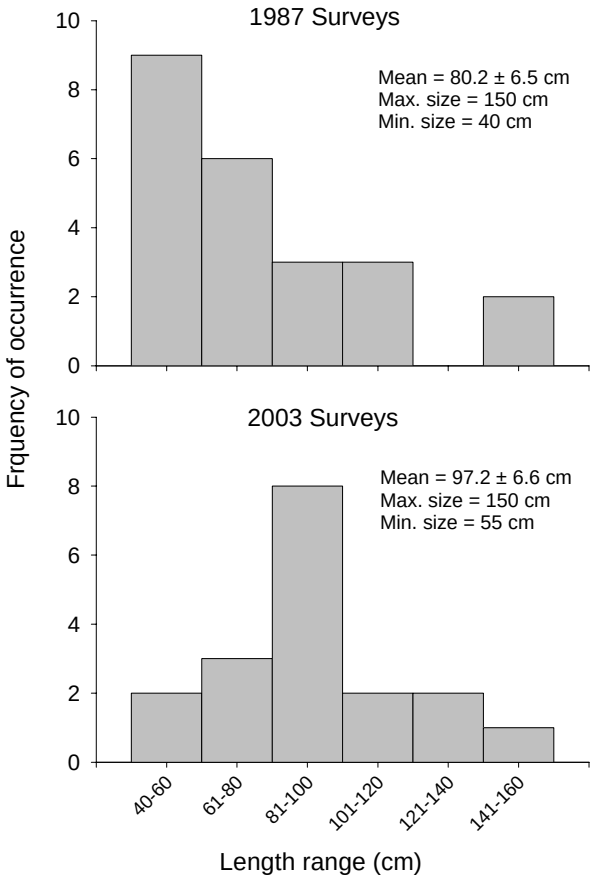

Figure 14. Lengths of Black cod (*Epinephelus daemelii*) visually estimated from Elizabeth and Middleton Reefs in 1987, and Elizabeth Reef in 2003. Mean (with standard error), maximum and minimum lengths are included.

3.1.3.4 Galapagos Shark

The Galapagos shark (*Carcharhinus galapagensis*) was common around Elizabeth Reef and is generally only found in circum-tropical waters around isolated oceanic islands and reefs, where it may be locally abundant. Galapagos sharks were encountered on 7 of the 10 timed swims and usually ranged in number from 2 to 5 individuals (Appendix 2). However, at the lagoon site, 21 individuals were recorded, ranging in size from around 1.2 to 2.2m. These sharks tended to aggregate in loose schools and were extremely inquisitive, often approaching the divers at close range.

3.1.4 COMPARISONS WITH PREVIOUS SURVEYS

3.1.4.1 Benthos

Veron (1993) sampled 118 species from Elizabeth and Middleton Reefs, while 111 hard coral species were recorded in this survey from Elizabeth Reef.

During surveys in 1984, Dr Terry Done made estimates of hard and soft coral cover from a series of transects: with each transect covering depths from 0 to >20m. The reef mean cover for all sites and transects from his visual estimates was 25% for hard coral and 11% for soft coral (unpublished data and Australian Museum 1992). The 2003 surveys (this report), conducted in a more restricted depth range (average 9m), gave a reef mean for hard coral of 25.4% and soft coral of 2.4%. It is worth noting that Done's highest estimates for soft coral were from deeper sites >9m.

Comparisons of the hard coral community on sites, where previous visual observations were made, suggest the community type is similar to previous surveys. For the lagoon site the community description in Australian Museum (1992) is virtually identical to the community observed in 2003. Comparable data from Done's surveys in 1984 exists for sites 5 and 6 on the SW corner. For site 5, Done's data suggests higher coral cover but similar community type (*Acropora* most abundant followed by *Porites*, and Faviids). At site 6, Done reported higher coral cover and greater relative abundance of *Acropora* spp. In summary, there is a high similarity in the hard coral community between surveys conducted in the 1980's and our survey in 2004. There is evidence to suggest that *Acropora* spp. were more abundant in 1984 but no evidence to suggest that there has been a decline in coral diversity.

3.1.4.2 Fish Species richness: 2003 vs 1987

Some assessment of temporal change in fish assemblages was obtained by comparing the six most species-rich genera at Elizabeth and Middleton Reefs based on all data to 1987 (Australian Museum 1992) with the six most species rich genera at Elizabeth Reef in 2003. The four most species rich genera were the same in 1987 and 2003, with the numbers of species within each of these genera being very similar, totalling 39 and 42 respectively (Table 10). Within these four genera the majority of species recorded in 1987 were also present in 2003. The absence of three *Epinephelus* species in 2003 that had been recorded previously may reflect the general rarity of these species (all listed as uncommon in 1987) and/or sampling of a greater depth/habitat range in 1987 and other previous surveys. The absences of *Eviota* species in 2003 is simply related to the fact that small cryptic fishes are often not seen using visual census techniques but are more likely to be collected using poisons, as in 1987.

Table 10. Numbers of species in the six most species rich genera (numbers bolded) from all data up to 1987 (Australian Museum report 1992) and from 2003 surveys (this study). Species within the genus *Chlorurus* were included in the genus *Scarus* in 1987.

***Genus* (Family)**	**1987**	**2003**
Chaetodon (Chaetodontidae)	**16**	**17**
Scarus/Chlorurus (Scaridae)	**11**	**12**
Thalassoma (Labridae)	**6**	**8**
Chromis (Pomacentridae)	**6**	**5**
Epinephelus (Serranidae)	**6**	3
Eviota (Gobiidae)	**5**	0
Anampses (Labridae)	3	**5**
Coris (Labridae)	4	**5**

3.2 Bêche-de-mer and clam surveys

The habitats surveyed, the methods used and the area covered are shown in Table 11. Only four of the 14 bêche-de-mer species groups (Table 3) were observed during surveys. They were *Holothuria whitmaei (nobilis), Holothuria edulis, Holothuria atra* and *Holothuria impatiens*.

Table 12 presents a comparison of bêche-de-mer densities between Elizabeth Reef, and surveys conducted on the GBR and the Indian Ocean Reserves. There have been no previous published surveys of bêche-de-mer densities in the Reserve though collections were made and species lists compiled during the 1987 expedition (Australian Museum 1992). The most detailed bêche-de-mer surveys in Australian waters, were conducted by Benzie and Uthicke (2003) between 1998 and 2000. They visited 59 outershelf and midshelf reefs in the GBR. The outstanding observation from Elizabeth Reef was that the densities of *H. whitmaei* (*nobilis*) observed at Elizabeth Reef in the two channel areas were higher than have been previously reported in other areas in Australia (133.3 ind. ha $^{-1}$ in this survey cf. 91.2 ind. ha $^{-1}$ from 8 transects on Michaelmas Cay, the highest previously reported in the literature, Uthicke and Benzie 2000). The numbers recorded from the shallow lagoon floor were also high (38 ind. ha $^{-1}$) relative to most other regions in Australia.

Holothuria atra were also found in high densities, though these densities are similar to many other areas in the Indo Pacific. *Holothuria edulis* were recorded in the lagoon at a density of 200 ind. ha $^{-1}$ during SCUBA searches at site 1 and at a much lower density on the lagoon floor (7 ind. ha $^{-1}$) (Table 13).

Table 11. Location of bêche-de-mer surveys at Elizabeth Reef showing habitats surveyed along with the area covered.

Site	**Survey method**	**Habitat**	**Area surveyed**	**Notes**
Lagoon	Snorkel swim	Lagoon floor	1 ha	
1,2,8	SCUBA search	Reef upper slope	750 m^{2}/site	High levels of sand in habitat.
3,4,5,6,7,9,10	SCUBA search	Reef upper slope	750 m^{2}/site	

Table 12. Comparison of average densities of two holothurian species between Elizabeth Reef, the GBR and the Coringa-Herald Nature Reserve (ind. ha^{-1}, SD in brackets). Species contrasted are those surveyed and present in all regions.

Location	Reference	*H. whitmaei (nobilis)*	*H. atra*
Lagoon floor, Elizabeth Reef (10,000m^2 sampled)	This report	38 (20.8)	398 (143.5)
Upper Reef slope, lagoon and channel area, Elizabeth Reef (2,250m^2 sampled)	This report	133.3 (157.2)	84.4 (134.9)
Reef flat, 26 Outer shelf reefs GBR	Benzie and Uthicke (2003)	10.84 (9.13)	83.47 (166.57)
Reef flat, 33 Mid shelf reefs GBR	Benzie and Uthicke (2003)	6.07 (8.60)	244.78 (275.65)
Reef flat, 2 Outer shelf reefs GBR	Hammond *et al.* (1985)	1.25	88.75
Back reef, 2 Outer shelf reefs GBR	Hammond *et al.* (1985)	2.5	0
Reef flat, Cartier Reef, Indian Ocean	Smith *et al.* (2002)	0	8.4
Reef flat, Ashmore Reef, Indian Ocean	Smith *et al.* (2001)	0.71	96.7
Reef flat, 5 reefs Coringa-Herald NNR	Oxley *et al.* (2003)	1.60 (3.58)	21.8 (21.8)
Back reef, 5 reefs, Coringa-Herald NNR	Oxley *et al.* (2003)	6.04 (9.68)	641.86 (1414.40)

Table 13. Density of four holothurian species recorded at Elizabeth Reef (ind. ha^{-1} , SD in brackets) for each site where they occurred. No holothurians were found in the sites where significant sand substrate did not exist.

Site	Area sampled (m^2)	Habitat/Substrate	*H. whitmaei (nobilis)*	*H. atra*	*H. impatiens*	*H. edulis*
Lagoon swim 1	10,000	Lagoon sand	38 (20.8)	398(143.5)	153 (61.9)	7 (8.9)
1	750	Upper reef slope, sand/ consolidated	0	0	0	200.0
2	750	Upper Reef slope, sandy Channel	93.3	240.0	80.0	0
8	750	Upper Reef slope, sandy, Channel	306.7	13.3	0	0

Giant clams (*Tridacna gigas*) have not been recorded as far south as Elizabeth Reef while low numbers of *T. derasa* have previously been observed in the lagoons of both Elizabeth and Middleton Reefs (Australian Museum, 1992). During the three days of underwater surveys at Elizabeth Reef, the only evidence of *T. derasa* was one shell from this species, observed lying on the lagoon floor during snorkel swims.

