Marine Surveys undertaken in the Coringa-Herald National Nature Reserve, March-April 2003

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EXECUTIVE SUMMARY

The Coringa-Herald National Nature Reserve (CHNNR or Reserve) is one of two protected areas in the Coral Sea region. The Reserve is located some 400 kilometres east of Cairns, Far North Queensland. It was proclaimed on the 16th August 1982 under the National Parks and Wildlife Conservation Act 1975, and is one of 12 Marine Protected Areas (MPAs) managed by Environment Australia (EA). The Australian Institute of Marine Science (AIMS) conducted fish, benthic, and bêche-de-mer surveys in the CHNNR, 28 March – 2 April 2003. The outstanding feature observed during these surveys was the dramatically low cover of live hard coral. Comparisons with a number of GBR offshore reefs revealed a nearly 7-fold difference in cover (GBR 30%: 4.5% NE flanks CHNNNR). Comparisons with earlier surveys conducted in the CHNNR indicated historically low levels of hard coral cover in the Reserve with a maximum of 20% cover in 1997 and then a dramatic decline to the current level of less than 5%. During these surveys we observed strong evidence of bleaching mortality of hard corals and a suggestion of storm wave damage at a few exposed sites. These observations are supported by the additional information presented in this report showing significant cyclone activity and increased water temperatures, which are likely to have caused coral mortality through wave action and coral bleaching respectively. Hard coral diversity was also very low in the CHNNR. On GBR reefs for which comparable data are available, diversity levels were 1.5-2.3 times those in the Coral Sea. The reef fish assemblages showed a similar pattern of low diversity and density when compared to assemblages on the GBR. The reef fish assemblages observed were unique compared to anywhere on the GBR with many species common to Coral Sea reefs, rare or absent from similar habitats on the GBR and visa versa. This report also represents the first published bêche-de-mer surveys in the Reserve. Direct comparison with data from the Timor Sea Reserves, where the same species occur, suggests higher densities in the CHNNR. In general, densities of bêche-de-mer were lower in the CHNNR than on the GBR. Of note were the higher densities of the high value species *H. nobilis* within the CHNNR. The importance of the stocks of bêche-de-mer within the CHNNR is highlighted, with recent overexploitation of stocks in other areas of Australia, and a bêche-de-mer fishery in the waters surrounding the CHNNR. It is clear that reefs in the Coral Sea are under significant pressure, especially from the effects of cyclones and, more recently, coral bleaching. Bêche-de-mer are also under increased pressure as evidenced by the decline in the catch per unit effort (CPUE) and catch rates outside the CHNNR. The importance of the CHNNR in the protection and sustainability of threatened species (a key objective of the management plan) is highlighted. This report is also available in an interactive multimedia version where video footage of sites can be viewed.

1 INTRODUCTION

The Coringa-Herald National Nature Reserve (CHNNR or Reserve) is one of two protected areas in the Coral Sea region. The Reserve is located some 400 kilometres east of Cairns, Far North Queensland. It was proclaimed on the 16th August 1982 under the National Parks and Wildlife Conservation Act 1975, and is one of 12 MPAs managed by Environment Australia (EA), nine of which contain coral reef ecosystems.

The Coringa-Herald National Nature Reserve & Lihou Reef National Nature Reserve Management Plan (Environment Australia 2001) made clear that both reserves 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 reserves also form 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 Marine Protected Areas (MPAs). Rigorous environmental research and monitoring programs are a core element of performance assessment (ANZECC, 1999).

Environment Australia place a high priority on research and monitoring in the nine Commonwealth MPAs with coral reef ecosystems and in 2003 contracted surveys to be conducted in six of these MPAs.

This document describes the fish, benthic, and bêche-de-mer surveys conducted by the Australian Institute of Marine Science (AIMS) in the Coringa-Herald National Nature Reserve in March-April 2003. A summary of the results is presented along with a discussion of their significance and some comparison with other coral reef ecosystems.

The Australian Customs Service provided the vessel ACV Arnhem Bay and her crew for this survey: support that was critical to allowing work to be conducted in this remote area, where only two surveys of fish and benthic communities have been conducted since the Reserve was proclaimed in 1982 (Ayling and Ayling 1985, Byron *et al.* 2001).

2 METHODS

2.2 Sampling design

Five of the six islets and cays in the Reserve were surveyed between 28 March and 2 April 2003. These were NE and SW Herald, Coringa (also known as South West Islet), Chilcott and SE Magdelaine (Figure 1). Figures 2-6 show the location of sampling sites on each reef.

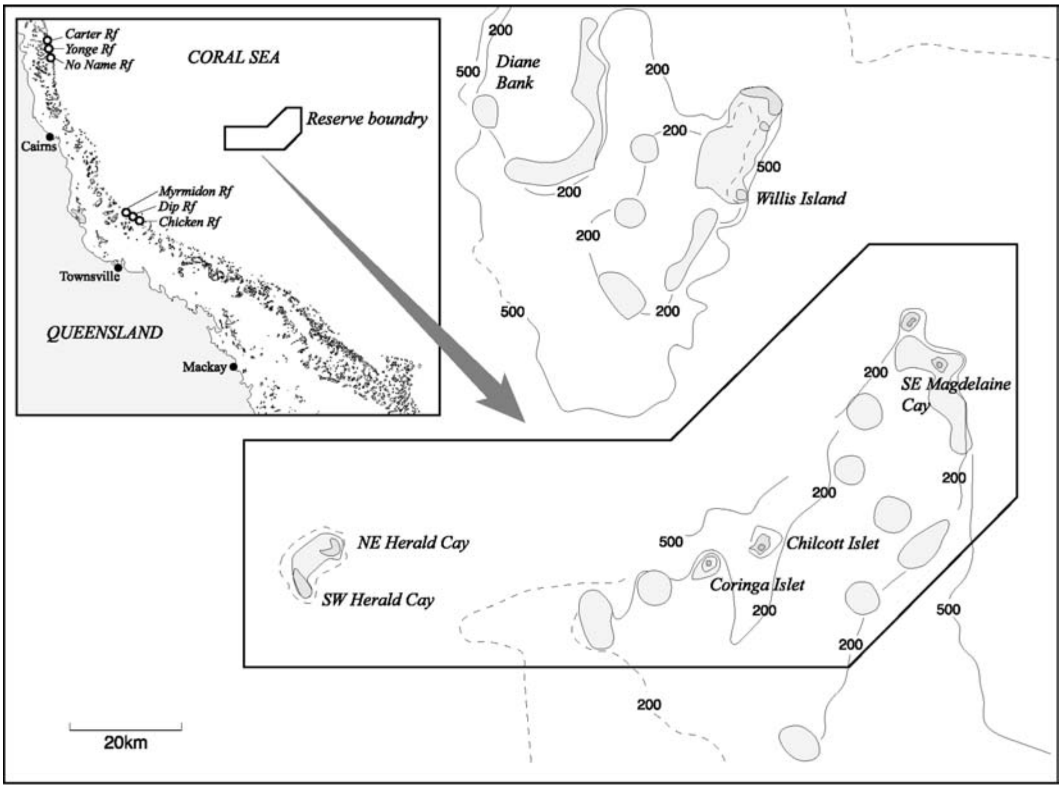


Figure 1. Location of Coringa-Herald National Nature Reserve and reefs surveyed. The GBR reefs used for comparison are also shown.

As the primary scale of interest for EA was the entire nature Reserve, a decision was taken to sample as many reefs as possible within the Reserve. The limited time available meant that approximately one day could be spent at each reef. Current Australian scientific diving standards mandate that diving time be decreased with increasing distance from a recompression chamber. The remoteness of the Reserve meant that, at each reef, daily diving was restricted to 4 dives (max. duration 45 min.) to a depth of around 9 m. It was therefore decided to sample four sites on each reef, distributed so as to include the major habitats, reef fronts, back reefs, and reef flanks (Table 1).

Where possible, comparisons were also made with the two previous fish and coral surveys conducted in the Reserve. The presence of participants from both previous surveys (Tony Ayling in 1985, Angus Thompson in 1997) assisted in these comparisons.

Weather conditions were not ideal for working on these exposed reefs, with winds averaging in excess of 20 knots on most days. However, with the exception of SE Magdelaine, where only limited sampling was possible, all planned work was completed.

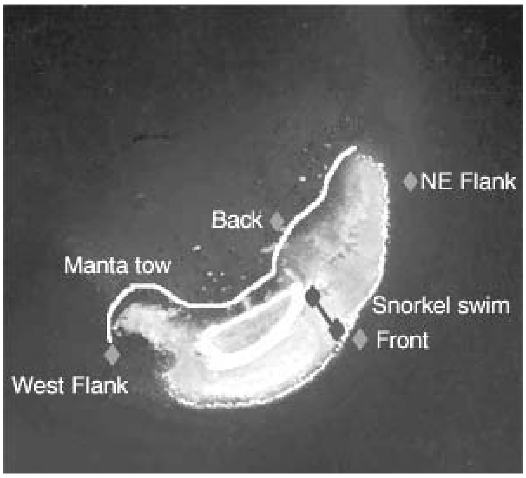


Figure 2. Chilcott

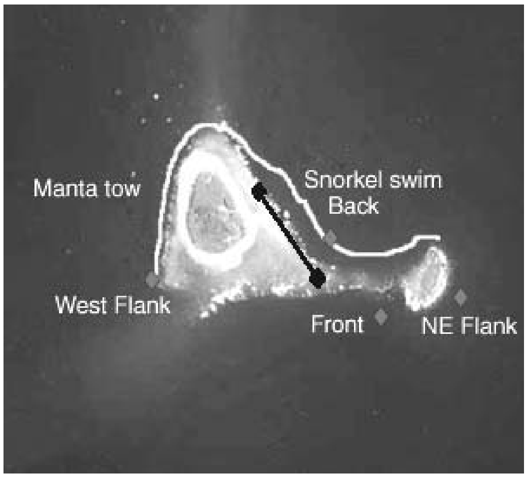


Figure 3. Coringa

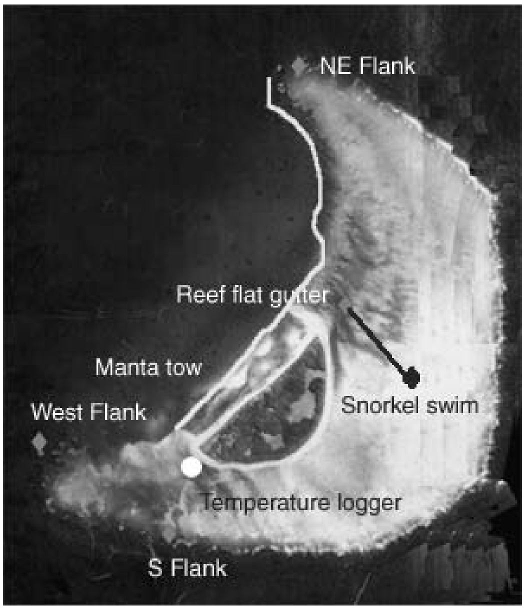


Figure 4. NE Herald

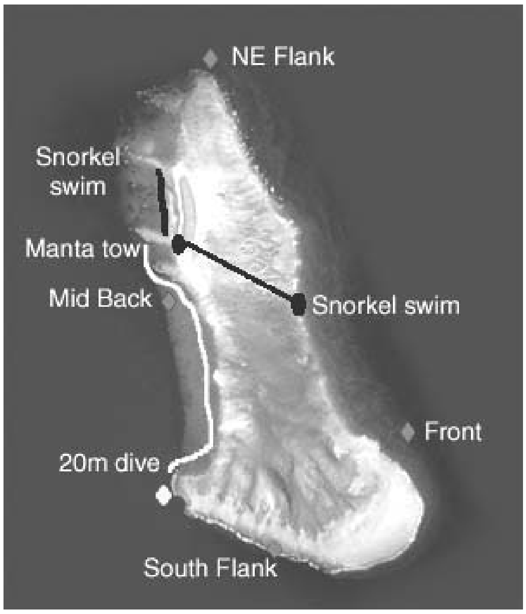


Figure 5. SW Herald

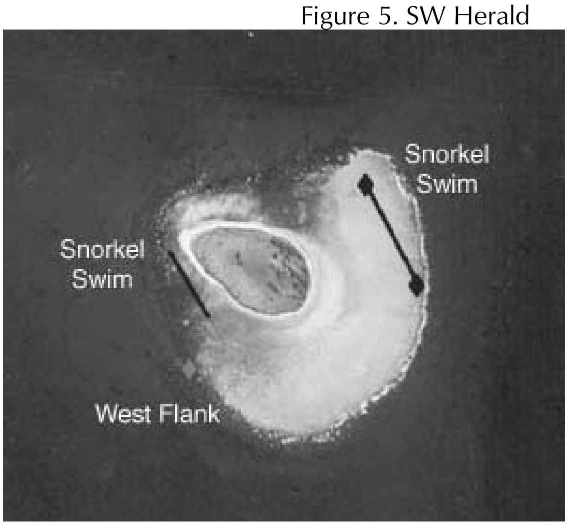


Figure 6. SE Magdelaine

Figures 2-6. Location of survey sites on each reef. Grey diamonds (◆) show sites where detailed fish and coral surveys were undertaken. White line shows path of manta tow and black line shows location of snorkel swims on each reef. Figure 4 also shows location of temperature loggers.

The isolation of these reefs precluded sampling of deeper habitats and therefore all results and discussion pertain to shallow water communities only.

Table 1. Survey sites from the Coringa- Herald National Nature Reserve.