4 DISCUSSION

4.1 Fish and coral communities

Elizabeth and Middleton Reefs are unique, being the southernmost coral atolls in the world. Few other coral reef systems support such an assemblage of tropical, temperate and cosmopolitan species. Elizabeth Reef is likely to be ecologically unique amongst Australia's marine ecosystems due to the biogeographic diversity of fish and coral species recorded at this Reef. It is likely that reef communities at the nearby Middleton Reef are similar, but even at Lord Howe Island, only 200 km distant, coral communities have a different structure and composition (Australian Museum 1992) and lower diversity. This is the case even though the life history of both fish and corals includes an oceanic dispersal phase during which larvae may be transported long distances. It is the location of Elizabeth Reef, close to the boundary between the Coral and Tasman Seas, which allows for the existence of such a unique range of species. Elizabeth Reef lies in the path of both warm tropical currents and cooler temperate oceanic currents that may act as larval transport highways for fish and coral species of varied geographic origin. Support for this pathway was recently provided after a wave measuring buoy went adrift in November 2002 off Brisbane. This buoy was tracked by the French ARGOS satellite system and travelled down the NSW coast, then east across the Tasman Sea to the north and east of the Elizabeth and Middleton Reefs Marine National Nature Reserve, then eventually returned to the NSW coast (EPA press release 2003). Lord Howe Island tends to lie beneath this convergence zone and generally receives less consistent Coral Sea influences (Australian Museum 1992). The extremes of seawater temperatures at Elizabeth Reef (Figure 3) are probably at the upper range of thermal tolerance for many temperate and lower range for many tropical species, yet allow for the long-term persistence of both groups.

A total of 122 species of coral were identified by Done and Veron following their expedition to these reefs in 1981 (in Australian Museum 1992), compared with the 111 species found during this survey of Elizabeth Reef. However, as our surveys were more depth restricted, it is likely that deeper water species recorded in 1981 were not observed in 2003. Hutchings (in Australian Museum 1992) suggested that the relatively low diversity of corals at Elizabeth and Middleton Reefs could be attributed to the limited number of reefal habitats. While Elizabeth Reef has relatively low coral diversity when compared with the Great Barrier Reef's 550 species, it should be noted that diversity is significantly lower at Lord Howe Island where only 83 species occur (Veron and Done 1979, Veron 1993, Harriott *et al.* 1995.)

The coral community at Elizabeth Reef was similar to previous surveys. The percent cover of hard coral is at a moderate level and is consistent with a reef recovering from disturbance. In 1998, Harriot reported that no *Acropora* corals larger than 20cm were seen at Middleton Reef and that the density of coral recruits was dramatically lower than at Green Island on the GBR. With so few observations available, it is difficult to calculate recovery times. Connell *et al.* (2004) found that recovery times varied from 3-25 years at monitoring sites on Heron Island. At the time of this survey *Acropora* spp., which are a good indicator of many disturbance types, were observed in all size classes. There was little evidence to help hindcast the impact of coral

bleaching or COTS in recent years. Corals in the Pocilloporidae, a family highly susceptible to bleaching, were still present but there are insufficient data to assess whether abundance has declined. *Seriatopora,* a genus highly susceptible to bleaching, is abundant at the lagoon site at depth. Branching *Acropora* were abundant up to the intertidal zone at the lagoon site and there was no evidence of recent mortality on the reef flat. The largest colony size at Elizabeth Reef was found in the Faviid, *Leptoria,* which Marshall and Baird (2000) list as being moderately susceptible to bleaching. In summary, the current state of the coral community would suggest that there has not been severe mortality from bleaching in the lagoon in recent years.

COTS were common and observed on the outer slopes during every dive at both Elizabeth and Middleton Reefs during the 1987 surveys (Australian Museum 1992). At this time, it appeared that there had been extensive loss of live coral since the 1981 surveys of Done and Veron, and COTS were implicated in this decline (Australian Museum 1992). The next recorded visit was by Harriott in 1998 (Harriott 1998). She visited Middleton Reef and suggested that the reef was showing little sign of recovery from these earlier COTS outbreaks. Elizabeth Reef was not visited due to poor weather conditions. Geoff Kelly (Lord Howe Island Marine Park Manager) visited both Elizabeth and Middleton Reefs in January 2002 and observed very active COTS populations at Middleton Reef in particular, with densities up to 0.9/m^2 (Whitting unpublished report). Seven sites around the perimeter of Elizabeth Reef (in similar locations to this survey) were visited by Kelly and no COTS or evidence of feeding scars was recorded. There was, however, evidence of extensive storm damage at one site.

Average monthly significant wave height climatological data shows that the Elizabeth and Middleton Reefs are more frequently exposed to large swells than the GBR (Australian Oceanographic Data Centre 2004). The high disturbance regime, in combination with the distance from other reef systems, and the presence of COTS at high densities on at least one occasion in the past, suggests that a high abundance of *Acropora* on the reef perimeter is likely to be a rare event. Consequently, it is not surprising that the percent cover of *Acropora* seen around the reef perimeter during this survey was lower than seen by Done in 1981.

The relatively high abundance of Faviidae corals observed in the Elizabeth and Middleton Reefs Marine National Nature Reserve compared to the Coringa-Herald National Nature Reserve may be a result of the greater dispersal capacity of Faviids relative to other families (Nozawa and Harrison 2000) whilst the high relative abundance of Poritidae at Coringa-Herald likely reflects the persistence of *Porites* following coral mortality from bleaching.

Species in the coral fauna, which historically have been found at Elizabeth and Middleton Reefs, and are uncommon on the GBR (*Acropora lovelli, A. tortuosa, A. glauca, A. solitaryensis, Scolymia australis* and *Turbinaria heronensis*) were recorded during the timed swims. Other *Turbinaria* species and *Porites heronensis* that were recorded by Harriott *et al.* (1995) as being characteristic of the tropic/temperate ecozone, were not recorded due to taxonomic uncertainty (as no collections of corals were made). It is also worth noting that there have been significant changes to hard coral taxonomy since the visit by Done in 1981 and the Australian Museum in 1987 (Australian Museum 1992).

Wallace and Christie (1992) confirmed that the hard corals at Elizabeth and Middleton Reefs were reproductively mature, however the amount of self-seeding versus recruitment from other reefs is not known. Harriott *et al.* (1995) observed that the coral community at Lord Howe Island was dominated by coral species that brood their larvae. While it is possible that this situation could result from reduced larval supply, it is also possible that brooding species have superior settlement ability in areas of high wave action or abrasion.

Very few fish surveys have been conducted at Elizabeth Reef. In 1992, data were collated from 1987 Australian Museum surveys and other prior surveys, resulting in a list of 240 species for Elizabeth Reef (Australian Museum 1992). As the 1987 surveys used a variety of invasive techniques (i.e. rotenone poisoning, spearing and fishing), a larger number of cryptic species were recorded than in this study. Even so, 61 of the fish species recorded during these 2003 visual surveys were new records, raising the number of species recorded at Elizabeth Reef to 311.

The structure of reef fish assemblages at Elizabeth Reef is quite different from those observed on the GBR and Coringa-Herald reefs in two ways. The assemblage at Elizabeth Reef included a number of species with southern distributions while several tropical taxa (e.g. the genus *Pomacentrus*) were less diverse and less abundant there than in the other locations. It has been estimated that 24% of species at Elizabeth Reef with recorded zoogeographic affinities, had more temperate distributions while the rest were cosmopolitan throughout the tropical west Pacific and west Pacific (Australian Museum 1992). The presence of some of the taxa with more temperate distributions at the Solitary Islands Marine Park reflects the similar latitude of this region to that of Elizabeth Reef, while differences in species richness of certain taxa between these two southern systems are probably linked to differences in habitat (i.e. coral cover), coastal influences and oceanographic mechanisms of recruitment from other reef systems. The lower species richness and differences in the proportion of different taxonomic groupings of reef fish recorded at Elizabeth Reef compared to the other regions may reflect the unique location of Elizabeth Reef. As the latitude of Elizabeth Reef is approaching the southernmost limit of coral reef formation, certain tropical species adapted to warmer waters maybe unable to survive even though the habitat appears suitable. Secondly, larval dispersal to Elizabeth Reef may not be possible for many species due to its isolation. It is unclear why numbers of large reef fish were significantly lower at Elizabeth Reef compared to the other two regions, yet damselfish numbers were comparable. These results may be related to the fact that damselfish more often form very large schools and in the relatively low diversity environment of Elizabeth Reef, the few damselfish species that were present could sustain higher numbers in the absence of competitors.

Comparisons between the most species rich fish genera at Elizabeth Reef in 1987 and 2003 showed that the species richness and species complement of dominant genera differed little after a 16-year gap in surveys. As this time period likely exceeds the maximum age of some of these species, it is clear that sufficient recruitment had occurred since 1987 to maintain the pattern of dominant genera. These common species are almost certainly maintaining local breeding populations, although it is unknown what proportion of fish spawned at Elizabeth Reef return to their natal reef, as most reef fishes have a pelagic larval phase in the water column away from adult reef habitat. This period can last from days to months and averages around one month. It is most likely that a proportion of recruits to Elizabeth Reef were spawned at other nearby reefs

(Middleton Reef and Lord Howe Island), yet it is feasible that some may arrive from more distant locations such as New Zealand, other Pacific Islands and eastern Australia. Some of the most dominant species of their genera at Elizabeth Reef (i.e. *Chaetodon tricinctus*, *Chromis hypsilepis* and *Pseudolabrus luculentus*) have distributions extending from New Zealand to mainland Australia (Australian Museum 1992, Kuiter 1993).

Differences in fish assemblage structure across different habitat zones (reef slope, channel and lagoon) recorded at Elizabeth Reef are common within reef systems due to specific habitat and feeding preferences of the constituent species. A high degree of variation in species richness and abundance between sites is also not uncommon and reflects the patchy nature of different habitat types around coral reefs, the relative exposure of different sites and the random nature of site selection. Lowest numbers of species at the two channel sites likely reflect the relatively low coral cover and high sand cover at these locations: greater numbers of species are usually found in sites of highest topographic complexity (influenced by coral cover and complexity of the underlying substrate).

Black cod (*Epinephelus daemelii*) are a protected species at Elizabeth Reef and are listed as "vulnerable" by the Environmental Protection and Conservation Act 1999 (Commonwealth) and the Fisheries Management Act (NSW), and "potentially threatened" by the Australian Society for Fish Biology (NSW Fisheries 2003). This species was once widespread along the Australian NSW coast but spearing and fishing pressure dramatically reduced numbers, leading to black cod being afforded total protection in NSW waters (including Elizabeth and Middleton Reefs) in 1983. While the estimated black cod abundance of 4 cod/hectare may appear low it is not unusual for large territorial cod species to have low abundance and there was no evidence that cod numbers had either increased or decreased since last surveyed in 1987, although direct abundance comparisons were not possible. It is unknown whether numbers may be greater at depth (beyond 12m) as they have been recorded to depths of at least 50m. The maximum length of 1.5m recorded at Elizabeth Reef during 2003 surveys was around the maximum recorded in Australia but they have been recorded up to 1.8m in New Zealand (NSW Fisheries 2003). Comparisons of visual estimates of lengths of black cod between 1987 and 2003 suggest that proportionally more large fish were present in 2003. This is encouraging given the higher fecundity of larger individuals, however, this trend could be related to differences in length estimations among observers between 1987 and 2003. Even so, the fact that the length of 44% of individuals recorded in 2003 fell within the 81-100cm category may indicate a particularly strong cohort. Recruitment of many reef fish species is not consistent from year to year and one strong recruitment event may sustain numbers for many years before another major replenishment event occurs. It is not known whether the larvae of black cod spawned at Elizabeth Reef return to settle on their natal reef or whether significant recruitment occurs from nearby Middleton Reef and Lord Howe Island, or from more distant populations in locations such as New Zealand (present in the Kermadec Islands) or the NSW coast of Australia. The larval duration of this species, and thus its capacity for long distance dispersal, is unknown

There is anecdotal evidence of large catches of black cod and other fish in the early 80s and in 1993 the crew of a commercial fishing boat was found guilty of taking 24 black cod from Elizabeth and Middleton Reefs over a four-day period (NSW Fisheries 2003). It is therefore possible that

our surveys in December 2003, encountered considerably reduced target fish populations. Due to their boldness and inquisitive nature black cod are susceptible to fishing pressure. It is noteworthy that the NSW Fisheries in a draft recovery plan for the black cod (NSW Fisheries Report 2003) stated that the accidental capture and release of black cod might cause a range of impacts on the fish, including infection and internal bleeding. Released fish captured in deep water often do not survive and accidental hooking may cause sub-lethal affects resulting in restricted feeding or inability to mate. For these reasons it was recommended that fishing gear "identified as having a significant chance of incidentally capturing black cod" be restricted. Given the uncertain status of black cod numbers at Elizabeth Reef, any management plans related to fishing practices on this reef should take in to account the potential affects of accidental capture.

Other finfish taxa of recreational and commercial fishing interest, regularly encountered in similar depths on the Great Barrier Reef, were poorly represented at Elizabeth Reef. Yellowtail kingfish-amberjack may be more abundant in deeper waters around Elizabeth Reef than on our shallow survey sites. As pointed out in the Australian Museum (1992) a number of colourful species with restricted distributions may be of interest to collectors for sale in the aquarium trade. A major issue when considering the effects of fishing or collecting pressure on isolated ecosystems such as Elizabeth Reef is the capacity of fish stocks to be replenished. Compared to systems with consistent annual replenishment, fish populations at Elizabeth Reef, may naturally maintain lower numbers of individual species until a major recruitment event occurs. Such populations are therefore at higher risk of population reduction due to fishing pressure.

The presence and behaviour of the Galapagos sharks (*Carcharhinus galapagensis*) provides a unique perspective to the marine fauna of Elizabeth Reef, as this species is unlikely to be present at other Australian governed reef systems (excluding the nearby Middleton Reef and Lord Howe Island). Their presence has been reported in previous studies at Elizabeth Reef dating back to the 1920's (Whitley 1937). The higher abundance of sharks at the lagoon site compared to all others may reflect the fact that young sharks stay in shallow protected waters to avoid predation and cannibalism before moving out to deeper waters as they mature (from Florida Museum of Natural History, Ichthyology, www.flmnh.ufl.edu). This is supported by the fact that the maximum size of sharks observed in the lagoon was around 2.2m and shark maturity occurs at lengths of 2.1 to 2.5m. These data suggest that the Elizabeth Reef lagoon might be an important nursery area for Galapagos sharks. We consider the number of these sharks to be high on Elizabeth Reef. On the GBR, similar numbers of Grey Reef Whaler sharks were seen 15-20 years ago (AA personal observation), but have since declined in most locations. It is likely that the inquisitive Galapagos sharks are easy prey for fishermen and although there is little available information on the use of this shark as a food source, it has flesh of excellent quality for human consumption (from Florida Museum of Natural History, Ichthyology, www.flmnh.ufl.edu).

The fish and coral communities of the Elizabeth and Middleton Reefs Marine National Nature Reserve are characterised by isolation from recruitment sources and a high disturbance regime, two factors that are likely to have strongly influenced the observed patterns of low diversity and rarity of many species. Vagaries in broad scale climate and oceanographic currents may influence survival and spatial location of larvae, and hence settlement success at isolated reef locations. At Elizabeth Reef it is probable that influx of larvae is variable and sporadic, and the composition of

rare species (unlikely to be maintaining large breeding populations) will vary over time, as their presence will be most influenced by chance recruitment events. An emerging concept in coral reef fish ecology is that self-recruitment (larvae returning to natal reefs) may be more common than previously expected. Larvae can stay near reefs within entrained eddy systems, while late stage larvae can swim actively and directionally for long periods, and may have the olfactory ability to scent reefs and swim towards them. Two studies have definitively demonstrated self-recruitment of small reef fishes (Jones *et al.* 1999, Swearer *et al.* 1999) although the percentage of annual recruits that return to the same reef may be negligible or relatively high (up to 60% Jones *et al.* 1999).

Given the nature of Elizabeth Reef and presumably also Middleton Reef, there are three compelling reasons why high levels of protection should be afforded to the fish and coral communities of both reefs:

1) Population replenishment from other reef systems is likely to be unreliable and inconsistent, therefore the stability of the ecosystem may be reliant on the longer term presence of resident species
2) Although there is no information on self-recruitment, it is possible that a substantial proportion of post-larval recruits may have been spawned from locally breeding populations. Adopting the precautionary principle, it is wise to assume that self-recruitment is important at these isolated reefs
3) Recent research has concluded that low diversity locations are vulnerable to loosing whole families or functional groups of corals by chance alone and that this has 'the potential to severely compromise ecosystem function, resilience and stability'. (Bellwood and Hughes 2001). Clearly, any activities that increase the "chance" of community disturbance should be avoided.

4.2 Bêche-de mer

This report represents the first published bêche-de-mer surveys in the Reserve and consequently it is not possible for historical comparisons to be made. Whilst the high bêche-de-mer densities reported here should be treated with caution (because of the clumping behaviour of several of the species), they may well be representative for reefs which have never been subjected to fishing pressure and therefore provide an indication of 'natural' densities (Uthicke personal communication). Reference to the current literature suggests that the highest densities observed were 275 ind. ha^{-1} in Papua New Guinea (Lokani 1991 in Preston 1993) compared with 306.7 ind. ha^{-1} observed on site 8 during this survey (video footage available from senior author).

4.3 Other observations relevant for management

We saw no evidence of marine pollution (apart from the wrecks which have already been documented) and no marine debris was observed. We did not observe any other vessels during our visit to the reserve.

5 RECOMMENDATIONS

Key recommendations resulting from this report are:

- ***Survey Middleton Reef as soon as possible, preferably in the 2004/05 summer period.*** Middleton Reef could not be surveyed in the 2003/04 summer due to very poor weather conditions. Consequently information on the current status of this reef is sorely lacking. The presence of a better anchorage than Elizabeth Reef suggest that Middleton Reef is the more likely of the two reefs to be visited and therefore subject to an increased chance of human impact. In addition, high densities of crown-of-thorns starfish have been recorded as recently as 2002 and this requires further investigation.
- ***Deploy temperature loggers at Middleton Reef during the next survey***. Coral bleaching presents a significant threat to coral reefs world-wide and elevated sea surface temperature is known to be a trigger for bleaching. Continuous *in situ* data recording will provide a dataset that can be used to correlate with changes in the coral community between surveys and will enhance the understanding of the extent and impact of bleaching.
- ***Repeat this programme of monitoring on at least a three-year cycle***. These surveys provide a solid baseline against which future change can be assessed allowing for informed management decisions to be taken in the future.
- ***Conduct 18 month spot checks within the Reserve***. These spot checks could be done from Customs vessels using two experienced scientists in 5 days. Temperature loggers could be retrieved and video transects conducted on a subset of the sites. Assessments could also be made against other key management indicators including numbers and abundance of crown-of-thorns starfish, size of Black cod, and densities of black teatfish.
- ***Support and encourage regular patrols and flyovers of the Elizabeth and Middleton Reefs Marine National Nature Reserve especially during the summer months.*** This will help ensure protection for the Reserve by discouraging illegal fishing.
- ***Support involvement of the Lord Howe Island Marine Park manager in the monitoring of visits to the Reserve.*** Many of the visits to the Reserve come from charter operators/ private vessels operating out of Lord Howe Island. A log of visits should be kept and spot checks made relating to fishing activity conducted.
- ***Encourage and support research on the Galapagos shark and Black cod populations of the Reserve and Lord Howe Island.*** In light of the findings of this report and the rarity of these species in Australian waters, further research would provide additional information on the stocks, which would assist in more effective management and conservation of these species.
- ***It is recommended that existing coral collections from the Elizabeth and Middleton Reefs Marine National Nature Reserve be consolidated at the Museum of Tropical Queensland in Townsville***. On any future visits, additional collections (in tandem with photos of the live specimen) should be made where taxonomic uncertainty exists. This would provide a solid reference point for future monitoring in an environment that is very different from other coral reef habitats in Australia and improve the quality of future data collected.

6 ACKNOWLEDGEMENTS

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8 APPENDICES

APPENDIX 1. List of coral species recorded in the Elizabeth and Middleton Reefs Marine National Nature Reserve.

Presence = P, 0-10% of total hard coral=1, 11-30% of total hard coral = 2.