Reef	Site #	Locality	Depth range
NE HERALD	1	West flank	1-12
	2	NE flank	1-12
	3	Reef flat gutter	1-6
	4	South flank	1-15
SW HERALD	1	NE flank	1-12
	2	Back	1-10
	3	South flank	1-12
	4	Front	1-12
CORINGA SW	1	NE flank	1-10
	2	Front	1-10
	3	Back	1-10
	4	West flank	1-8
CHILCOTT	1	NE flank	1-9
	2	Front	1-9
	3	Back	1-8
	4	West flank	1-12
MAGDELAINE SE	1	West flank	1-12

2.2 Fish and benthic communities

2.2.1 BENTHIC RAPID ASSESSMENT PROTOCOL (RAP)

A rapid visual assessment protocol (RAP) for reef benthic abundance and diversity developed by DeVantier (see DeVantier *et al.* 1998) was used as part of this survey. This method provided species level data and crude abundance estimates of the benthic communities.

The reef was relatively shallow at all survey sites. The maximum depth listed in Table 1 was usually the bottom, and the reef slope was gentle. Many of the back reef sites included large areas of flat sand substratum. Each survey started at the maximum depth and finished in the shallowest water and the diver searched all available habitats within the depth range. Total distance swum during each survey was 200-400 metres.

The overall abundance of combined hard corals, all soft corals, all sponges and all thallous algae were estimated on a five point scale (Table 2) at each site. There were two subdivisions within each ranking (eg 1- indicates 1-5% cover, 1+ indicates 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 accounted for by each species. 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 cover.

Table 2. 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%

An estimate was also made for each species of the proportion of colonies in three size classes:

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

Another estimate was made of the proportion of colonies of each species that were damaged in some way.

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 finer 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 50m haphazard 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 360^0 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 and can be viewed on the electronic version of this report.

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 between 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 3. The complete list of species found at each site is listed in Appendix 2.

Table 3. 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 the Coral Sea by two members of the AIMS team allowed for unbiased biogeographic comparisons of fish assemblage diversity between the Coral Sea and the GBR.

Fishes from a list of over 200 species, representing 10 families, were counted on three 50 m transects within each reef zone. (The tapes used in laying out these transects formed the left edge of the benthic video transects described above.) 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 observer bias, 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 communities

Fish and benthic communities of the GBR are strongly structured along environmental gradients largely linked to distance from the coast. It was therefore considered most appropriate to compare the Coringa-Herald National Nature Reserve (CHNNR) communities with those showing similar environmental conditions on the GBR. For this reason we chose six outer reefs from the Coral Sea margin of the GBR, which share similar latitudes and levels of exposure to wave energy as CHNNR reefs. Three of these reefs are off Cairns to the NW of the CHNNR, with the remainder situated off Townsville to the SW of the CHNNR (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 over 4 zones. Therefore, only the data from the NE flanks are directly comparable with the GBR.

As species richness varies with area surveyed, some data manipulation was required to allow direct comparisons between the GBR and the CHNNR. 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 total species richness across the three transects on the NE flank and other zones of the CHNNR reefs. Comparisons of abundance values between the GBR and CHNNR are based on mean density of individuals per zone. 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 both the benthic and reef fish communities were investigated by use of ordination plots of principal coordinates analysis. In each ordination, the Manhattan distance matrix was used. For comparisons between CHNNR and GBR reefs, species level fish transect data were used. These data were fourth root transformed to improve the multivariate normality of the data matrix. No multivariate comparison between the GBR and CHNNR benthic communities are presented, as the simple univariate plots adequately describe the differences between these communities at the taxonomic resolution afforded by the video transects.

Rapid visual assessment data for both the fish and benthic communities were used for comparisons of community structure within the CHNNR. The species level category data for the fish community were used with no transformation. The benthic community data were converted to presence absence (binary) data as only a very few species at single sites were recorded in abundance category 2, all other records being category 1 or 0.

Having determined any groupings from the ordination plots, an indicator species analysis was performed to investigate the species most influencing those groupings. Indicator values represent a combination of group fidelity and evenness in the following way (equation 1).

$$I = (\rho * \eta) / 100 \qquad (1)$$

where I is the indicator value, ρ is the proportion of sites where a particular species is recorded within a given group and, η is the proportion of the total abundance of the species recorded in that group. Dividing by 100 simply scales I to between 0 and 100. Hence, if a species occurs on all sites within a group and at no sites in any other group then I will be 100, and if a species does not occur on any site within a group the value of I will be a minimum 0. Categorical data were converted to category mid points prior to calculation of I.

2.5 Holothuria (bêche-de-mer), crown of thorns starfish (COTS) and giant clams (*Tridacna gigas*)

Thirteen species of holothuria were chosen for survey (Table 4). COTS were counted during the timed swims, manta tows and SCUBA searches. Any incidental sightings were also noted. Only one clam species (*Tridacna gigas*) was specifically targeted during these surveys however, none were observed.

Two habitats were selected for surveys of bêche-de-mer and *T. gigas* clams: the reef flat and the back reef. Each habitat required a different method to sample. The reef flats were sampled by snorkel swims and the back reefs sampled by manta tow. 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 shallow water reef flats. These reef flats were only accessible by small boats when the tide height was at least 1.5m above Lowest Astronomical Tide (LAT). Therefore, around the morning high tide, each observer censused a 500 m by 5 m belt transect, covering 2500 m^2 of substrate. The four observers swam side-by-side, from just behind the surf zone, towards the back of the reef (with the prevailing waves) approximately 10m apart. Observers recorded numbers of clams, COTS, and bêche-de-mer. 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 1-5m. The latitude and longitude of the start and end point of each transect were recorded (using a GPS) to assist in future surveys of the same area.

2.5.2 MANTA TOWS

The manta tow technique allowed a rapid, large-scale, assessment of benthic organisms on shallow substrata. This technique was used to survey back reef habitats. Two snorkel divers (observers) were towed at a constant speed (~2.5 knots= 1.35m/s), using two manta boards, one behind the other, with the front board attached, with 17 m of rope, to a small boat (see Bass and Miller 1996). The front observer visually assessed coral cover, numbers of clams and COTS, while the rear observer counted numbers of bêche-de-mer species from the list shown in Table 4. Each tow was 4 minutes duration. Data were recorded onto waterproof paper attached to the manta board. Each manta tow censused approximately a 325 m by 2 m transect (650 m^2). The length of tow was determined using a speed-time distance calculation and confirmed by recording the geographic position of the start and end point of each manta tow with a GPS, calculating the distance between these two points and then deriving an average distance covered for all tows. The transect width was estimated by the observers.

Table 4. List of bêche-de-mer species sampled and rationale for their selection.

Species	Common name	Rationale for inclusion
Holothuria nobilis	Black Teatfish	Coral Sea Fishery logbooks indicate species collected. Main target. Catch limit 1000kg.
Actinopyga mauritania	Surf Redfish	Coral Sea Fishery logbooks indicate species collected. Main target. Catch limit 10t.
Actinopyga other	Blackfish	Coral Sea Fishery logbooks indicate species collected
Holothuria atra	Lollyfish	Coral Sea Fishery logbooks indicate species collected. Main target.
Stichopus chloronotus	Greenfish	Coral Sea Fishery logbooks indicate species collected.
Thelenota ananas	Prickly Redfish	Coral Sea Fishery logbooks indicate species collected. Main target. Catch limit 20t.
Holothuria fuscogilva	White Teatfish	Coral Sea Fishery logbooks indicate species collected. Main target. Catch limit 4t.
Holothuria scabra	Sandfish	Coral Sea Fishery logbooks indicate species collected. Targeted in areas with high terrigenous input. Catch limit. 10t.
Stichopus variegates	Curryfish	Surveyed in Timor Sea MPAs. Present on GBR
Bohadschia argus	Leopardfish	Surveyed in Timor Sea MPAs. Present on GBR
Holothuria edulis	Pinkfish	Surveyed in Timor Sea MPAs. Present on GBR
Thelenota anax	Amberfish	Coral Sea Fishery logbooks indicate species collected. Surveyed in Timor Sea MPAs. Present on GBR
Holothuria leucospilota/ coluber		Surveyed in Timor Sea MPAs. Present on GBR

2.6 SCUBA search

SCUBA searches provided information on numbers of 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 2m belt (1m either side of the central tape measure) was visually searched along each 50m transect and data recorded for the categories shown in Table 5.

Table 5. Data collected using SCUBA search method.

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 on the transect.

2.7 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.

2.8 Historical Sea Surface Temperature (SST) data

SST data were obtained for the Coral Sea Region for the period March 1991 to April 2003. Data from 1991-1999 were generated from satellite imagery and provided average SST for the CHNNR (Hobday 2001). Data from 1/01/1999 to 18/05/03 were obtained from Willis Island. Sea temperature was measured in the Willis lagoon each afternoon using a hand thermometer (data provided by Gary Malpass, BOM). Mean monthly sea surface temperatures were then calculated to allow assessment of SST peaks, which may have contributed to coral bleaching in the CHNNR.

2.9 Deployment of temperature loggers

Two temperature loggers were deployed in the NE Herald Cay lagoon, in position 16° 56.752′ S, 149° 11.616′ E during these surveys, to redress the lack of SST data in the CHNNR. The loggers were located 50-70m off the beach rock on the SW shore of the cay in a depth of approximately 3m LAT. (Figure 7). This is an area of reasonably strong water flow and each logger was positioned on the NW side of a small bommie providing some protection. Four plastic star pickets were set up as two transits on the shore to assist a snorkeller swimming out from the beach in locating the loggers. The two eastern pickets line up on the inshore logger and the two western pickets line up on the logger 12m further seaward.

The data loggers instantaneously record sea temperatures every 30 minutes and it is intended that they be replaced with new loggers every 6 to 12 months, during routine turtle and bird surveys on NE Herald Cay. The loggers are double or triple calibrated against a certified reference thermometer after each deployment and are generally accurate to ± 0.2°C.

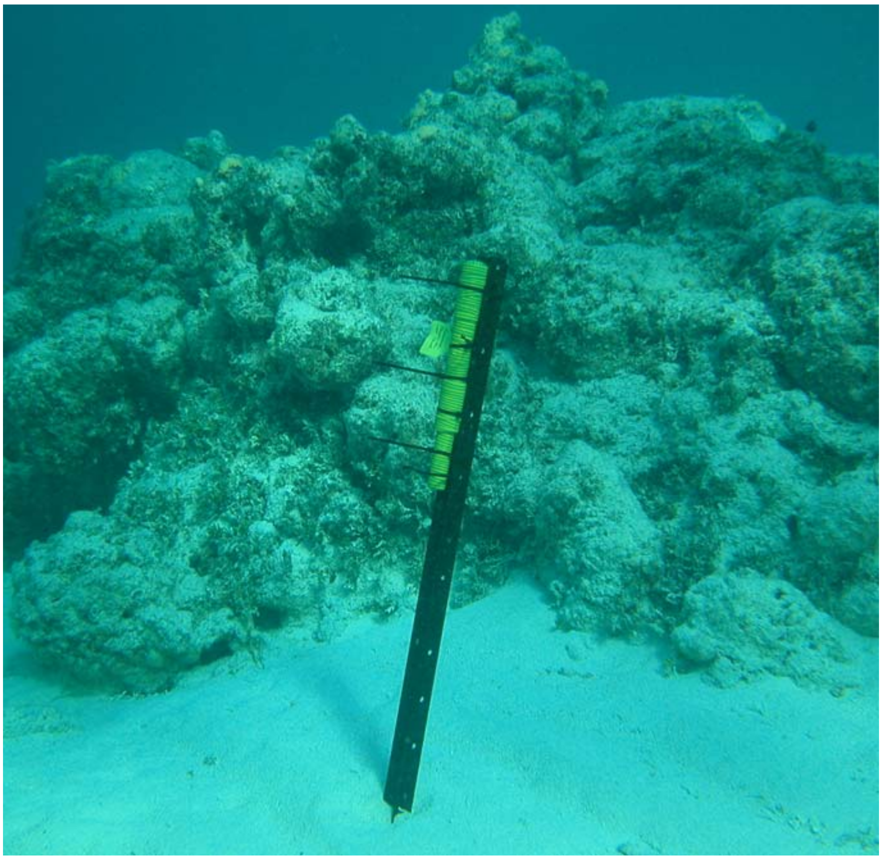


Figure 7. Logger in place at NE Herald Cay

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 by comparisons with similar data collected from adjacent GBR reefs. Secondly, spatial differences in assemblage structure and diversity among reefs within the Reserve are compared. Finally, the current "status" of the CHNNR communities is 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 GBR COMPARISONS

Sites on the NE flanks of CHNNR reefs have a dramatically lower cover of live hard coral (mean of 4.5% compared to 30.0%) and lower densities of reef fish (averages of 1030 vs 1842 fish ha^{-1} of selected large reef fishes and 9150 vs 17118 fish ha^{-1} of Damselfishes) than comparable NE Flank sites on the GBR reefs (Figures 8 and 9). Note also that the NE flanks had the highest average hard coral cover among the habitat zones surveyed on the Coral Sea reefs.

Figure 8 also contrasts the percent cover of the other major benthic groups between the GBR and the CHRNNR. The space occupied by high coralline algae and turf algae cover on the CHNNNR reefs, is replaced by hard coral and soft coral cover, on the GBR reefs. Note also that the cover of *Halimeda* on the Coral Sea reefs is high in comparison with the GBR reefs.