Benthic category	Site									
	1	2	3	4	5	6	7	8	9	10
Red algae species						P				
Caulerpa species	P	P		P	P	P	P			
Chlorodesmis species							P			
Codium species		P			P		P			
Halimeda species	P		P	P						
Trichoglea species							P			
Acropora listeri					1					1
Acropora aculeus									1	
Acropora anthocercis			1			1				1
Acropora aspera	1								1	
Acropora austera				1						
Acropora cerealis			1						1	
Acropora clathrata			1				1		1	1
Acropora cuneata	1			1	1	1		1		1
Acropora cytherea							1		1	1
Acropora digitifera			1							1
Acropora divaricata			1				1		1	1
Acropora formosa	1								1	
Acropora gemmifera				1	1	1	1		1	
Acropora glauca				1	1	1	1	1	1	
Acropora horrida	1									
Acropora humilis				1	1		1		1	
Acropora hyacinthus				1		1	1		1	
Acropora latistella				1	1	1	1		1	1
Acropora lovelli	2									
Acropora lutkeni									1	
Acropora millepora							1			
Acropora monticulosa			1		1	1	1			
Acropora nana			1	1						1
Acropora nasuta			1	1					1	
Acropora paniculata										1
Acropora pulchra	1									
Acropora robusta				1			1			1
Acropora samoensis	1						1	1	1	1

Benthic category	Site									
	1	2	3	4	5	6	7	8	9	10
Acropora sarmentosa									1	
Acropora secale			1	1	1		1			1
Acropora selago			1	1					1	
Acropora solitaryensis							1	1	1	1
Acropora subulata								1	1	
Acropora tenuis									1	1
Acropora tortuosa	1									1
Acropora valida			1		1				1	1
Acropora yongei	2									
Astreopora myriophthalma								1		
Astreopora species	1	1								
Montipora capricornis	2	1								
Montipora danae				1						
Montipora efflorescens							1			
Montipora encrusting				1		1				
Montipora foveolata				1				1	1	
Montipora hoffmeisteri								1		
Montipora mollis	1							1		
Montipora spongodes		1								
Montipora spumosa						1				
Montipora turgescens							1			
Montipora venosa							1			
Pavona minuta			1		1		1			
Pavona varians			1	1	1	1	1	1	1	1
Turbinaria frondens								1		
Turbinaria heronensis			1	1					1	
Turbinaria mesenterina		1	1		1		1	1	1	1
Turbinaria stellulata				1						
Australogyra zelli									1	
Barabattoia amicorum	1				1					
Cyphastrea serailia		1	1	1	1	1	1	1	1	1
Favia favus		1	1	1	1	1	1	1	1	1
Favia laxa					1					
Favia maritima							1			
Favia maxima				1						
Favia pallida		1	1	1	1		1		1	1
Favia rotumana		1	1	1	1	1	1	1		1
Favites abdita			1	1	1		1	1	1	1
Favites chinensis							1			
Favites halicora			1				1			

Benthic category	Site									
	1	2	3	4	5	6	7	8	9	10
Favites pentagona		1				1		1		
Favites russelli		1	1	1	1	1	1	1		
Goniastrea australensis		1	1	1		1	1	1	1	1
Goniastrea favulus	1	1	1	1			1	1		1
Goniastrea palauensis		1						1		
Goniastrea pectinata	1									
Leptastrea inaequalis		1			1			1	1	1
Leptastrea pruinosa					1				1	
Leptastrea purpurea								1		
Leptastrea transversa									1	
Leptoria phrygia		1	1	1	1	1	1	1	1	1
Montastrea curta		1	2	1	2	2	1	1	1	1
Montastrea magnistellata								1		
Montastrea valenciennesi			1							
Oulophyllia crispa			1			1			1	1
Platygyra daedalea		2	2	1	1	1	2	1	1	1
Platygyra lamellina		1								
Platygyra pini								1		
Platygyra sinensis						1	1	1		
Plesiastrea versipora		1								
Fungia scutaria			1							
Fungia species			1							
Hydnophora microconos		1	1		1	1	1			
Hydnophora pilosa			1	1					1	
Scaphophyllia cylidrica		1								
Acanthastrea hemprichii		1	1	1	1	1	1	1	1	1
Lobophyllia hemprichii			1				1	1		1
Lobophyllia pachysepta	1	1	1		1	1				
Scolymea australis			1	1		1		1		1
Echinophyllia aspera						1	1			
Echinophyllia orpheensis		1		1				1		1
Pocillopora damicornis	1			1	1	1	1	1	1	1
Seriatopora caliendrum	1									
Seriatopora hystrix	2							1		1
Stylophora pistillata		1		1	1	1	1	1	1	
Goniopora minor						1				
Goniopora species		1		1	1			1		
Porites cylindrica	1									
Porites lichen	1		1	2	2	2	1	1	1	
Porites lutea										1

Benthic category	Site									
	1	2	3	4	5	6	7	8	9	10
Porites massive species	I		I	I	I	I	I	I	I	I
Coscinaraea columna		I	I	I	I		I	I	I	I
Psammocora species		I		I	I					
Psammocora superficialis						I				
Ascidian species					P				P	
Corallomorpharian species					P					
Palythoa species		P	P		P					
Tridacna species	P								P	
Zoanthid species									P	
Alcyonium species			P							
Lobophytum species			P					P	P	
Rhytisma species								P		
Sarcophyton species		P	P	P	P		P			P
Sinularia species		P	P	P	P	P	P		P	P
Capnella species		P	P	P	P	P	P	P	P	P
Lemnalia species			P							
Parerethropodium species								P		
Briareum species			P				P		P	
Tubipora musica				P	P			P		P
Eflattounaria species								P		P
Xenia species					P			P	P	
Sponge encrusting			P						P	

APPENDIX 2. List of fish species recorded in the Elizabeth and Middleton Reefs Marine National Nature Reserve.

"Other" column: *P = present on reef but not during transect or timed swim surveys*
"New" column: *N = new record for Elizabeth and Middleton Reefs, E = new record for Elizabeth only*
Numbers represent log5 counts: 1=1 fish, 2=2 to 5 fish, 3=6 to 25 fish, 4=26 to 125 fish, 5=126 to 625 fish, 6=>625 fish

Family	Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10	Other	New
Acanthuridae	*Acanthurus albipectoralis*	Whitefin surgeonfish					3	4	3					N
Acanthuridae	*Acanthurus blochii*	Ringtail surgeonfish	2											N
Acanthuridae	*Acanthurus dussumieri*	Eyestripe surgeonfish			3	2	3	4	3		2	3		
Acanthuridae	*Acanthurus nigrofuscus*	Brown surgeonfish		1	3	3	4	3	4	4	2	4		
Acanthuridae	*Ctenochaetus strigosus*	Goldring bristletooth	1											N
Acanthuridae	*Naso brevirostris*	Spotted unicornfish									1			
Acanthuridae	*Naso unicornis*	Bluespine unicornfish	3	1	2	1	2	3	3		3	3		
Acanthuridae	*Naso vlamingii*	Vlaming's unicornfish	1											N
Acanthuridae	*Prionurus maculatus*	Yellowspotted sawtail	4	2	3	5	3	4	3		4	5		
Acanthuridae	*Zebrasoma scopas*	Twotone tang	1						2					E
Acanthuridae	*Zebrasoma veliferum*	Sailfin tang											P	E
Apogonidae	*Apogon cyanosoma*	Yellow striped cardinalfish		2										N
Apogonidae	*Apogon doederleini*	Doederlein's cardinalfish		1										
Apogonidae	*Apogon norfolcensis*	Unnamed	5									3		
Apogonidae	*Cheilodipterus quinquelineatus*	Five-lined cardinalfish		2										
Aulostomidae	*Aulostomus chinensis*	Chinese trumpetfish							2			1		
Balistidae	*Sufflamen chrysopterus*	Halfmoon triggerfish		2	1					2		1		E
Balistidae	*Sufflamen fraenatus*	Masked triggerfish		2	3	3	2	3	3	3	3	2		
Blenniidae	*Cirripectes alboapicalis*	Unnamed			2	2	1	2				1		
Blenniidae	*Cirripectes castaneus*	Chestnut eyelash blenny											P	N
Blenniidae	*Ecsenius fourmanoiri*	Unnamed		2	1	1	3	3	2					
Blenniidae	*Plagiotremus tapeinosoma*	Piano fangblenny		3	3	2	2	2	2	2	3	2		
Blenniidae	*Stanulus talboti*	Talbot's blenny				1								
Carangidae	*Carangoides orthogrammus*	Thicklip trevally							1					N
Carangidae	*Caranx lugubris*	Black trevally											P	
Carangidae	*Elagatis bipinnulata*	Rainbow runner					2				2			
Carangidae	*Pseudocaranx dentex*	White trevally	1			2			2					
Carangidae	*Seriola lalandi*	Yellowtail amberjack				3	1	3	2	1	2	2		
Carangidae	*Seriola rivoliana*	Almaco jack							1		1			E
Carcharhinidae	*Carcharhinus amblyrhynchos*	Grey reef shark				2			1					
Carcharhinidae	*Carcharhinus galapagensis*	Galapagos shark	3		2	2		2		2	2	2		
Chaetodontidae	*Chaetodon auriga*	Threadfin butterflyfish	3	3	3		2	2	2	2	3	2		
Chaetodontidae	*Chaetodon citrinellus*	Speckled butterflyfish			3	2	3		3	2	3	4		
Chaetodontidae	*Chaetodon ephippium*	Saddle butterflyfish	2											E
Chaetodontidae	*Chaetodon flavirostris*	Black butterflyfish	3	2			3	3	4			3		
Chaetodontidae	*Chaetodon guentheri*	Crochet butterflyfish								2				
Chaetodontidae	*Chaetodon kleinii*	Sunburst butterflyfish	1							1				
Chaetodontidae	*Chaetodon lineolatus*	Lined butterflyfish	1			2	3		1					
Chaetodontidae	*Chaetodon melannotus*	Blackback butterflyfish	3		1	3	3							
Chaetodontidae	*Chaetodon mertensii*	Atoll butterflyfish		3	1				2	3				
Chaetodontidae	*Chaetodon pelewensis*	Sunset butterflyfish				2	2							
Chaetodontidae	*Chaetodon plebeius*	Blueblotch butterflyfish			2		3	2	3	1	2			
Chaetodontidae	*Chaetodon speculum*	Mirror butterflyfish						2						E
Chaetodontidae	*Chaetodon tricinctus*	Three-striped butterflyfish	3	3	3	4	4	4	3			3		

Family	Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10	Other	New
Chaetodontidae	*Chaetodon trifascialis*	Chevron butterflyfish	3		2	2	3				2	3		
Chaetodontidae	*Chaetodon trifasciatus*	Melon butterflyfish	3											
Chaetodontidae	*Chaetodon unimaculatus*	Teardrop butterflyfish				2	2							
Chaetodontidae	*Chaetodon vagabundus*	Vagabond butterflyfish							3		2			
Chaetodontidae	*Forcipiger flavissimus*	Longnose butterflyfish					3		2			2		
Cheilodactylidae	*Goniistius ephipium*	Painted moki					1							
Cheilodactylidae	*Goniistius vittatus*	Hawaiian morwong			2	3	4	3	3	1		3		
Cirrhitidae	*Cirrhitichthys falco*	Dwarf hawkfish							1					
Cirrhitidae	*Cirrhitus splendens*	Splendid hawkfish				2			1			1		
Cirrhitidae	*Paracirrhites arcatus*	Arc-eye hawkfish				1								
Cirrhitidae	*Paracirrhites forsteri*	Blackside hawkfish				1	1							
Coryphaenidae	*Coryphaena hippurus*	Dolphinfish											P	N
Dasyatidae	Species not identified	Stingray											P	N
Diodontidae	*Diodon hystrix*	Spot-fin porcupinefish					1							
Echeneidae	*Echeneis naucrates*	Live sharksucker											P	E
Exocoetidae	*Cheilopogon furcatus*	Flying fish						3						
Fistulariidae	*Fistularia commersonii*	Bluespotted cornetfish	1						1					E
Haemulidae	*Plectorhinchus picus*	Painted sweetlip	2	1	2	2	1	1	1	1	2	2		
Hemiramphidae	*Euleptorhamphus viridis*	Ribbon halfbeak						3						
Holocentridae	*Myripristis kuntee*	Shoulderbar soldierfish					3							E
Kyphosidae	*Girella cyanea*	Bluefish				2	2							
Kyphosidae	*Kyphosus bigibbus*	Grey sea chub	4	1	3	3	4	4	4		3	3		
Kyphosidae	*Kyphosus sydneyanus*	Silver drummer					2							N
Labridae	*Anampses caeruleopunctatus*	Bluespotted wrasse			2		1							N
Labridae	*Anampses elegans*	Elegant wrasse	3		3				2		2	2		
Labridae	*Anampses femininus*	Blue-striped orange tamarin	3	3	4	2	3	4	2	3	2	2		
Labridae	*Anampses geographicus*	Geographic wrasse											P	N
Labridae	*Anampses neoguinaicus*	New Guinea wrasse	3		4	3	3	3	1			3		
Labridae	*Bodianus axillaris*	Axilspot hogfish					2							
Labridae	*Bodianus loxozonus*	Blackfin hogfish											P	N
Labridae	*Bodianus mesothorax*	Splitlevel hogfish											P	N
Labridae	*Bodianus perditio*	Golden-spot hogfish						2	1					
Labridae	*Cheilinus bimaculatus*	Twospot wrasse	1											N
Labridae	*Cheilinus chlorurus*	Floral wrasse											P	
Labridae	*Cheilinus orientalis*	Oriental maori wrasse	1											N
Labridae	*Cheilinus trilobatus*	Tripletail maori wrasse											P	N
Labridae	*Cheilio inermis*	Cigar wrasse											P	
Labridae	*Cirrhilabrus laboutei*	Labout's wrasse		3	2						3			
Labridae	*Coris aygula*	Clown coris											P	
Labridae	*Coris bulbifrons*	Doubleheader		3	3	1	3	3	2	3	3	2		
Labridae	*Coris gaimard*	Yellowtail coris								1				N
Labridae	*Coris picta*	Comb wrasse		4						2				
Labridae	*Coris pictoides*	Blackstripe coris									1			N
Labridae	*Gomphosus varius*	Bird wrasse			3	3	2		1					
Labridae	*Hemigymnus fasciatus*	Barred thicklip											P	N
Labridae	*Hemigymnus melapterus*	Blackeye thicklip	2									1		
Labridae	*Hologymnosus annulatus*	Ringwrasse			1									N
Labridae	*Labroides dimidiatus*	Bluestreak cleaner wrasse	3	3	3	1	3	2	2		3	3		
Labridae	*Labropsis australis*	Southern tubelip	1											N
Labridae	*Macropharyngodon meleagris*	Blackspotted wrasse						1		1		1		
Labridae	*Macropharyngodon negrosensis*	Yellowspotted wrasse				2								

Family	Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10	Other	New
Labridae	*Novaculichthys taeniourus*	Rockmover wrasse											P	N
Labridae	*Oxycheilinus unifasciatus*	Ring-tail wrasse					2							N
Labridae	*Pseudocoris yamashiroi*	Redspot wrasse									3	1		N
Labridae	*Pseudodax moluccanus*	Chiseltooth wrasse						1						N
Labridae	*Pseudolabrus luculentus*	Orange wrasse	4	5	5	5	4	4	5	5	6	4		
Labridae	*Pteragogus cryptus*	Cryptic wrasse	1											N
Labridae	*Stethojulis bandanensis*	Red shoulder wrasse		3	3	3	3	3	3	4	3	1		
Labridae	*Stethojulis strigiventer*	Three ribbon wrasse	1						1					E
Labridae	*Thalassoma amblycephalum*	Bluntheaded wrasse		4	6	4	5	6	5	4	5	4		
Labridae	*Thalassoma hardwicke*	Sixbar wrasse		2		2		3						
Labridae	*Thalassoma jansenii*	Jansen's wrasse			4	2	3	4	3			3		
Labridae	*Thalassoma lunare*	Moon wrasse	3	2		2	1	3	1	3		1		
Labridae	*Thalassoma lutescens*	Yellow-brown wrasse	3	2	6	5	5	6	5	4	2	4		
Labridae	*Thalassoma purpureum*	Surge wrasse		1		4	2	3						
Labridae	*Thalassoma quinquevittatum*	Fivestripe wrasse			2		1							N
Labridae	*Thalassoma trilobatum*	Ladder wrasse					2							N
Labridae	*Xyrichthys pavo*	Peacock razorfish		2										N
Lethrinidae	*Gymnocranius euanus*	Japanese large-eye bream											P	
Lutjanidae	*Aphareus furca*	Smalltoothed jobfish					1							N
Lutjanidae	*Aprion virescens*	Green jobfish				1		1	1					
Lutjanidae	*Lutjanus bohar*	Two-spot red snapper			1	2	1	3	3		1	1		
Lutjanidae	*Paracaesio xanthura*	Yellowtail blue snapper	2			4	3	4	5		4	4		
Microdesmidae	*Nemateleotris magnifica*	Fire goby									2			N
Microdesmidae	*Ptereleotris evides*	Blackfin dartfish			2				3		2			
Microdesmidae	*Ptereleotris microlepis*	Pale dartfish					2							N
Microdesmidae	*Ptereleotris zebra*	Zebra dartfish			4									N
Monacanthidae	*Cantherhines dumerilii*	Whitespotted filefish			1		2							
Monacanthidae	*Cantherhines fronticinctus*	Spectacled filefish			1	1	1							N
Monacanthidae	*Cantherhines pardalis*	Honeycomb filefish			1			2						N
Mullidae	*Parupeneus multifasciatus*	Manybar goatfish					1		2					
Mullidae	*Parupeneus pleurostigma*	Sidespot goatfish				1				1				
Mullidae	*Parupeneus signatus*	Black spot goatfish		3	2	3	4	4	3			3		
Muraenidae	*Enchelycore ramosa*	Mosaic moray			1									
Muraenidae	*Gymnothorax meleagris*	Whitemouth moray		1										N
Ostraciidae	*Ostracion cubicus*	Yellow boxfish					1							
Pinguipedidae	*Parapercis hexophtalma*	Speckled sandperch			1									
Pomacanthidae	*Centropyge tibicen*	Keyhole angelfish	3	1										
Pomacanthidae	*Centropyge vrolikii*	Pearlscale angelfish			1									
Pomacanthidae	*Chaetodontoplus conspicillatus*	Conspicuous angelfish					2	2			3			
Pomacanthidae	*Genicanthus semicinctus*	Halfbanded angelfish					3							
Pomacentridae	*Amphiprion mccullochi*	White-snout anemonefish	2	3								2		
Pomacentridae	*Chromis atripectoralis*	Black-axil chromis											P	E
Pomacentridae	*Chromis flavomaculata*	Yellow-spotted chromis			2		3	5	5		6			
Pomacentridae	*Chromis hypsilepis*	Brown puller		4	6	5	6	5	5		6	6		
Pomacentridae	*Chromis margaritifer*	Bicolor chromis					3							
Pomacentridae	*Chromis vanderbilti*	Vanderbilt's chromis			4	2	5	6	3		5	3		
Pomacentridae	*Chrysiptera notialis*	Southern demoiselle	2	5	6	3	5	4	5	5	6	5		
Pomacentridae	*Dascyllus aruanus*	Whitetail dascyllus	4											
Pomacentridae	*Dascyllus reticulatus*	Reticulate dascyllus											P	
Pomacentridae	*Dascyllus trimaculatus*	Threespot dascyllus											P	E
Pomacentridae	*Neoglyphidodon polyacanthus*	Multispine damselfish	5									2		