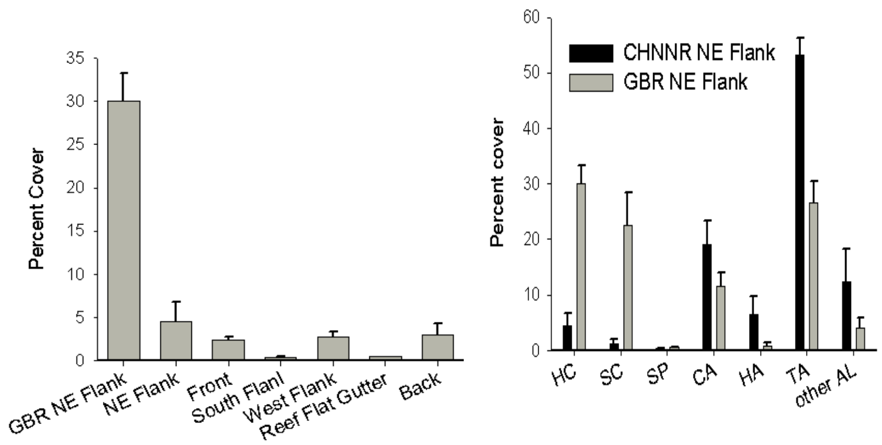


Figure 8. Comparison of Benthic Groups between NE flanks of CHNNR and GBR reefs. (HC: hard coral, SC: soft coral, SP: sponge, CA: coralline algae, HA: *Halimeda*, TA: Turf Algae, other AL: other algae). Error bars indicate Standard Errors.

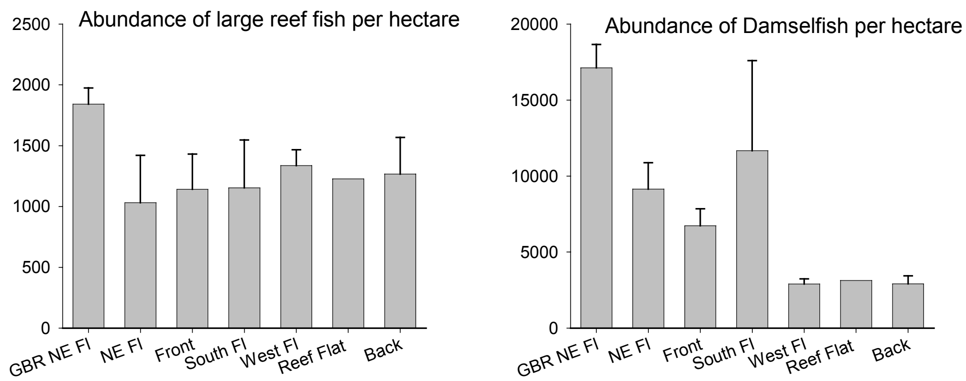


Figure 9. Reef fish abundance between the GBR NE flank and other reef zones in the CHNNR. Error bars indicate Standard Errors.

Total species richness on fish transect counts was also lower on CHNNR reefs with an average of 22 species per site on NE flanks, compared to 44 per site on GBR reefs (Figure 10). These patterns were maintained across all reef zones with GBR NE Flank communities showing higher coral cover, fish density and species richness than any reef zone on the CHNNR reefs.

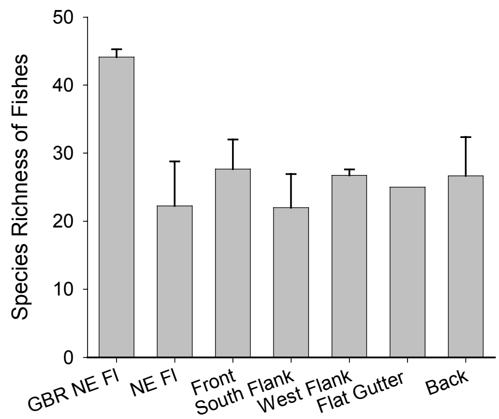
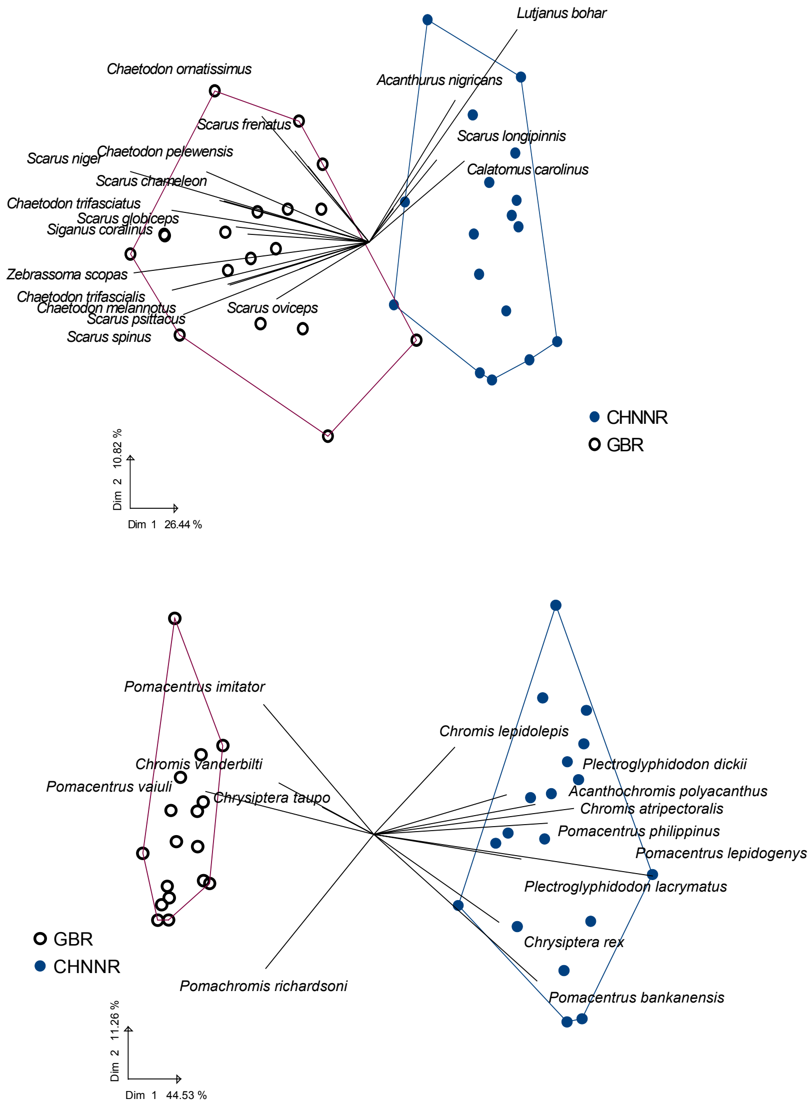


Figure 10. Fish Species Richness comparison between the GBR NE flanks and all zones in the CHNNR. Error bars indicate Standard Errors.

In addition to overall lower density and species richness the community structure of reef fish on CHNNR reefs is distinct from that observed on outer shelf GBR reefs. Ordination of transect data shows clear separation between GBR and CHNNR sites (Figures 11 and 12).



Figures 11 and 12. Biplots showing separation of fish communities between the GBR and the CHNNR in the first 2 dimensions of multivariate space. Top figure shows larger species surveyed on 5m wide transects while the bottom figure shows pomacentrid data. Species that characterise the difference between CHNNR and GBR are represented by vectors (as determined by Indicator Species Analysis). The percentage of variance explained by each dimension is indicated at the bottom left of each plot.

Pie charts (Figure 13) highlight the differences in proportions of higher taxonomic groupings. The large mobile reef fish community in the CHNNR has a higher proportion of surgeon fishes (Acanthuridae) and lower proportions of butterfly fishes (Chaetodontidae) and parrot fishes (Scaridae) compared to the GBR community. The damselfish community on CHNNR reefs is dominated by the genera *Chromis* and *Pomachromis,* though in each case this is due to a single species (*Chromis vanderbilti* and *Pomachromis richardsoni* respectively). The GBR damselfish community also has a high proportion of the genus *Chromis,* though several species are represented in high numbers. The genus *Pomacentrus* dominates the GBR community but is poorly represented on CHNNR reefs, with two abundant GBR species (*P. lepidogenys* and *P. philippinus*) absent from the Coral Sea. The species that characterise the differences between the two areas are represented on Figures 11 and 12 by vectors (as determined by indicator species analysis).

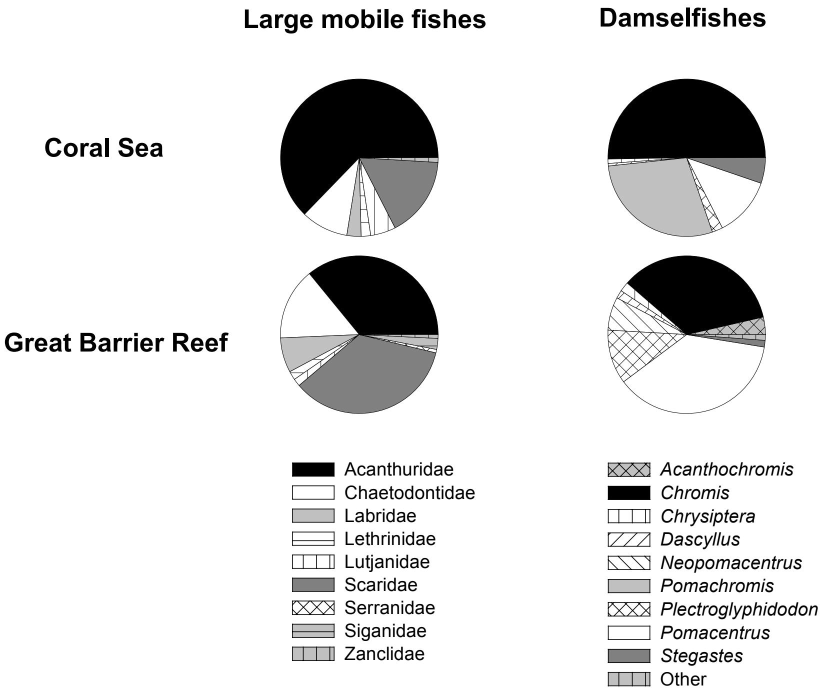


Figure 13. Differences in proportions of higher taxonomic groupings of fishes between the GBR and the CHNNR.

3.1.2 CHNNR COMPARISONS: BENTHOS

Characterisation of the CHNNR communities.

A clear separation in coral community structure was observed between the Herald Cays and the Coringa Bank reefs (Figure 14). The species that characterised these differences are shown as vectors (as determined by indicator species analysis). The Coringa Bank communities were distinguished by the presence of a number of *Acropora* spp. and *Portites lichen* while the Herald Cays reefs were characterised by *Fungia concina, Turbinaria messenterina,* and a small sub-massive *Porities* species.

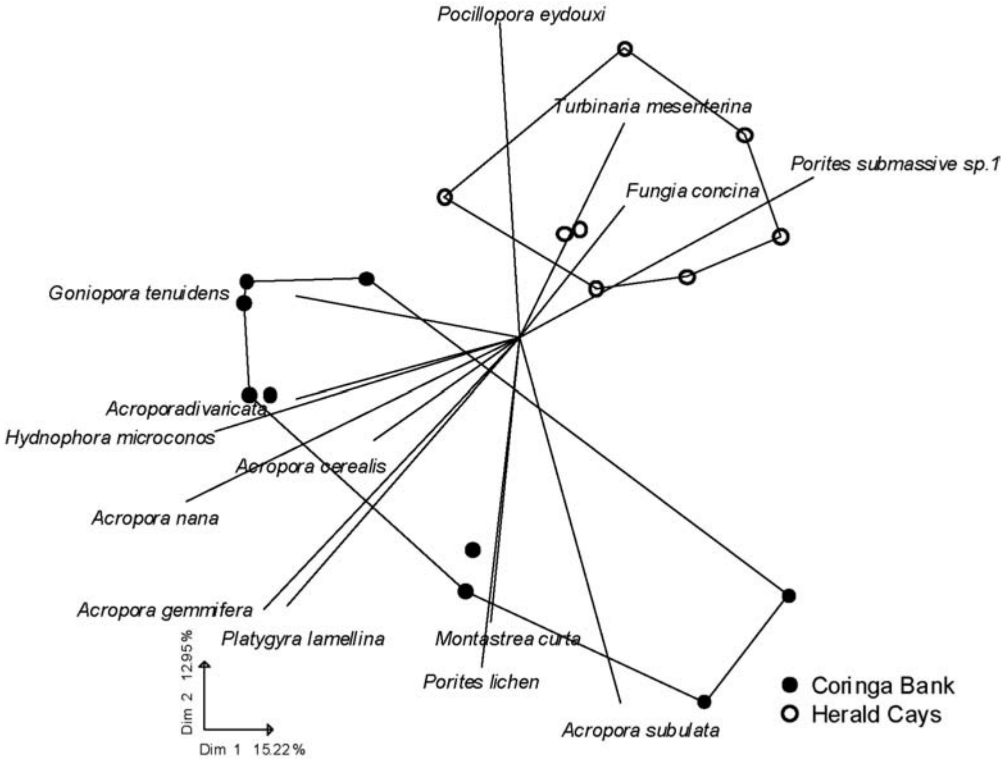


Figure 14. Biplot showing separation of coral communities between the Coringa Bank and the Herald Cays in multivariate space. Species that characterise the differences between the Coringa Bank and the Herald Cays are represented by vectors (as determined by Indicator Species Analysis). The percentage of variance explained by each dimension is indicated at the bottom left of each plot.

Table 6 shows a summary of the relative differences between the survey reefs. For example, the pocilloporid *Stylophora pistillata* was only common on Magdelaine Reef, and fungiid corals were only common on the two Herald Cay Reefs. The finger poritid *Porites cylindrica* was common at one back reef site on SW Herald and was not recorded anywhere else.