Family	Scientific Name	Common Name	1	2	3	4	5	6	7	8	9	10	Other	New
Pomacentridae	*Parma polylepis*	Banded parma		3	3	3	3	2	3		2	3		
Pomacentridae	*Plectroglyphidodon dickii*	Blackbar devil	2			2	2	3						
Pomacentridae	*Plectroglyphidodon imparipennis*	Brighteye damsel				2								N
Pomacentridae	*Plectroglyphidodon johnstonianus*	Johnston Island damsel	1		4	2	3	2	2		1	2		
Pomacentridae	*Pomacentrus coelestis*	Neon damselfish			2			2	3	3	3	3		
Pomacentridae	*Stegastes fasciolatus*	Pacific gregory			3	4	4	6	3			3		
Pomacentridae	*Stegastes gascoynei*	Coral sea gregory	3	4	5	5	4	6	5	5	6	4		
Pseudochromidae	*Pseudochromis novaehollandiae*	Multi-cloured dottyback								2				
Scaridae	*Cetoscarus bicolor*	Bicolour parrotfish	1											N
Scaridae	*Chlorurus frontalis*	Tanfaced parrotfish	1						2		1	2		N
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	1		3	2	3		2		1	1		
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	3	3	3	3	2	2	3			3		
Scaridae	*Scarus altipinnis*	Filament-finned parrotfish	2	1	3	1	3	3	3	2	4	3		
Scaridae	*Scarus chameleon*	Chameleon parrotfish		3		1	2		1	2				N
Scaridae	*Scarus frenatus*	Bridled parrotfish		3	2	3	3	3	2			3		
Scaridae	*Scarus ghobban*	Blue-barred parrotfish	2	1	2			1	1		3	2		
Scaridae	*Scarus globiceps*	Globehead parrotfish		2	1				2	1				
Scaridae	*Scarus longipinnis*	Highfin parrotfish	1											N
Scaridae	*Scarus niger*	Dusky parrotfish	3			1			2					E
Scaridae	*Scarus psittacus*	Common parrotfish	5	2	2	3		2	4	4		3		
Scaridae	*Scarus schlegeli*	Yellowband parrotfish	2						3					
Scorpaenidae	*Dendrochirus zebra*	Zebra turkeyfish											P	N
Scorpaenidae	*Pterois volitans*	Red lionfish	1	1										
Serranidae	*Acanthistius cinctus*	Yellowbanded perch					1							
Serranidae	*Cephalopholis argus*	Peacock hind			2		2		2		3	1		
Serranidae	*Cephalopholis miniata*	Coral hind					1	3	2					E
Serranidae	*Epinephelus daemelii*	Saddletail grouper	2			2			2	1	2	1		
Serranidae	*Epinephelus fasciatus*	Blacktip grouper						2			1	1		
Serranidae	*Epinephelus merra*	Honeycomb grouper											P	
Serranidae	*Pseudanthias squamipinnis*	Sea goldie				3	3	2						E
Serranidae	*Variola louti*	Yellow-edged lyretail			2	1	1	1	2					E
Siganidae	*Siganus fuscescens*	Mottled spinefoot						1	1					N
Synodontidae	*Synodus hoedti*	Unnamed		1										N
Tetraodontidae	*Canthigaster valentini*	Valentinni's sharpnose puffer							1		1			
Zanclidae	*Zanclus cornutus*	Moorish idol				3	3	3			2	2		

APPENDIX 3. List of fish species recorded from transect surveys in the Elizabeth and Middleton Reefs Marine National Nature Reserve.

Family	Species	Total abundance (all transects)
Acanthuridae	*Acanthurus dussumieri*	8
	Acanthurus nigrofuscus	19
	Naso unicornis	15
	Prionurus maculatus	76
Chaetodontidae	*Chaetodon auriga*	9
	Chaetodon citrinellus	9
	Chaetodon flavirostris	34
	Chaetodon kleinii	1
	Chaetodon lineolatus	1
	Chaetodon melannotus	8
	Chaetodon mertensii	5
	Chaetodon pelewensis	2
	Chaetodon plebeius	7
	Chaetodon tricinctus	78
	Chaetodon trifascialis	10
	Chaetodon trifasciatus	11
	Chaetodon unimaculatus	8
Cheilodactylidae	***Goniistius ephipium***	1
	Goniistius vittatus	13
Haemulidae	***Plectorhinchus picus***	3
Labridae	*Coris bulbifrons*	6
	Hemigymnus melapterus	1
Lutjanidae	*Lutjanus bohar*	4
Pomacentridae	*Chromis flavomaculata*	29
	Chromis hypsilepis	382
	Chromis vanderbilti	33
	Chrysiptera notialis	468
	Dascyllus aruanus	2
	Neoglyphidodon polyacanthus	8
	Parma polylepis	4
	Plectroglyphidodon dickii	2
	Plectroglyphidodon	5
	Pomacentrus coelestis	15
	Stegastes fasciolatus	74
	Stegastes gascoynei	350
Scaridae	*Chlorurus frontalis*	1
	Chlorurus sordidus	12
	Scarus altipinnis	10
	Scarus chameleon	5
	Scarus frenatus	12
	Scarus ghobban	3
	Scarus niger	1
	Scarus psittacus	43
	Scarus schlegeli	5
Serranidae	***Cephalopholis argus***	2
	Epinephelus daemelii	2
Zanclidae	*Zanclus cornutus*	9

bolding = species excluded from comparison with southern GBR species.

APPENDIX 4. Black cod (*Epinephelus daemelii*) lengths at Elizabeth Reef 2003

ts = timed swim; t = transect; misc = miscellaneous sighting

Site	Length (cm)	Method
1	100	ts/misc
1	95	t
1	60	ts
1	140	ts
2	95	misc
4	55	ts/misc
4	65	ts
7	150	misc
7	90	ts/misc
7	95	ts
7	110	ts
8	140	ts
9	80	ts
9	95	ts/misc
10	90	ts
10	70	t
Lagoon	120	misc
Lagoon	100	misc

APPENDIX 5. Comparison of number of coral species within each genus between locations.

Hard Coral genus	Coral Sea (Veron)	Coringa-Herald	Cap-Bunker Veron	Eliz/Midd (Veron)	Lord Howe I Harriott *et al.1995*	This survey
Acanthastrea	2	2	3	4	4	1
Archelia	0	0	1	0	0	0
Acropora	54	26	48	24	13	37
Alveopora	5	0	3	2	2	0
Anacropora	0	0	0	0	0	0
Astreopora	7	1	6	4	1	2+
Australogyra	0	0	0	0	0	1
Barabattoia	1	0	1	0	0	1
Blastomussa	1	0	1	1	0	0
Catalaphylllia	0	0	1	0	0	0
Caulastrea	3	0	0	0	0	0
Coeloseris	1	1	0	1	0	1
Coscinarea	4	2	2	3	2	1
Ctenactis	1	0	0	0	0	0
Cycloseris	2	0	4	1	0	0
Cynarina	1	0	1	0	0	0
Cyphastrea	4	0	3	2	3	1+
Diaseris	0	2	1	0	0	0
Diploastrea	1	0	0	0	0	0
Duncanopsammia	0	0	0	0	0	0
Echinophyllia	3	1	2	2	1	2
Echinopora	2	1	4	1	0	0
Euphyllia	1	0	3	1	0	0
Favia	10	5	11	6	4	6
Favites	7	3	6	5	4	5
Fungia	10	3	9	1	0	1
Galaxea	2	1	2	0	0	0
Gardinoceris	1	1	1	0	0	0
Goniastrea	5	2	7	4	3	4
Gonipora	10	2	8	5	4	2+
Halomitra	1	0	0	0	0	0
Heliofungia	1	0	1	0	0	0
Herpolitha	2	1	1	0	0	0
Heteropsammia	0	0	1	0	0	0
Hydnophora	3	2	3	2	2	1
Leptastrea	4	2	4	5	1	4
Leptoria	1	0	1	1	0	1
Leptoceris	6	1	6	2	2	0
Lithophyllon	0	0	0	0	0	0
Lobophyllia	4	1	4	1	1	2
Madracis	0	0	0	0	0	0

Merulina	2	0	2	0	1	0
Montastrea	3	2	4	2	2	3
Montipora	24	7	24	9	9	11+
Moseleya	0	0	0	0	0	0
Mycedium	1	0	1	0	1	0
Ouphyllia	1	2	2	1	1	1
Oxypora	1	0	2	1	0	0
Pachyseris	1	0	1	0	0	0
Paulastrea	0	0	1	0	0	0
Paraclavarina	0	0	1	0	0	0
Pavona	7	5	8	5	4	2
Pectinia	0	0	2	0	0	0
Physogyra	1	0	1	0	0	0
Platygyra	2	4	4	3	1	4
Plerogyra	0	0	1	0	0	0
Plesiatrea	1	0	1	1	1	0
Pocillopora	5	2	3	1	1	1
Podobacia	1	0	1	0	0	0
Polyphyllia	1	0	0	0	0	0
Porites	12	5+	11	3	5	3+
Psammocora	1	2	4	4	2	2+
Pseudosiderastrea	1	0	4	4	0	0
Sandalolitha	1	1	1	0	0	0
Scaphophyllia	1	1	1	0	1	1
Scolymia	1	0	2	2	0	1
Seriatopora	2	0	2	2	1	2
Stylophora	1	1	1	1	1	1
Symphyllia	4	1	4	1	1	0
Trachyphyllia	0	0	1	0	0	0
Turbinaria	3	3	7	6	5	4+

APPENDIX 6. Position of sites surveyed (WGS-84 datum).

Site	Description	Lat	Long	Date Surveyed
1	lagoon	S29 56.2820	E159 03.1530	5/12/2004
2	channel	S29 56.0210	E159 05.7800	5/12/2004
3	east	S29 56.9800	E159 07.5100	5/12/2004
4	south corner	S29 59.0200	E159 06.2000	3/12/2004
5	south	S29 57.7980	E159 02.8320	5/12/2004
6	south-west	S29 57.2000	E159 01.2000	3/12/2004
7	west wreck	S29 55.9700	E159 01.3900	4/12/2004
8	north-west	S29 55.6000	E159 02.9400	4/12/2004
9	north	S29 54.5500	E159 04.6500	4/12/2004
10	north-east	S29 55.1550	E159 05.3800	4/12/2004

APPENDIX 7. Selection of underwater photos.

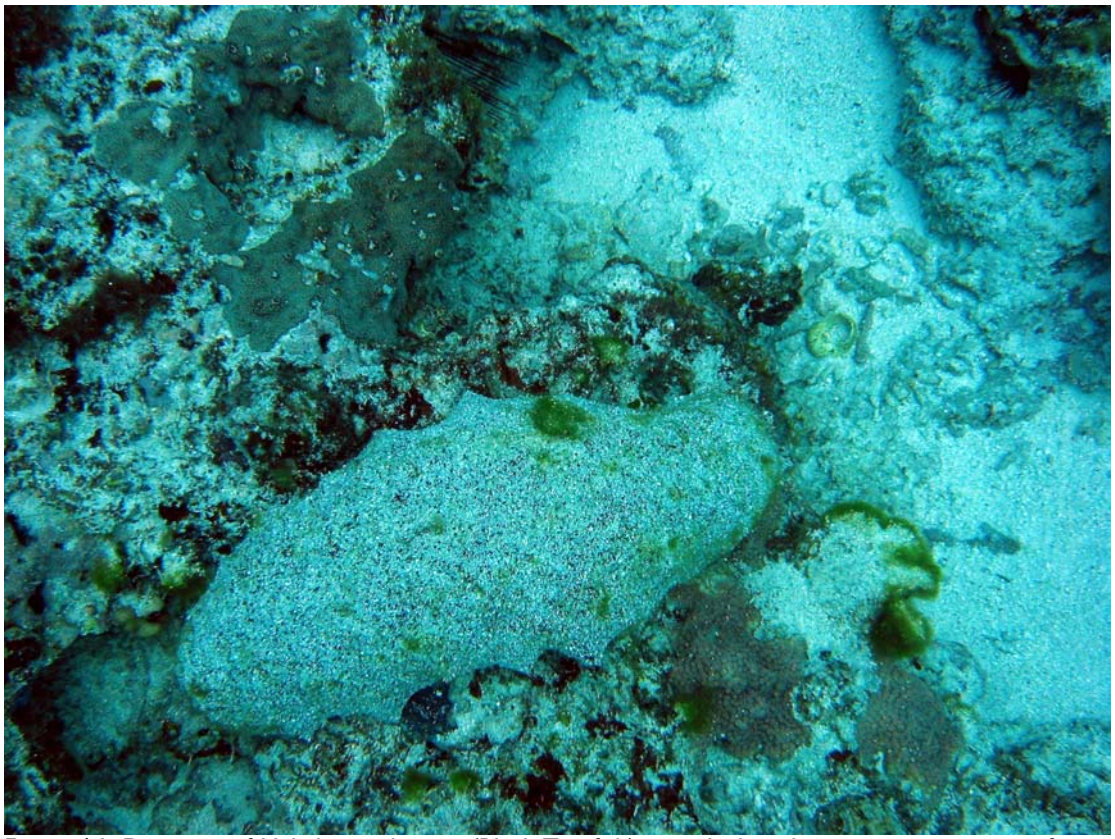

Figure A1: Densities of *Holothuria whitmaei* (Black Teatfish) were higher than previous estimates from elsewhere in Australia.

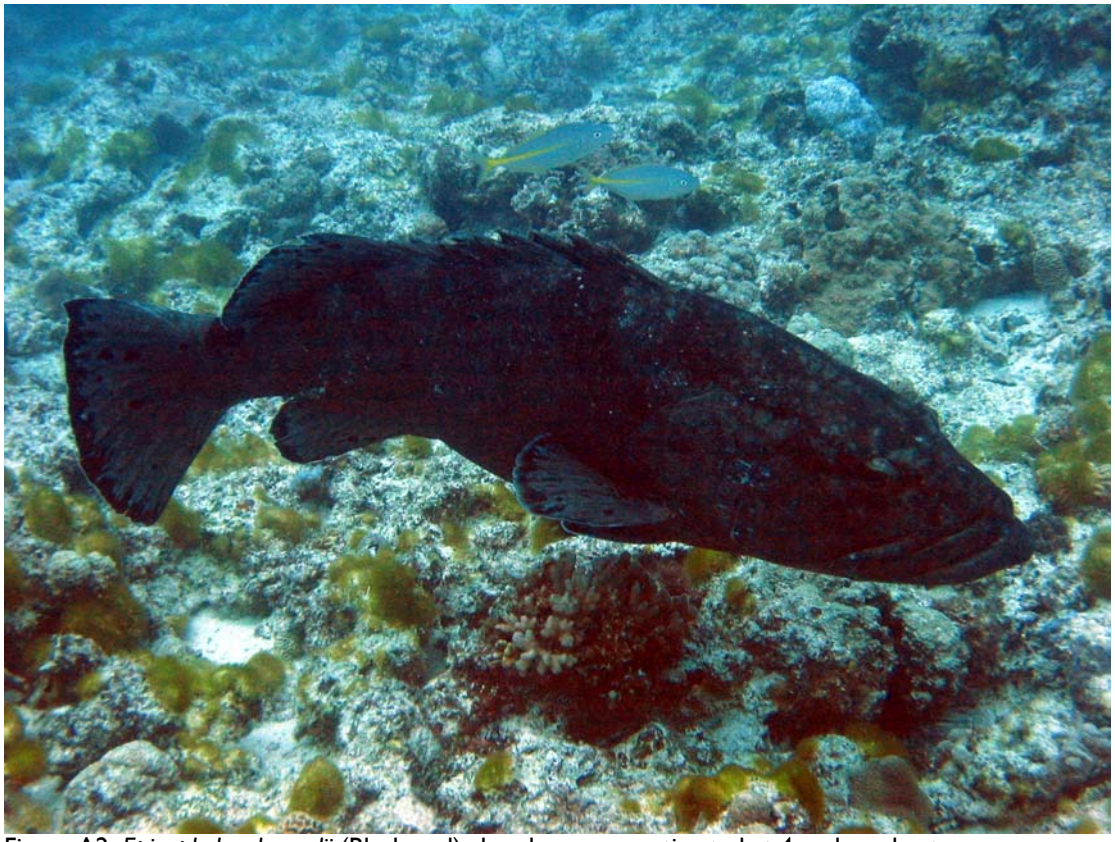

Figure A2: *Epinephelus daemelii* (Black cod) abundance was estimated at 4 cod per hectare.

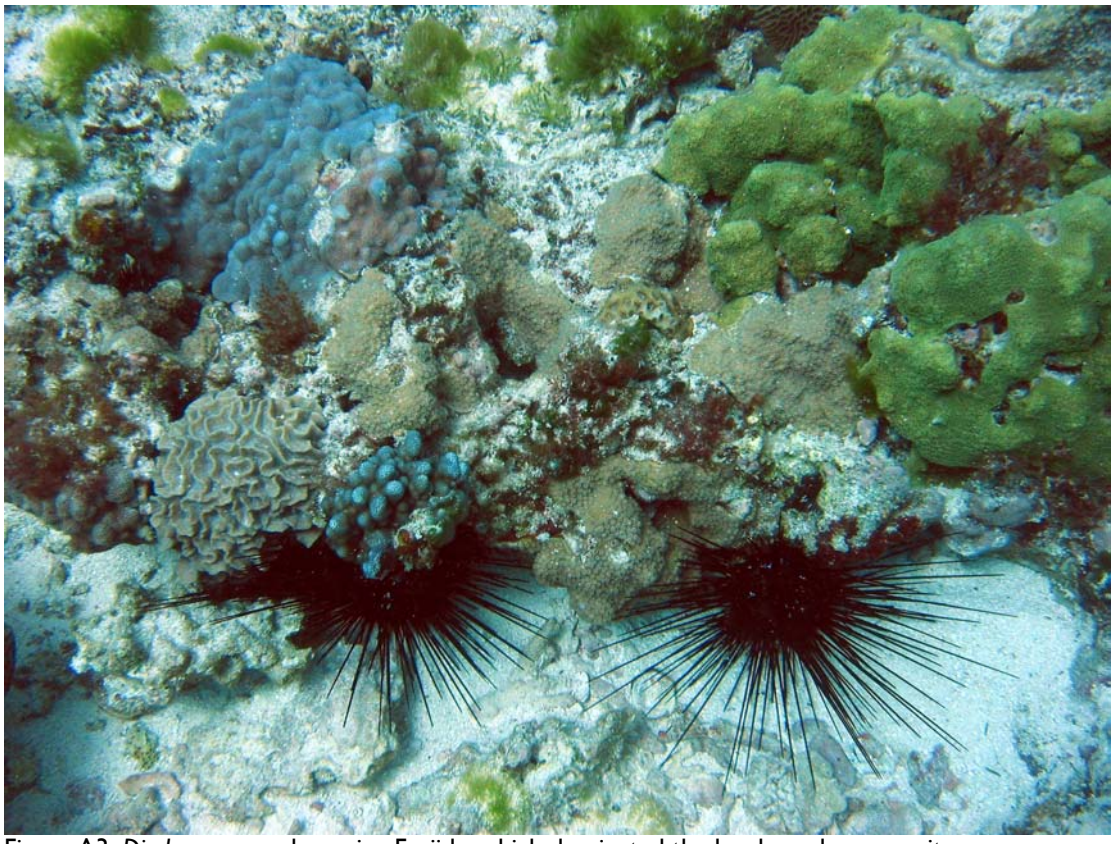

Figure A3: *Diadema* sp. and massive Faviids, which dominated the hard coral community.

Figure A4: The wreck of a Japanese long line vessel (identify unclear) on the reef crest.

Figure A5: A sea star on a massive *Leptoria* coral colony. Bites marks from parrot fish and an unidentified scar are visible on the coral.

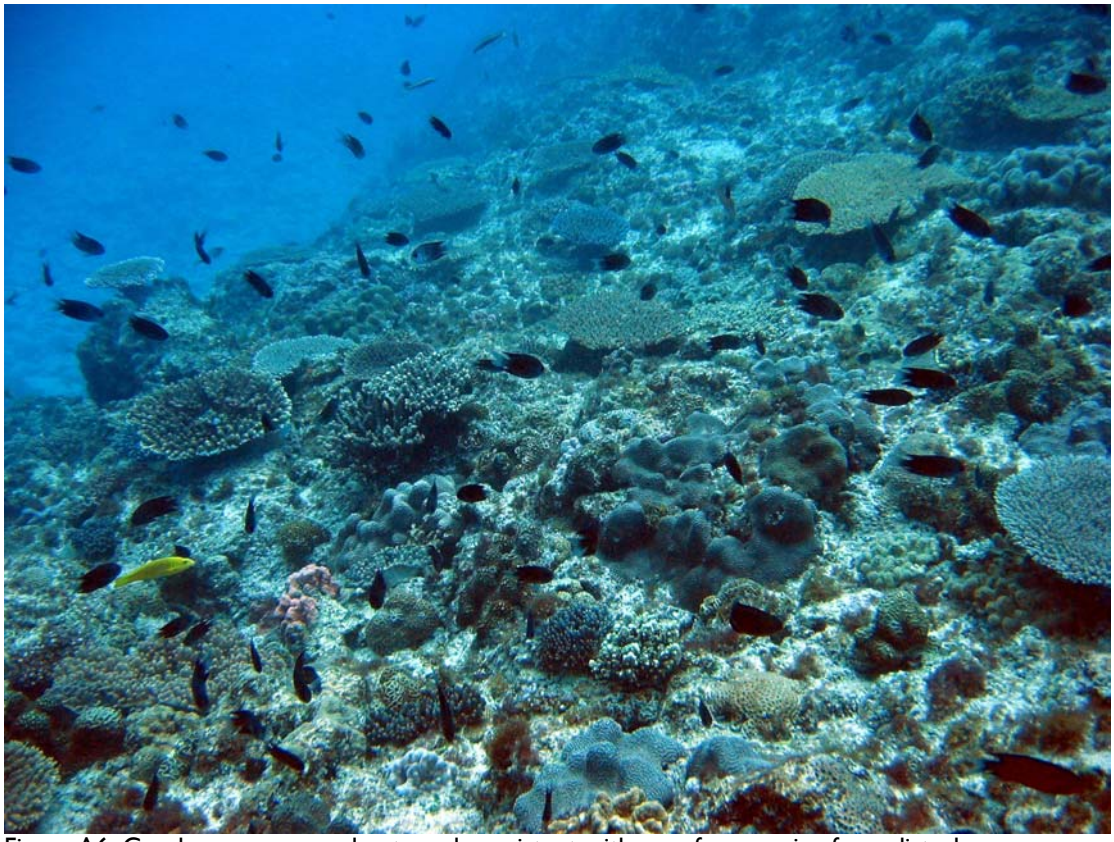

Figure A6: Coral cover was moderate and consistent with a reef recovering from disturbance.