Acroporid and pocilloporid corals, where they were present, were more common in the upper few metres of the depth range surveyed. Sponges were generally more common in deeper water and were more foliose in sheltered sites. Exposed front reef sites were distinctive in having a smooth undulating hard substratum that was largely bare of corals (Figure 3 in Appendix 3). A low cover of small sponges and algae covered the bottom below about 5 m depth, with some small massive corals and a few widely scattered acroporid colonies. The shallow reef front substrate was either completely bare or had a patchy cover of acroporid and pocilloporid corals. In the sheltered flank and back reef sites, the terrain was more broken, with extensive sand areas amongst moderate to steep sided reef patches with many overhangs and caves. Stands of foliose sponges were common in these localities along with *Porites lichen* on Coringa, Chilcott and Magdelaine Reefs (Figure 8 in Appendix 3). A number of coral species were more abundant on vertical walls and under overhangs than on the open bottom. These included *Pavona explanulata, P. maldivensis, P. varians, Leptoseris mycetoceroides* and *Coscinarea columna*.

Table 6. Summary of relative differences between survey reefs

Species/Group	NE Herald	SW Herald	Coringa	Chilcott	Magdelaine
Hard coral	Low	Low	Low	Very low	Low
Soft coral	Low	Low	Very low	Low	Low
Sponges	Moderate	Low	High	High	Moderate
Algae	High	Moderate	Moderate	High	High
Pocillopora verrucosa	Moderate	Moderate	Moderate	Low	Absent
Stylophora pistillata	Very low	Very low	Very low	Low	Moderate in patches
Acropora gemmifera	Low	Low	Moderate	Moderate	Low
A. nana	Absent	Absent	Moderate	Low	Low
A. robusta	Low	Low	Moderate	Low	Absent
Porites massive	Moderate	Low	Low	Low	Low
P. murrayensis	Moderate	Low	Very low	Very low	Absent
P. cylindrica	Absent	High (1back site)	Absent	Absent	Absent
P. lichen	Absent	Very low	High (back reef)	High (back reef)	High (back reef)
Coscinarea	Low	Low	Low	Low	Moderate
Fungiids	Moderate	Moderate	Absent	Very low	Absent
Hydnophora	Absent	Low	Moderate	Moderate	Low
Turbinaria	Low	Low	Very low	Absent	Absent

3.1.2.2 Benthic diversity and abundance

Hard coral diversity was very low on CHNNR reefs with a total of only 99 species recorded in five days of diving on five reefs. The number of species recorded per site ranged from 17 to 45 with a mean of 34 (Table 8, Figure 15). Only 11 species were recorded at 75% or more of the sites (Table 7), with a further 15 species recorded at more than 50% of sites. This indicates that many of the coral species present in the CHNNR were rare. The complete list of species recorded is shown in Appendix 1.

Table 7. Hard Coral Species Recorded at nine or more of the 17 survey sites.

Coral species recorded at >13 sites	Coral species recorded from 9-12 sites
Pocillopora verrucosa	*Montipora grisea*
Astreopora myriophthalma	*Acropora anthocercis*
Porites massive	*Acropora gemmifera*
Coscinarea columna	*Porites murrayensis*?
Pavona varians	*Goniopora tenuidens*
Acanthastrea echinate	*Pavona duerdeni*
Favia species	*Pavona maldivensis*
Favia stelligera	*Symphyllia recta*
Platygyra sinensis	*Hydnophora microconos*
Leptastrea inequalis	*Favitea halicora*
Cyphastrea seralia	*Goniastrea pectinata*
	Goniastrea retiformis
	Platygyra pini
	Leptoria phrygia
	Leptastrea purpurea

The lowest average number of species per site (29.8) was recorded at NE Herald Cay (Figure 15). For the 4 reefs where 4 sites were sampled, total coral species numbers were very similar: Coringa, 61; Chilcott and NE Herald, 64; and SW Herald, 66 (Table 8).

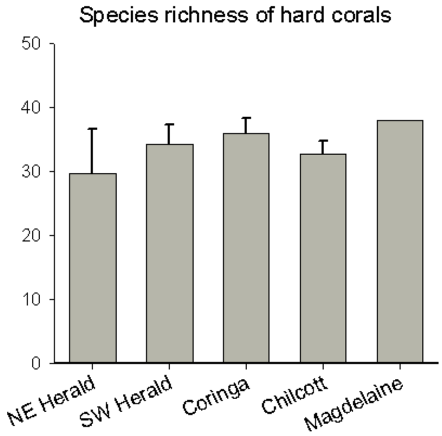


Figure 15. Hard coral species richness for each reef. Error bars indicate Standard Errors.

Estimates of hard coral cover obtained using the RAP method are shown in Table 8. They are in general agreement with the data obtained using the more quantitative video analysis method. However, when coral cover is low, the more qualitative RAP is likely to produce less precise estimates of cover. Consequently the video method estimates are referred to when interpreting fine scale differences in the cover of coral and other major benthic groups.

Table 8. Abundance and diversity of major benthic groups in the survey sites.

Reef	Total hard coral species Reef level	Site	Total hard coral species Site level	Hard coral cover	Dead standing coral	Soft coral cover	Algae cover
NE HERALD	64	1	41	1+	2-	1+	3-
		2	45	1+	2-	1-	3-
		3	17	1+	2+	1-	2-
		4	19	1-	1-	1+	3-
SW HERALD	66	1	44	1+	2-	1+	2+
		2	36	1+	2+	1-	2+
		3	27	1-	1-	1-	2+
		4	32	1-	3-	1+	1+
CORINGA	61	1	30	1+	1-	1-	1+
		2	37	1-	1-	1-	2+
		3	34	1+	2-	1+	2-
		4	42	1+	2-	1-	2+
CHILCOTT	64	1	30	1-	1+	1+	3-
		2	31	1-	1-	1+	3-
		3	34	1+	2-	1+	2+
		4	36	1+	1+	1+	2+
SE MAGDELAINE		1	37	1+	2-	1+	3-

Data from the video transect method showed that hard coral cover was very low on all reefs, ranging from 1.9% at Coringa to 3.7% cover at SE Magdelaine (Figure 16). The highest hard coral cover on any site was only 5.2% (SW Herald back).

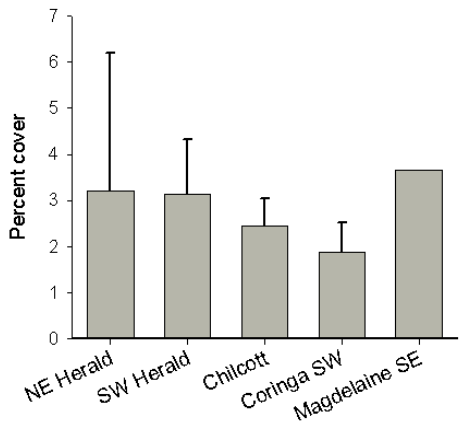


Figure 16. Percent hard coral cover on each reef surveyed in the CHNNR. Error bars indicate Standard Errors.

Soft coral cover was also very low at all the survey sites with less than 2% cover on any reef (Figure 17). A total of only nine soft coral species were recorded in the combined survey sites with *Sinularia* spp. being the most abundant.

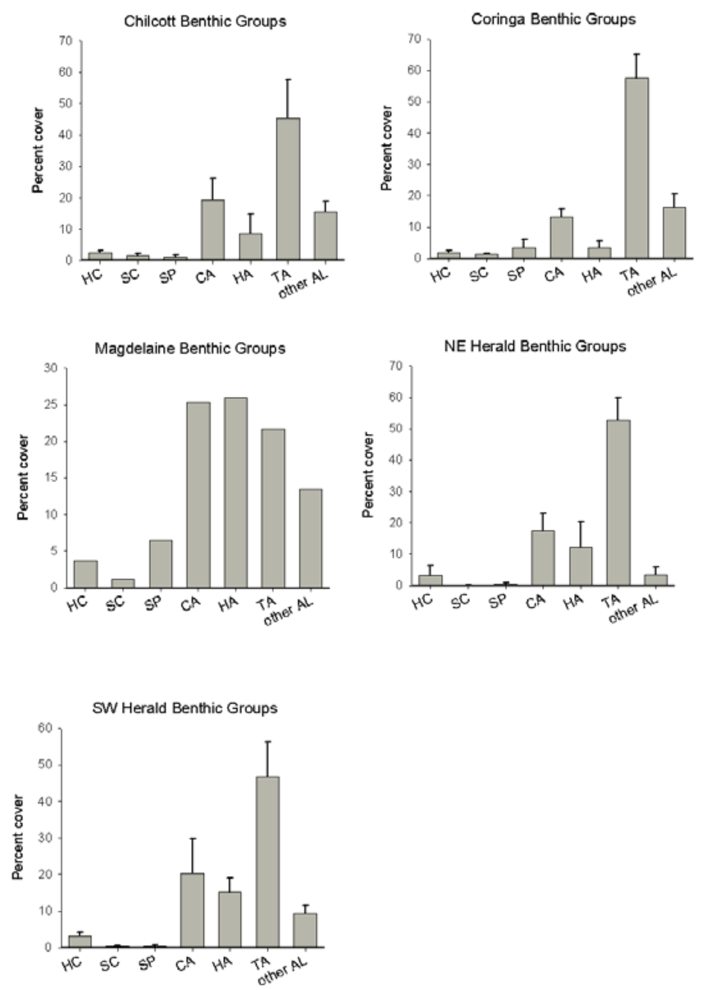


Figure 17. Benthic cover of major groups on each surveyed reef in the CHNNR. (HC: hard coral, SC: soft coral, SP: sponge, CA: coralline algae, HA: *Halimeda*, TA: Turf Algae, other AL: other algae). Error bars indicate Standard Errors.

Sponges were more abundant than hard corals on two of the 6 reefs (Figure 17). The maximum cover of sponges (6.5%) was found on Magdelaine Cay.

Several species of foliose dictyoceratid sponge were present at most sites. These sponges have a highly variable growth form and the taxonomy is not well understood (Bergquist *et al.* 1988). The most abundant of these species were *Phyllospongia papyracea, P. lamellosa* and *P. alcycornis*. Other sponges were also common, including *Dyscidea herbacea* and *Xestospongia*.

Thallous algae were also common at all sites (Table 8), especially *Halimeda* and an unknown green alga that formed extensive mats covered with a fine layer of sand. *Halimeda* cover ranged from 3.6% at Coringa to an impressive 26% at Magdelaine Cay (Figure 17).

Turf algae was the dominant feature on all reefs and ranged from 21.7% cover at Magdelaine to 57.6% at Coringa (Figure 17).

3.1.2.3 Size of coral colonies

In general, the size of each coral colony was typical for its species, but there were very few large colonies of any species. With the exception of a single, multi-headed massive *Porites* colony in the reef flat gutter site on NE Herald, there were very few colonies over a metre in diameter. Except for a few species that have a small maximum size,there were very few small colonies, and almost no new recruits less than 5 cm diameter.

3.1.2.4 Coral damage in the survey sites

Moderate numbers of dead standing coral colonies were present at all sites, as well as a large number of partially dead colonies (Table 8, Figures 7 & 9 in Appendix 3). Figure 18 shows SST data for the region and a clear spike in water temperature is apparent for 2002. SST anomalies for the GBR and the Coral Sea region (Dec 2001-Apr. 2002), derived from satellite analyses, indicate that the CHNNR was bathed regularly in hotter than average water over this time (Figure 19). Coral bleaching was clearly implicated as a major cause of damage to the hard corals on these reefs and may have been responsible for a marked reduction in live coral cover at all sites.

During the five day survey period, only 6 COTS were seen. One adult COT was observed on NE Herald during the timed fish counting, three adult COTS were observed while manta towing on the back of SW Herald and two adult COTS were observed at 18m during a 20 minute dive on the south wall of SW Herald. Coral mortality, resulting from COTS predation, was observed at these sites.

Drupella were only observed on the Herald Cay reefs. Only one site had more than 2 individuals (NE Flank, NE Herald: 33 *Drupella* at a density of 0.11/m^2).

Damage to hard corals from disease was only observed on a few colonies during this survey.

There was also a suggestion that storm generated wave action had damaged corals at some sites. At a few exposed reef front sites the substratum in shallow water looked as if it had been peeled off at some time in the past decade leaving a relatively smooth surface covered by algal turf with no corals or encrusting coralline algae (Figure 1 in Appendix 3). Figure 20 shows the cyclones that have passed in the vicinity of the CHNNR between 1979 and 2003. Five cyclones passed through the NNR in the 8 years prior to surveys by Ayling in 1985, 3 cyclones between Ayling's and Byron's surveys in 1997 and 1 major cyclone (T.C. Katrina) between Byron's and this survey. Tropical Cyclone Katrina passed through the centre of the CHNNR in January 1998. Katrina was a Category 2/3 cyclone generating hurricane force winds (sustained wind speeds 118 km/hr and over) during the time she passed through the Reserve. A Category 2 cyclone's strongest winds are destructive winds with gusts to 125 -170 km/h.