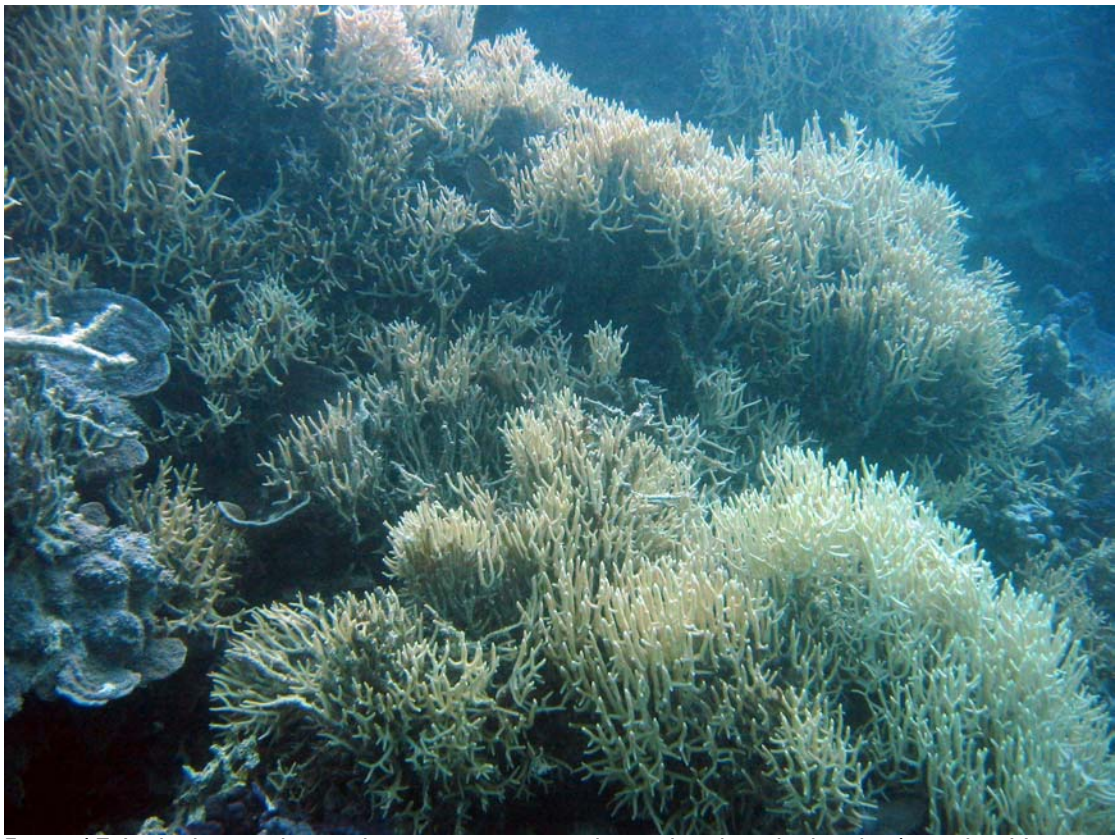

Figure A7: In the lagoon the coral community was similar to that described in the Australian Museum report (1992). Large stands of *Seriatopora hystrix* were common at 6-9m depth.

Figure A8: High numbers of Galapagos sharks (*Carcharhinus galapagensis*) were observed especially in the lagoon.

Figure A9: *Holothuria impatiens* is a small, non-commercial species that was frequently observed.

Figure A10: This anemone fish, *Amphiprion mccullochi* is endemic to the Lord Howe Island region.

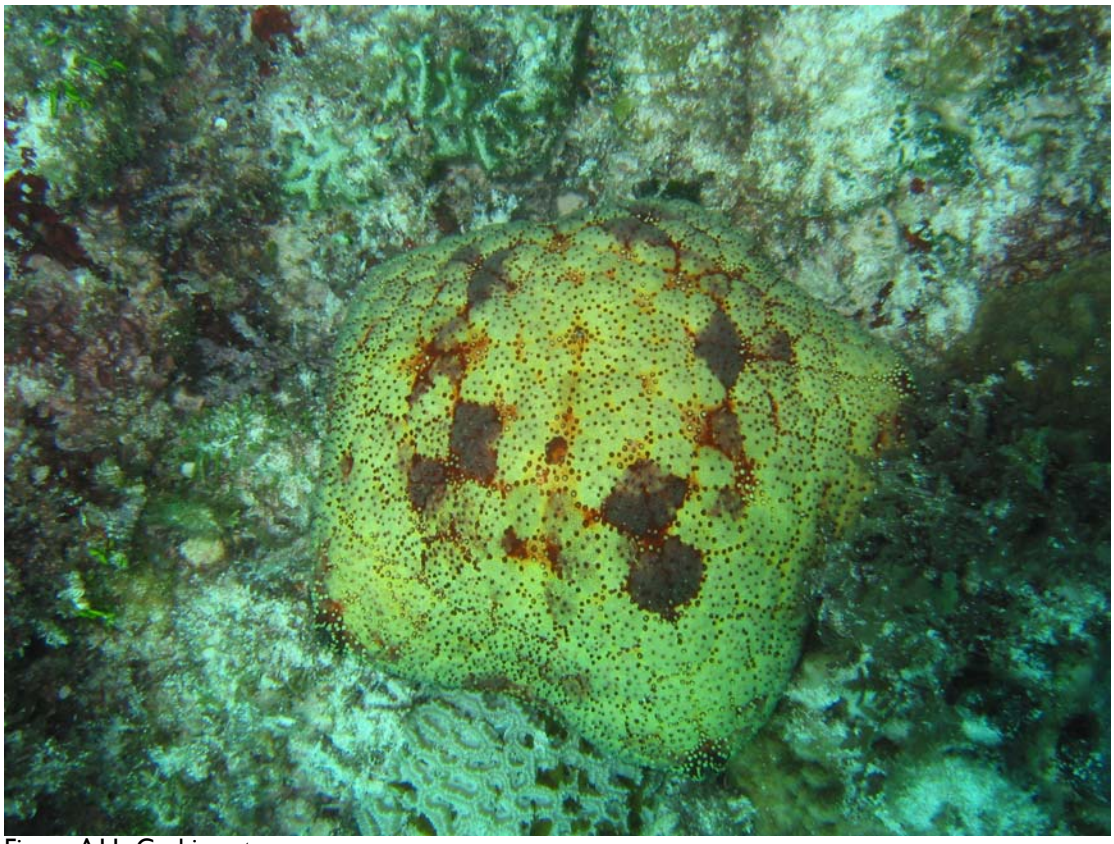

Figure A11: Cushion star

Figure A12: Only a few *Acanthaster planci* were observed and there was no evidence of recent outbreaks.

Figure A13: *Goniistus vittatus* is one of the subtropical/temperate fish species that occurs at Elizabeth Reef.

Figure A14: Deep grooves in the reef slopes were one of the few topographic features observed.

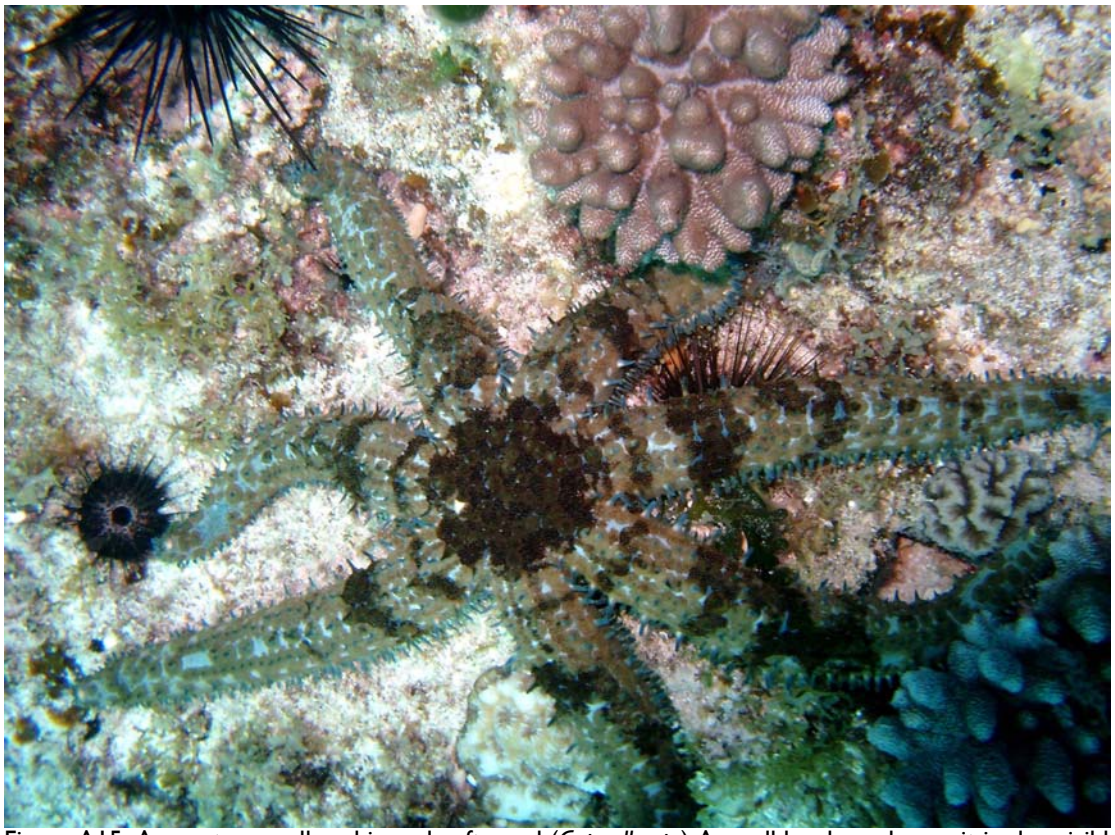

Figure A15: A sea star, small urchin and soft coral (*Capnella sp.*) A small hard coral recruit is also visible on the right.