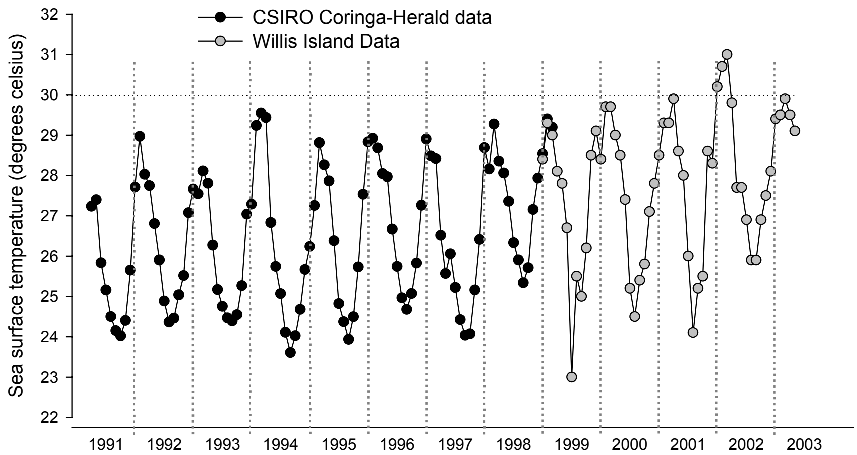


Figure 18. Mean monthly surface temperature data from the Coringa-Herald region (CSIRO data based on satellite imagery, March 1991 to February 1999) and Willis Island (data from manual readings taken daily from lagoon, December 1998 to April 2003).

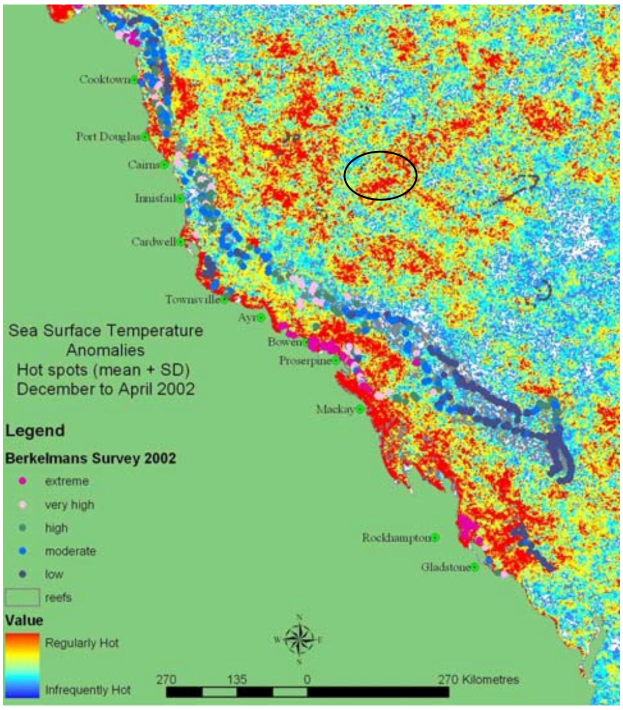


Figure 19. Bleaching surveys by Ray Berkelmans on the GBR in 2002 show a clear relationship between elevated SST and bleaching anomalies. The increased SST anomalies in the region of the CHNNR can be seen inside the oval.

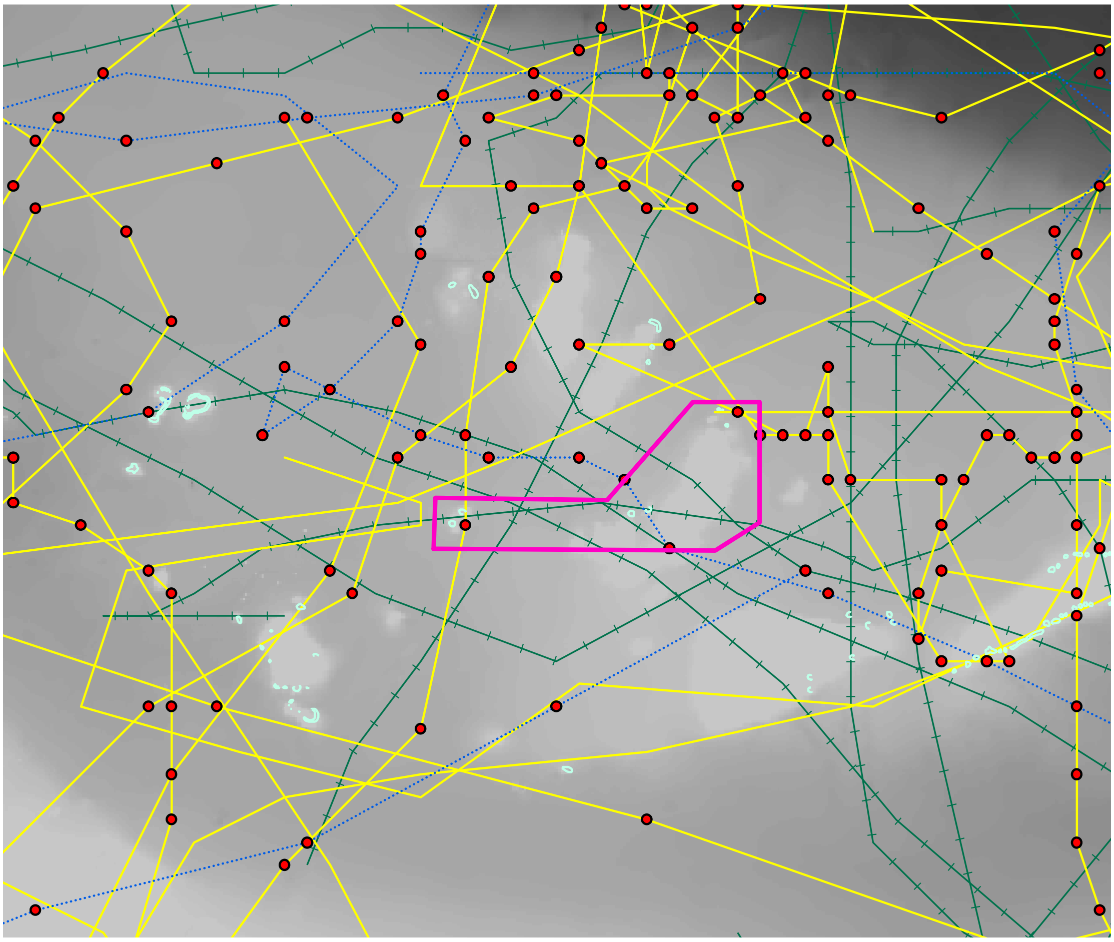


Figure 20. Cyclone Tracks from July 1979- May 2003. The location of the CHNNR is shown within the marked area. Tracks are coded in relation to the 3 benthic surveys completed in the CHNNR as follows: Green {train line}: 1979/1980 - 1983/84 (Pre Ayling), Yellow {line}: 1984/85 - 1996/97 (Post Ayling and pre Byron 1997) Blue{dashed line}: 1997/98 - 2002/03 (Post Byron and prior to this survey). Red dots on the lines indicate that the reported wind strength, where available, was greater than 20 m/s (37 knots).

3.1.3 CHNNR COMPARISONS: FISH

A total of 342 species of reef fish were observed on the five reefs visited. Nine of these species were absent from previous fish surveys (Ayling and Ayling 1985, Allen 1988 and Byron *et al.* 2001) and thus represent new records for the Coral Sea (Table 9). Appendix 2 provides a table of the species observed and recorded, their abundance and distribution within the sites surveyed.

Table 9. New records of fish species for the Coringa-Herald National Nature Reserve.

Family	Species
Apogonidae	*Apogon bandanensis* (Bleeker, 1854)
	Cheilodipterus artus (Smith, 1961)
Balistidae	*Pseudobalistes fuscus* (Bloch & Schneider, 1801)
Carangidae	*Caranx papuensis* (Alleyne & MacLeay, 1877)
	Scomberoides tol (Cuvier, 1832)
Mullidae	*Parupeneus barberinoides* (Bleeker, 1852)
Pomacentridae	*Chromis lineata* (Fowler & Bean, 1928)
	Pomacentrus chrysura (Cuvier, 1830)
Serranidae	*Epinephelus polyphekadion* (Bleeker, 1849)

Ordinations of the rapid assessment fish data show communities on the Herald Cays to be distinct from those on the three Coringa Bank reefs (Coringa, Chilcott and Magdelaine) (Figure 21).

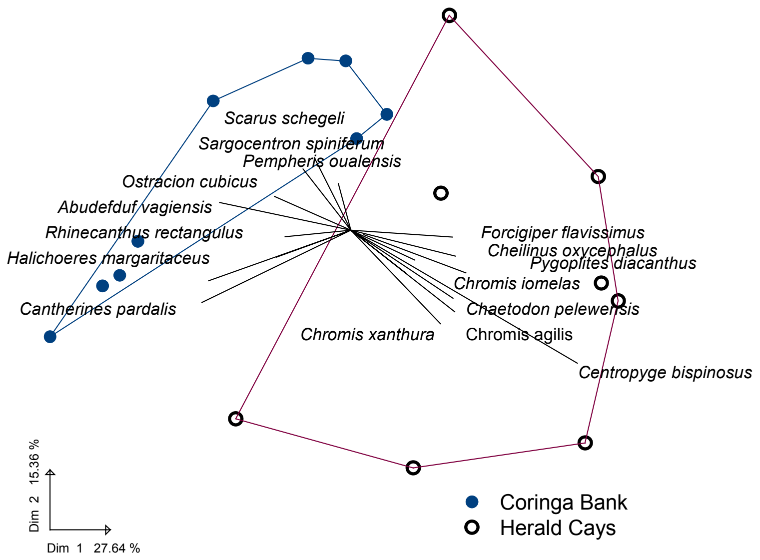


Figure 21. Biplot highlighting regional separation in the fish communities within the CHNNR in the first 2 dimensions of multivariate space. Species that characterise the difference between Coringa Bank and Herald Cays are represented by vectors (as determined by Indicator Species Analysis). The percentage of variance explained by each dimension is indicated at the bottom left of each plot.

Summary plots of overall abundance of large reef fish and damselfish from transect data (Figure 22) and tabulated species richness from the rapid assessment swims (Table 10) indicate higher abundance and species richness on the Herald Cay reefs compared to Coringa Bank reefs. At a finer scale, indicator species analysis highlighted species with disparate distribution between the two plateaus within the Reserve (Figure 21).

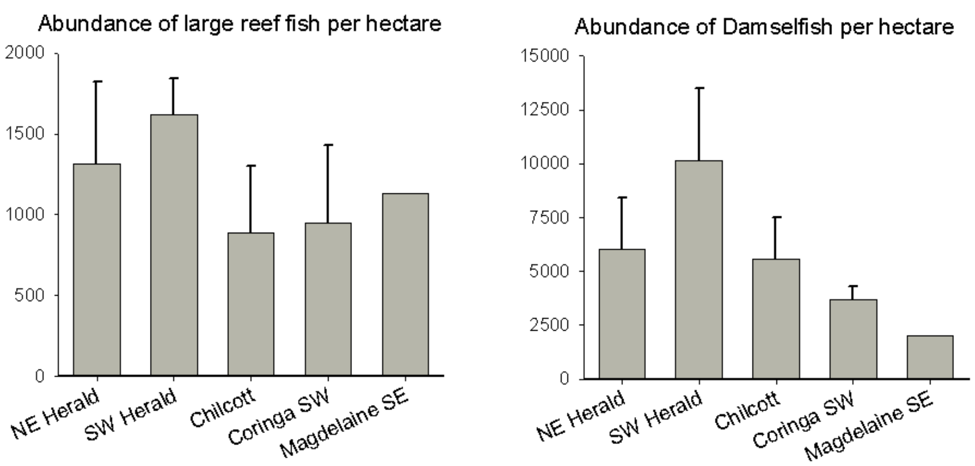


Figure 22. Fish abundance per hectare compared between reefs within the CHNNR. Error bars indicate Standard Errors.

Table 10. Species richness of fish accumulated over all timed swims at each reef (Swim Total) and over all observations including timed swims, transect counts and incidental observations during other activities (Reef Total). The grand total is the number of species observed over all reefs.

Reef	Back	Front	NE Flank	South Flank	West Flank	Flat Gutter	Swim Total	Reef Total
NE HERALD			113	95	89	113	156	223
SW HERALD	117	133	129	123			169	257*
CORINGA SW	96	91	79		110		129	183
CHILCOTT	89	78	65		105		128	187
MAGDELAINE SE					113		113	133**
						Grand Total	299	342

* 20 of these species were observed in greater than 15m, a depth not observed on other reefs. ** only one site was surveyed on this reef .

There were also clear differences in the fish communities inhabiting the zones exposed to high wave energy (NE flank, Front reef and South flank) compared with those in the more sheltered areas of the reefs (West flank, Back reef and Reef flat gutter)(Figures 9 and 23). In Figure 23, species, which differ most in their distribution between the exposed and sheltered zones (as determined by indicator species analysis), are shown as vectors. One of the features distinguishing the communities was that several small plankton feeders favoured the exposed zones, while algal grazers favoured the more sheltered areas.

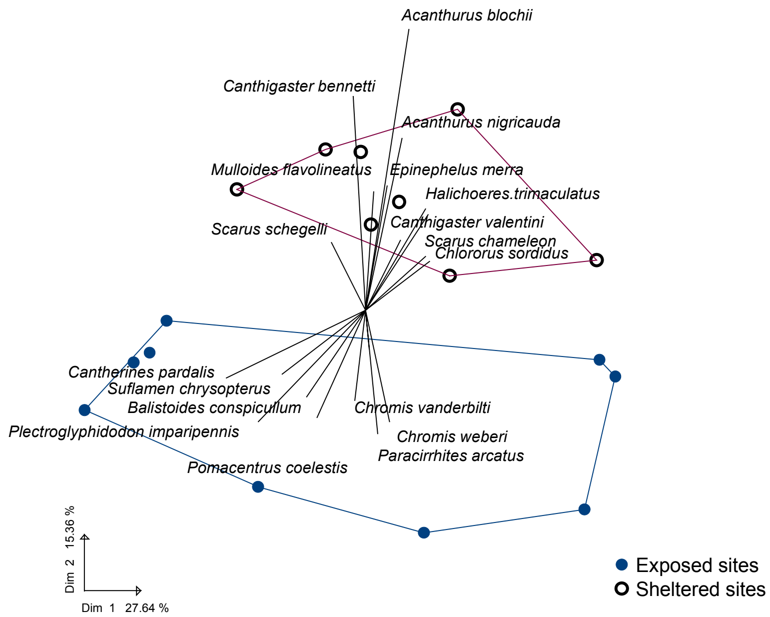


Figure 23. Multivariate biplot contrasting exposed and sheltered sites within the CHNNR in the first 2 dimensions of multivariate space. Species, which characterise the two groupings, are displayed as vectors (as determined by Indicator Species Analysis). The percentage of variance explained by each dimension is indicated at the bottom left of each plot.

Summary data on both benthic and fish communities for sites within reefs can be viewed on the multimedia version of this report.

3.1.4 TEMPORAL COMPARISONS WITH PREVIOUS SURVEYS

Previous benthic surveys were made on NE Herald and Chilcott in October 1984 (Ayling and Ayling 1985), and on NE Herald in June 1997 (Byron *et al.* 2001). Subsampling of these earlier data, to include similar survey areas allows some temporal comparisons to be made (Table 11).

Table 11. Comparison of present mean benthic cover estimates with surveys from 1984 and 1997. Early data are from studies done by Ayling and Ayling (1985) in 1984 and Byron *et al.* (2001) in 1997. Note that site positions are only approximately comparable and that no fronts were surveyed in 1997 due to strong winds. Numbers in parentheses are Standard Errors.

Reef	Year	No. Sites	Hard coral	Soft coral	Sponges
NE Herald	1984	5	13.6 (6.9)	3.7 (4.3)	1.6 (3.3)
	1997	3	20.0 (5.5)	3.2 (1.1)	2.8 (0.5)
	2003	**4**	**3.2 (5.2)**	**0.1 (0.2)**	**0.4 (0.7)**
Chilcott	1984	3	17.7 (15.0)	16.4 (8.9)	16.4 (16.9)
	2003	**4**	**2.5 (1.0)**	**1.5 (1.2)**	**1.0 (2.3)**

Hard coral cover decreased on both reefs between 1984 and 2003. Of the other major benthic groups, soft coral abundance declined over all years to very low current levels while sponges also declined between 1984 and 2003.

Hard corals varied considerably in cover between 1984 and 1997 while soft corals remained at similar levels of cover over this time frame. The cyclone information and the SST data both indicate disturbance events in the CHNNR between the 1997 and 2003 surveys (Figures 18-20).

Similar timed swim reef fish surveys to those used in this study were undertaken by Thompson in 1997, on several sites at NE Herald Cay (Byron *et al.* 2001). Qualitative comparison between the observed communities suggested that at three sites, for which timed swims were undertaken in 1997 and 2003, there had been a consistent decline in both overall abundance and species richness. This decline was most evident in species with strong associations to living coral, including several species of the families Chaetodontidae and Pomacentridae.

3.2 Bêche-de-mer

The habitats surveyed, the methods used and the area covered are shown for each reef in Table 12. A minimum of 0.5 ha. was surveyed in each habitat on each reef.

Only six of the 13 bêche-de-mer species groups (Table 4) were observed during surveys. They included the commercially important (*H. nobilis, A. mauritania, T. ananus,*) and, in commercial terms, less important *(H. atra, S. chloronotus, B. argus*).

Table 13 presents a comparison of bêche-de-mer densities between the CHNNR, and surveys conducted on the GBR and the Timor Sea Reserves. There have been no previous published surveys of bêche-de-mer densities in the CHNNR. The most detailed bêche-de-mer surveys in Australian tropical waters, were conducted by Benzie and Uthicke (2003), between 1998 and 2000. They visited 59 outershelf and midshelf reefs in the GBR. In general, bêche-de-mer densities were lower on the CHNNR than the GBR reefs. *H. atra* (lollyfish) was the exception with very high densities found on Chilcott (3414 ind. Ha $^{-1}$). Reference to the raw data indicates that this was due to extremely high numbers of individuals on three manta tows around the back reef area (raw numbers: 530, 855 and 364 per 4 min. tow). Most individuals were 15-20cm in length.

Direct comparison with data from the Timor Sea Reserves where the same species occur, suggests lower densities in the Timor Sea. Of note are the lower densities of the high value species, *H. nobilis*. These comparisons should be treated with caution because of the clumping behaviour of several of the species and the resulting high variation within reefs.

Table 12. Location of bêche-de-mer surveys in the CHNNR, showing reefs and habitats surveyed along with the area covered.

Reef	Survey method	Habitat	Area surveyed	Notes
Chilcott	Swim	Reef flat	1 ha	
Chilcott	Manta	Back reef	5200 m^2	Majority of *H. atra* animals on 3 tows average size 15-20cm.
Coringa	Swim	Reef flat	1 ha	
Coringa	Manta	Back reef	5200 m^2	
NE Herald	Swim	Reef flat	1 ha	
NE Herald	Manta	Back reef	5200 m^2	
SE Magdelaine	Swim	Reef flat	0.5 ha	Only two observers
SE Magdelaine	Swim	Back reef	0.5 ha	20 min swim. One person.
SW Herald	Swim	Reef flat	1 ha	
SW Herald	Swim	Sand cay back	1 ha	
SW Herald	Manta	Back reef	6500 m^2	

Table 13. Comparison of average densities of six holothurian species between the GBR and the Coringa-Herald Nature Reserve (ind. Ha^{-1},SD in brackets). Species contrasted are those surveyed and present in both regions. N/D indicates no data.

Location	Reference	*H. nobilis*	*H. atra*	*S. chloronotus*	*B. argus*	*A. mauritania*	*T. ananus*
Reef flat, 26 Outer shelf reefs GBR	Benzie and Uthicke (2003)	10.84 (9.13)	83.47 (166.57)	28.71 (55.33)	4.11 (4.88)	Not counted	1.22 (5.30)
Reef flat, 33 Mid shelf reefs GBR	Benzie and Uthicke (2003)	6.07 (8.60)	244.78 (275.65)	115.86 (163.78)	5.75 (9.07)	Not counted	0.74 (2.51)
Reef flat, 2 Outer shelf reefs GBR	Hammond *et al.* (1985)	1.25	88.75	0	0	7.5	N/D
Back reef, 2 Outer shelf reefs GBR	Hammond *et al.* (1985)	2.5	0	22.5	22.5	15.0	N/D
Reef flat, Cartier Reef, Timor Sea	Smith *et al.* (2002)	0	8.4	4.2	0	0	0
Reef flat, Ashmore Reef, Timor Sea	Smith *et al.* (2001)	0.71	96.7	18.3	0	0	0
Reef flat, 5 reefs Coringa-Herald NNR	This report	1.60 (3.58)	21.8 (21.8)	0.60 (1.34)	0.20 (0.45)	0	0
Back reef, 5 reefs, Coringa-Herald NNR	This report	6.04 (9.68)	641.86 (1414.40)	14.80 (24.40)	4.44 (2.68)	1.44 (2.35)	5.9 (8.23)

Within the CHNNR, the high value *H.nobilis* was present on 4 of the 5 reefs with the highest density recorded on Coringa (25 ind. Ha^{-1}). No *H. nobilis* were recorded on NE Herald and the reef flat on this reef had extremely low densities of all bêche-de-mer with only one *B. argus* recorded during 1ha of surveying. Tables 14 and 15 show the densities present for each of these species on each reef for both habitats surveyed.

Table 14. Average density of six holothurian species on reef flats (ind. Ha^{-1} ,SD in brackets) on each reef surveyed.

Reef	*H. nobilis*	*H. atra*	*S. chloronotus*	*B. argus*	*A. mauritania*	*T. ananus*
Chilcott	8 (8.6)	45 (8.9)	3 (2)	0	0	0
Coringa	0	42 (31.1)	0	0	0	0
NE Herald	0	0	0	1 (2)	0	0
SE Magdelaine	0	22 (8.5)	0	0	0	0
SW Herald	0	0	0	0	0	0

Table 15. Average density of six holothurian species in back reef habitat (ind. Ha^{-1} ,SD in brackets) on each reef surveyed. The data for SE Magdelaine Cay are from one 20min swim.

Reef	*H. nobilis*	*H. atra*	*S. chloronotus*	*B. argus*	*A. mauritania*	*T. ananus*
Chilcott	3.9 (7.1)	3414.4 (5035.5)	61.5 (96.9)	7.7 (21.8)	1.9 (5.4)	0
Coringa	25.0 (24.6)	9.6 (11.4)	0	5.8 (8.0)	5.8 (16.3)	0
NE Herald	0	0	0	5.8 (8.0)	0	13.5 (17.3)
SE Magdelaine	2	10	14	0	0	0
SW Herald	1.5 (4.9)	20.0 (20.6)	3.1 (9.7)	4.6 (7.4)	0	18.5 (23.8)

4 DISCUSSION

4.1 Fish and coral communities

The Coral Sea reefs within the CHNNR are small isolated reefs on the Coral Sea Plateau between 220 and 320 km from the outer edge of the GBR. The outstanding feature observed during these surveys was the dramatically low cover of live hard coral. Comparisons with a number of GBR offshore reefs revealed a nearly 7-fold difference in cover (GBR 30%: 4.5% NE flanks CHNNNR). The only GBR location, with coral cover as low as that recorded in the Coral Sea during the present survey, is Green Island off Cairns (Sweatman *et al*. 2001). Here, extensive COT grazing in the late 1990s, and recent bleaching damage, have reduced coral cover to less than 5% (AIMS Reef Monitoring 2003).

This observation raised the question of whether coral cover has always been low in this region, or whether recent impacts have markedly lowered coral cover. Comparisons with earlier surveys conducted in the CHNNR indicated historically low levels of hard coral cover in the Reserve with a maximum of 20% cover in 1997 and then a dramatic decline to the current level of less than 5%. During our surveys there was strong evidence of bleaching mortality of hard corals from a 2002 bleaching event. In addition, there was a small amount of on-going grazing mortality at some sites from both COTS and *Drupella,* and a suggestion of storm wave damage at a few exposed sites. These observations are supported by the additional information presented in this report showing significant cyclone activity and increased water temperatures, which are likely to have caused coral mortality through wave action and coral bleaching respectively. This has occurred since the 1997 coral surveys of Byron *et al.* (2001). The evidence for the 2002 bleaching event is strongly supported by data from Wakeford (unpublished report, 2002) who, in 2002, reported devastation to the coral communities of Flinders Reefs, which lie approximately 100km southwest of Herald Cays. Wakeford (2002) reported that bleaching began in January 2002 and that by August 2002, live coral cover had been reduced from around 70-80% to 5-10%.

Hard coral diversity was also very low in the CHNNR. The mean number of species recorded per site was 34, and the mean species per reef (excluding Magdelaine where only one site was surveyed) was 64. On GBR reefs, where comparable data are available, diversity levels were 1.5-2.3 times those in the Coral Sea (Ayling and Ayling 2003, Veron 1987).

The reef fish assemblage showed a similar pattern of low diversity and density when compared to assemblages on the GBR. It seems likely that these differences are partly related to the dramatic differences in hard coral cover discussed above, with many species in the target list having strong affinities to hard coral. The relative lack of hard coral in the CHNNR may have precluded successful settlement or subsequent survival of these species, even if they were available as recruits. For example, in the southern GBR three dominant fish families (Chaetodontidae, Scaridae and Pomacentridae) suffered major reductions in diversity and abundance following severe storm damage (Sweatman *et al.* 2001). It is noteworthy that proportional representation of these three taxa was lower on CHNNR reefs than on the GBR.

Recovery of severely damaged coral communities relies mainly on recruitment of larvae via ocean currents from outside the local reef, although a few species such as pocilloporids brood their larvae and can recruit locally. Currents in the CHNNR run predominantly to the west under the influence of an offshoot of the South Pacific Equatorial Current, although there is likely a superimposed drift to the NW during episodes of strong SE wind and some southward movement in summer (Pickard *et al.* 1977). This suggests that recruitment of corals from the rich GBR reefs to the west is not probable, and that recruiting larvae could only be derived from scattered reefs in the Coral Sea to the south-east and the north. The low coral recruit numbers recorded during this survey suggest that influx of larvae is sporadic and infrequent and this, in combination with regular severe disturbance, is considered responsible for the low abundance and diversity of corals observed.

The structure of reef fish assemblages on CHNNR reefs are unique from those observed anywhere on the GBR, even taking into account the likely disturbance effects discussed above. Many species common to Coral Sea reefs, are rare or absent from similar habitats on the GBR (ie. *Chrysiptera taupou, Pomacentrus imitator* and *Pomachromis richardsoni*), while some particularly abundant species on the GBR are likewise very rare or absent on Coral Sea reefs (ie. *Pomacentrus lepidogenys and Pomacentrus phillipinus*).

The difference in assemblage structure between GBR offshore reefs and the CHNNR reefs is consistent with the extension of a well documented ecological gradient which sees community structure shift across the GBR with distance from the Queensland coast (Williams 1991). Presumably this gradient is partly a response to shifts in water mass chemistry, as coastal influence gives way to nutrient poor waters of the Coral Sea, though there are likely a myriad of interacting physical and biologically processes involved in creating and maintaining this gradient. The oceanographic setting of the CHNNR likely limits sources of fish recruitment to the CHNNR reefs as described above for coral recruitment. Furthermore, it is almost certain that this oceanographic isolation has resulted in the unique nature of the communities observed.

Within the CHNNR, finer scale structure of the fish communities is evident at two scales. The assemblages on the Herald Cays are more diverse and show higher abundance than reefs situated on the Coringa Bank. This is also reflected in the different coral communities. It is possible that this separation is a finer scale example of oceanographic setting as mentioned above. The Herald Cays are situated downstream (40km west) of the recruitment pool offered by populations on the Coringa Bank and as such may benefit from a one way transport of recruits.

Within each reef there are obvious differences in community structure between the exposed and sheltered habitats. This zonation of assemblages is typical of coral reef faunas in general and simply reflects preferred habitat of the constituent species.

The fish and coral communities of the CHNNR 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. The low diversity and rarity of many species, in both the fish and coral communities, is especially concerning with recent research concluding 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).

4.2 Bêche-de mer

This report represents the first published bêche-de-mer surveys in the Reserve and consequently it is difficult for historical comparisons to be made.

However, during the 1985 fish and coral surveys (Ayling and Ayling 1985) one of the authors (Tony Ayling) observed large numbers of *H. atra* on the back reef of Chilcott Islet and laid out three 10x1m transects to count them. He recorded 41, 46 and 83 respectively giving an average density of 56,666 ind/ha. (Ayling, unpublished data). These counts were only made because of the high densities observed at the time, however, it is interesting that the highest densities of bêche-de-mer observed during these surveys were from the back reef habitat of Chilcott Islet and were also *H. atra*. Densities were a lot lower (3,414.4 ind. ha^{-1}) during these surveys, though this likely reflects the increased sampling area and the clumping nature of the species. Conand (1994) reports that *H. atra* is the most common species in the Pacific region and that densities of several thousand per hectare have been reported in some atoll lagoons while a maximum density of 520,000 ind. ha^{-1} has been reported for this species in the Marshall Islands (Laurence 1980 in Uthicke 1996).

The waters surrounding the CHNNR support a bêche-de-mer fishery which operates on the other large reef systems in the Coral Sea, including Flinders Reef, Holmes Reef, Osprey Reef, Cato Reef and Wreck Reef. All the bêche-de-mer species observed inside the CHNNR have previously been recorded in the logbooks of the commercial fishers outside the park (Hunter *et al.* 2002). Other areas in Australia, which support a bêche-de-mer fishery, have been overexploited in recent years (Torres Strait: Skewes *et al*. 1998, Timor Sea; Skewes *et al*. 1999; and Queensland East Coast: Uthicke and Benzie 2001). There has recently been an assessment of the stocks in the Coral Sea fishery and it is clear that the stock has declined in recent years (54.4 t in 2000 to 29.7 t in 2001). Most species are under pressure with the *H. nobilis* catch declining from 8.4t in 2000 to 2.1 t in 2001 with a corresponding marked decline in catch per unit effort (CPUE) (Hunter *et al*. 2002). This raises serious concern about the sustainability of this species. Of the commercially valuable and targeted bêche-de-mer, *H. nobilis* (5.9 ind. ha^{-1}) had the highest densities inside the CHNNR. This highlights the importance the CHNNR may play in the protection and sustainability of threatened species.

There are currently 2 permits for the Sea Cucumber fishery in the waters surrounding the CHNNR and it is relevant that both permit holders in this fishery have an Integrated Computerised Vessel Monitoring System (ICVMS) fitted on board their vessels which allows their location to be determined at all times whilst they are at sea. This dramatically reduces the possibility for illegal fishing of bêche-de-mer by licensed operators.

5 RECOMMENDATIONS

It is clear that reefs in the Coral Sea are under significant pressure, most probably from the effects of cyclones and, in more recent times, coral bleaching. Bêche-de-mer are also under increased pressure as evidenced by the decline in the catch rates outside the CHNNR. This highlights the importance of managing a proportion of these reefs as strict nature Reserves (CHNNR and Lihou Reef NNR) in an attempt to maintain the long-term ecological viability of these habitats, ecosystems, and native species, by preventing additional human impacts. This is a key objective of the management plan for the CHNNR and Lihou Reef NNR.

Several key recommendations resulting from these recent studies are:

- **Repeat this programme of monitoring of the CHNNR 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.

- **Provide support for fish, coral and bêche-de-mer surveys of Lihou Reef NNR**.
  There is evidence that LRNNR may provide a significant source of recruitment for the CHNNR and therefore the status of this reef system may impact on the health of the CHNNR.

- **Support and encourage AFMA to continue to increase the use of ICVMS on other vessels in the Coral Sea Fishery, in particular the aquarium, and line fisheries.**
  This will help ensure protection for the CHNNR; preventing illegal fishing in the CHNNR by licensed operators.

- **Liaise with AFMA to try to ensure stock assessments of the Coral Sea fisheries (especially the bêche-de-mer fishery) and the CHNNR communities use similar methods.**
  Direct comparisons can then be made allowing for an assessment of the effectiveness of the NNR.

- **Continue support for the temperature logging data collection and routine monitoring**.
  This will improve understanding of the CHNNR and the longer term effects of the 2002 bleaching event.

- **Approach BOM and request installation of temperature loggers in the Willis Island lagoon**.
  These could be changed over every three-six months during supply ship visits and would provide a valuable addition to the other meteorological data collected.

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APPENDIX 1 : LIST OF CORAL SPECIES RECORDED IN THE CHNNR

Note: Only a single site surveyed at Magdelaine, four sites at the other four reefs. A total of only 99 species recorded altogether.

REEF:	**Herald NE**				**Herald SW**				**Coringa SW**				**Chilcott**				**Magdelaine**
Site #	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**
Total hard coral abundance	1+	1+	1+	1-	1+	1+	1-	1-	1+	1-	1+	1+	1-	1-	1+	1+	1+
TOTAL HARD CORAL SPECIES	**41**	**45**	**17**	**19**	**44**	**36**	**27**	**32**	**30**	**37**	**34**	**42**	**30**	**31**	**34**	**36**	**37**
Pocilloporidae																	
P. verrucosa	1	3		1	2	1	3	1	2	2	1	1	1	1			
P. eydouxi	1	1		1	1			1	1				1				
Stylophora pistillata				1			1			1			1	1	1		1
Acroporidae																	
Montipora encrusting					1					1	1	1			1		1
M. tuberculosa					1												
M. foveolata		1			1		1	1			1				1	1	1
M. grisea	1	1		1	1	1	1		1		1	1	1			1	1
M. informis					1							1					
M. verrucosa		1			1	1											
M. foliosa					1							1					
Acropora anthocercis					1		1		1	1	1	1	1	1	1		1
A. austera		1			1					1						1	
A. cerialis											1		1	1	1		
A. clathrata						1									1		
A. cytherea										1							
A. digitifera								1	1	1	1	1					1
A. dicaricata									1	1				1			
A. donei										1							
A. florida		1															
A. gemmifera				1	1				1	1	1	1	1	1	1	1	1
A. humilis	1	1															
A. hyacinthus										1							
A. listeri		1						1							1		
A. longicyathus					1												
A. monticulosa		1			1			1	1		1	1		1			
A. nana									1	1	1	1		1			1

REEF:	Herald NE				Herald SW				Coringa SW				Chilcott				Magdelaine
Site #	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**
A. nasuta	1	1			1				1	1	1	1					1
A. palifera					1		1				1	1			1	1	1
A. paniculata		1			1								1		1	1	
A. polystoma		1			1						1		1	1			
A. robusta		1			1				1	2	1			1			
A. subulata												1			1	1	1
A. tenuis	1								1				1			1	1
A. valida		1															
A. verwayi								1				1			1	1	1
A. vaughani																1	
Astreopora myriophthalma	2	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Poritidae																	
Porites massive	1	2	3	1	1	1	1	1	1	1	1	1	1	1		1	1
P. murrayiensis?	2	1	1	1	1	1	1					1				1	
P. cylindrica						3											
P. nigrescens														1		1	
P. lichen								1			2	2		1	3	3	2
P. vaughani		1												1	1	1	
Goniopora somaliensis											1	1					1
G. tenuidens	1					1	1		1	1	1	1	1	1			
Siderasteridae																	
Psammocora contigua			1														
P. superficialis								1									1
Coscinarea columna	1	1	1	1	1		1	1		1	1	1		1	1	1	2
C. wellsi										1							
Agariciidae																	
Pavona duerdeni		1			1	1	1		1	1				1	1		1
P. explanulata	1		1		1											1	
P. maldivensis	1	1	1			1					1	1			1	1	1
P. varians	1	1	1		1	1	1	1	1	1		1			1	1	1
P. venosa	1																
Leptoseris mycetoceroides		1				1											
Gardineroseris planulata												1					
Coeloseris mayeri		2				1										1	1

REEF:	Herald NE				Herald SW				Coringa SW				Chilcott				Magdelaine
Site #	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**
Fungiidae																	
Fungia danai	1																
F. concinna	1					1		1									
F. scutaria					1	1									1		
Herpolitha limax	1							1									
Sandalolitha robusta	1	1			1	1	1										
Oculinidae																	
Galaxea fascicularis		1			1			1						1			
Pectiniidae																	
Echinophyllia aspera						1				1					1		
Mussidae																	
Acanthastrea echinata	1	1	1	1	1	1	1	1	1	2	1	1	1	1			1
A. lordhowensis										1							
Lobophyllia hemprichii		1			1	1						1			1	1	
Symphyllia recta	1	1		1	1			1	1		1	1	1	1			1
Merulinidae																	
Hydnophora exesa											1	1	1				
H. microconos					1			1	1	1	1	1	1	1			1
Scapophyllia cylindrica	1																
Faviidae																	
Favia favus													1				
F. laxa			1		1								1				
F. species	2	1	1	1	2	2	1	1	1	1	2	1	1	1	1	1	1
F. stelligera	1	1	1	1	1	1	2	1	1	1	1	1			1	1	1
F. speciosa	1																
Favites abdita	1	1				1	1	1		1				1			1
F. halicora			1			1	1	1	1	1		1	1	1	1		1
F. complanata	1	1															
F. chinensis									1								
Goniastrea pectinata	1		1		1	1	1	1		1	1	1			1	1	1
G. retiformis	1	1	1		1	1	1						1	1	1		1

REEF:	Herald NE				Herald SW				Coringa SW				Chilcott				Magdelaine
Site #	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**
Platygyra daedalea		1		1					1	1	1						
P. lamellina									1	1	1	1	1	1	1	1	
P. pini	1	1		1		1	1	1	1		1	1	1	1			
P. sinensis	1	1		1	1	1	1	1		1	1	1	1	1	1	1	1
Montastrea curta	1								1	1		1	1		1	1	1
M. valenciennesi				1	1	1			1	1			1			1	1
Leptoria phrygia	1	1	1			1	1	1	1			1			1	1	
Oulophyllia crispa						1										1	
O. bennettae	1					1		1				1			1	1	
Leptastrea inequalis	1	1		1	1	1	1	1		1	1	1	1	1		1	1
L. purpurea	1	1	1		1	1	1	1				1	1	1		1	
Cyphastrea serailia	1	1	1	1	1	1		1	1	1			1		1	1	1
C. decadia	1																
Echinopora lamellosa	1	1					1					1			1	1	
Dendrophylliidae																	
Turbinaria mesenerina	1	1			1	1		1			1						
T. reniformis	1																
T. stellulata		1															
Soft coral abundance	1+	1-	1-	1+	1+	1-	1-	1+	1-	1-	1+	1-	1+	1+	1+	1+	1+
Sarcophyton	1	1		1	1		1	1		1		1				1	
Sinularia	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1
Lobophyton		1		1	1			1	1	1		1	1	1		1	1
Eflattounaria	1	1	1			1	1				1				1	1	
Briareum	1			1	1	1	1	1		1			1		1	1	1
Xenia										1	1	1		1	1	1	1
Isis		1		1	1		1	1	1	1			1	1			1
Rhytisma				1													
Zoanthid											1						
Sponge abundance	2-	2-	2-	1+	1+	1+	1+	1-	2+	3-	2-	3-	2+	2+	3-	2+	2-
Algal abundance	3-	3-	2-	3-	2+	2+	2+	1+	1+	2+	2-	2+	3-	3-	2+	2+	3-

APPENDIX 2. List of Fish Species Recorded in the CHNNR

	NE Herald					SW Herald					Coringa (SW)					Chilcott					Magdelaine	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
Acanthuridae																						
Acanthurus auranticavus					T																	
A. blochii	3		4			3	1		3		3	2	3	4				3	3		4	
A. dussumieri	3	3	2			1	2		3				2								1	
A. guttatus									3						P							
A. lineatus	3	3		3		4	2	4	4		3	1	4	3			3	3	3		4	
A. maculiceps		2							1					1					1			
A. nigricans		4		3		3		2	4					3				1	3			T
A. nigricauda			2			1	2	2	1				3	3				2	2		3	
A. nigrofuscus	5	4	4	3		5	2	4	3		5	4	4	5		4	5	4	4		4	
A. nigroris	2			3					4									1			4	
A. olivaceus			1	4		2						3						1				
A. pyroferus					P	1	3		3													
A. thompsoni										P												
A. triostegus										P	4									P	2	
A. xanthopterus			2				1											1				
Ctenochaetus striatus	5	5	3	3		5	3	5	5				3	4				4	4		4	
C. strigosus														1								
Naso annulatus			2									2				2	1	1	1			
N. brachycentron		1																				
N. brevirostris						1		3				2		2					1			
N. caesius		2																				
N. hexacanthus							1															
N. lituratus	2	2		3		3	3	3	1		1	1		1			1					
N. tuberosus	2	3	4				3		3		2		2	3		2	3	3	1		3	
N. unicornis	2	2	2	3		2		2	2		3	2	1	1		2	3				2	
N. vlamingii										P				1								
Zebrasoma scopas	3		3				3	2	1									1				
Z. veliferum	2	2	2			3	3	2	2				2	2				2			2	
Apogonidae																						
Apogon angustatus				1														1	1			
A. bandanensis							1															
A. kallopterus				1		2						1	2				1					
A. novemfasciatus												1										
A. properupta			3									1	4				2				2	
A. taeniophorus					P							2	2	1			1					
Cheilodipterus artus							1															
C. macrodon						1							1	2							3	
C. quinquelineatus			1				3							1								
Aulostomidae																						
Aulostomus chinensis										P												
Balistidae																						
Balistapus undulatus						1					2	1					2					
B. conspicullum	1	2		1		1			1		2	1		2		1	1					
B. viridescens	1	2		2			2	2			2	2	1	2		1	1		1		1	
Melichthys vidua						2					3	3				1						
Pseudobalistes flavimarginatus			1				1															
P. fuscus											1											
Rhinecanthus aculeatus			3												P					P	2	
R. rectangulus				2							4	2	2			4	2				2	
Suflamen bursa								2														
S. chrysopterus			2	3		3		3			4	4	3			3	1				2	

	NE Herald					SW Herald					Coringa (SW)					Chilcott					Magdelaine	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
Belonidae																						
Tylosaurus crocodilus										P												
Blennidae																						
Cirripectes castaneus								1			3					1		1	2			
C. stigmaticus								1	2		2			2								
Crossosalarias macrospilus										P						1						
Exallias brevis		1							1					1		1						P
Istiblennius edentulus					P																	
Meiacanthus atrodorsalis	2						2												1			
Plagiotremus rhinorhyncos																		2				
P. tapeinosoma		2	2	1					1			3	2				2				1	
Caesionidae																						
Caesio caerulaurea	3	4											3	2					2		1	
C. lunaris						3													3			
Pterocaesio marri								5											2			
P. tile						5		3	4								4		4		4	
P. trilineata																					4	
Carangidae																						
Carangoides ferdau		1	1																			
C. orthogrammus		2					1															
Caranx ignobilis										P	1					1					1	
C. melampygus	2	2	2	2		3	3	2	2		2	2	2	1		1	3	2			2	
C. papuensis											1											
C. sexfasciatus																						
Elagatis bipinnulata									1			1										
Scomberoides tol										P												
Trachinotus bailloni					P																	
Carcharinidae																						
Carcharhinus amblyrhinchos		1		1		2	1	2	3											P	2	
Chaetodontidae																						
Chaetodon auriga			3					2	3			1	1					1				P
C. bennetti										P												
C. citrinellus	4	2	3	3		3	3		2		3	3	3	3		3	3	3	3		3	
C. ephippium	2	2	2				2							2					2			T
C. flavirostris		3				2	2		2				2	2				2			2	
C. kleinii											2	1				3	2					
C. lineolatus	1		1			1					2		2									
C. lunula		2												2							1	
C. melannotus					T									2					2			
C. mertensii	2		3				3	3							T							
C. ornatissimus						2	2		3										1			
C. pelewensis	1	3	1			3	2	2	2													
C. plebeius		2	2				1		2		2	2	2	2			1	2	2			P
C. punctatofasciatus	1																					
C. reticulatus		2				2		2	2													
C. semeion							2															
C. speculum							1															
C. trifascialis																						P
C. trifasciatus	2	2				2	2											2	2		2	
C. ulietensis		1				2	1	2														
C. unimaculatus		2				1														T		
C. vagabundus		1	1			1											2		1		2	
Forcipiger flavissimus	3	2	2			1	3	3	2					1				1				
F. longirostris	1									P												
Hemitaurichthys polylepis								3														

	NE Herald					SW Herald					Coringa (SW)					Chilcott					Magdelaine	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
Heniochus chrysostomus			2			2	2		2					2								
H. monceros		2				2			2				1									
H. singularius										P												
Cirrhitidae																						
Cirrhitichthys falco								1			1	3				1						
Cirrhitus pinnulatus								1													2	
Neocirrhites armatus		2														2						
Paracirrhites arcatus	2	2		3		3	2	3	3		2	3		2		1	2					
P. forsteri	1							2	2		3	1				2		2				
P. hemistictus									1									1				
Dasyatidae																						
Dasyatus kuhlii							2															
Taeniura lymma						1								1							1	
Diodontidae																						
Diodon hystrix													1						1			
Echeneidae																						
Echeneis naucrates		1							2													
Fistulariidae																						
Fistularia commersonii		1								P												
Ginglymostomatidae																						
Nebrius ferrugineus			1								1											
Gobiidae																						
Amblyeleotris fasciata.																					2	
Istigobius sp.														2								
Valenciennea strigata			3	3		3		3	2		2	3	3	2			2		2		3	
Haemulidae																						
Plectorhinchus goldmanni		2																				
P. picus			2						3				1				1				1	
Hemigaleidae																						
Triaenodon obesus			2	1					1											P	1	
Holocentridae																						
Myripristis berndti		2	2	3					2		4	3	2	3			2	1	1		4	
M. kuntee		3				3	4	3	4					3			1	2	1		1	
M. pralinia		1				1																
M. vittata										P												
Neoniphon opercularis																					1	
N. summara		2	2				3		3			2	1	3							2	
Sargocentron caudimaculatum		2		2		3			2			1							1			
S. spiniferum			1								2	1		2				1	1		1	
S. tiere									1													
S. tieroides				2			1		3		2											
Kuhlidae																						
Kuhlia mugil					P																	
Kyphosidae																						
Kyphosus cinerascens					P				3				1									
K. vaigiensis		4							2													
Labridae																						
Anampses caeruleopunctatus		2				1		2	1				3									
A. geographicus												1	1					2	2			
A. neoguinaicus	4	3	2	2		4	3	3	3				1	3				3	3		2	
A. twistii	2	2				2	3												1		1	
Bodianus loxozonus	3	1				2			1													
B. mesothorax						2	1		2										2			
Cheilinus chlorourus		1	2	3			1	1	2		2		1						1		1	
C. oxycephalus	2	2	2			2	3	2	1												1	

	NE Herald					**SW Herald**					**Coringa (SW)**					**Chilcott**					**Magdelaine**	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
C. trilobatus						2	2	3	1										2		2	
C. undulatus			1					1	1		2		1	1			2					
C. unifasciatus	2	3	2	3		2	3	3	3			3	2	2		2	2	3	1		3	
Cirrhilabrus exquisitus				3																		
C. laboutei					P			3													2	
C. lineatus								3														
C. punctatus		3																				
C. scottorum		3	3	3		4		2				1										
Coris aygula	2	1	2	1		3	1		1													P
C. dorsomaculatus				2								2									2	
C. gaimard				1		2		2	2			1	1									P
Epibulus insidiator					P		3		1											T		
Gomphosus varius	4	2	3	3		1	4	3	2		2	1	2	2			1	3	2		3	
Halichoeres biocellatus	5	4	4	3		4	3	3	3				3	3				4	3		4	
H. hortulanus	3	3				3	4	2	3		2	2	4	3		2	1	3	3		2	
H. margaritaceus				5				3			4	4	2			5	4	1	2		4	
H. marginatus		2						2	2				3	3					1			
H. ornatissimus						3		4				1										
H. trimaculatus		2	4			2	4						2					4	1		3	
Hemigymnus fasciatus	1	1	3			1	3	2	3		1			2				1	1			T
H. melapterus																					1	
Hologymnosus annulatus												1										
H. doliatus				2																	1	
Labroides bicolor	1	2					2		2					2				1	1		2	
L. dimidiatus	1	3	4	4		4	2	3	3		2		2	2		2	2	3	3		2	
Macropharyngodon kuiteri			2					2				1									1	
M. meleagris	3	2	4	4		4	4	3	3		2	3	3	1		2	3	2	2		3	
M. negrosensis													1									
Novaculichthys taeniourus						1		3	2				2				1				1	
Pseudocheilinus evanidus							1															P
P. hexataenia	2	3	2	3		3	4	2	3			1	2	2		1						
Pseudocoris yamashiroi								3														
Pseudodax moluccans		2				3		3	2		2	1	3	3								
Pseudojuloides cerasinus			2	2		2		2														
Pteragogus amboinensis												2		2				2	1		1	
P. cryptus						1	2	1	1			2		2		1		1			2	
Stethojulis bandanensis	4		4	4		4		2	3		2	3	4	3		3	3	3	2		3	
Thalassoma amblycephalum	3			4		4	2	4			6	5	2			4	5		4			
T. hardwicke	4	2	4	3		3	4	3	4				4	5				4	4		4	
T. jansenii	3			4		2	3	2	2		5	5	3			4	4	2	2		3	
T. lunare	3		3																			
T. lutescens	3	4	4	4		4	4	3	4		4	4	2	3		3	4	3	4		4	
T. purpureum					P												1					
T. quinquevittatum	4	3		4		4	3	4	3		3	5	4	4		3	3	2	3		5	
T. trilobatum											3	3				2	2					
Xyrichtys aneitensis										P												
X. pavo																				P		
Lethrinidae																						
Gnathodentex aurolineatus			4			3			4											P		
Gymnocranius grandoculis							1															
G. sp.																		1	2			
Lethrinus erythracanthus		2					1		1											P		
L. nebulosus			1																			
L. olivaceus	2	2	2					1	2		2	1					1	1				
L. xanthochilus									3											P		P

	NE Herald					SW Herald					Coringa (SW)					Chilcott					Magdelaine	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
Monotaxis grandoculis	3	3	3			2	3		4				4	2			1	1	3		4	
Lutjanidae																						
Aphareus furca		2				2	2	1	2					3				1			2	
Aprion virescens				1					1					1						P	2	
Lutjanus bohar	2	3	4	2		1	2	3	4		3	1	2	2		2	2	2	1		3	
L. gibbus				1					4											P		
L. kasmira		3	1				2		5					1								
L. monostigma										P								1				
L. rivulatus										P												
Macolor macularis	2	4				2	2		3													
Macolor niger			3			2	2	2	4					2			2	1	1		3	
Malacanthidae																						
Hoploltilus starki										P												
Malacanthus brevirostris												1										
M. latovittatus				2																		
Microdesmidae																						
Nemateleotris magnifica								3														
Ptereleotris evides						2		3	2				2	2				3			3	
P. heteroptera								2														
P. zebra				2				4				4				2						
Monacanthidae																						
Amanses scopas						1																
Cantherhines dumerilii																				P		
C. pardalis			1	2				1	1		1	3	2			3	2		1			P
Oxymonacanthus longirostris		2																		P		P
Paraluteres prionurus														1								
Pervagor alternans				2							2	3	2	3					1			
P. aspricaudus				1																		
Mullidae																						
Mulloides flavolineatus			4				1		2		2		2					3	2		3	
M. vanicolensis		2	3										3	2			2	2			2	
Parupeneus barberinoides												2	3	1								
P. barberinus			2				1															
P. bifasciatus		4				3		3	3			1	1	2				1	3		2	
P. ciliatus									2													
P. cyclostomus	2		3	1		2	1	2			2		2	1			2	2				P
P. multifasciatus	4	2	3	4		4	3	4	3		3	3	3	3		2	1	3	2		4	
P. pleurostigma				2		2	2					2	3			1	3	3	3			
Muraenidae																						
Gymnothorax javanicus							1															
G. picta																				P		
Ostraciidae																						
Ostracion cubicus	1		1						1		3	4	1	1		1	2		3			
O. meleagris			1			1	2	1	2		2	3	3	3		1	1		1		1	
Pempherididae																						
Pempheris oualensis				1					2		3		3	3			4	3	1		1	
Pinguipedidae																						
Parapercis hexophtalma			3	2			2	1									2				1	
P. millepunctata		1		2				1				3	1							P	2	
Pomacanthidae																						
Centropyge bispinosus	2	3	2	1		3	3	3	3										1		1	
C. flavissimus				1							1			1								
C. heraldi				2				2	1													
C. vroliki	1	3	2	3		3	2	2	3		3	3		3			2		1		3	
Genicanthus melanospilos										P												

	NE Herald					SW Herald					Coringa (SW)					Chilcott					Magdelaine	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
G. watanabei										P												
Paracentropyge multifasciatus										P												
Pomacanthus imperator			1			2								1							1	
Pygoplites diacanthus	1	3	2	2		2	2	1													1	
Abudefduf septemfasciatus					P															P		
A. sordidus					P																	
A. vagiensis	2					4	3	4	3		4	5	5	4		2	4	3	4		5	
Acanthochromis polyacanthus							3		2			3		2				3	2			
Amblyglyphidodon aureus										P												
A. curacao	2		2															2			2	
A. leucopoma										P												
Amphiprion akindynos								2	2											T		
A. melanopus	2								3													
Chromis agilis		4	1	2		4	3	2	2										3			
C. alpha										P												
C. amboinensis										P												
C. atripectoralis			4												T				1			P
C. atripes				1		3		4											2			
C. chrysura	4			3		4	5	6						2					3			T
C. iomelas	3	4	3	3		4	5	5	2										4			
C. lepidolepis					T	4	2															
C. lineatus												1										
C. margaritifer	2	6	3	5		3	5		3		3	3		4		4	4	2	3			T
C. retrofasciatus										P												
C. ternatensis							4															
C. vanderbilti	3	6		5		6		5	3		4	3	3	3		5	4					
C. viridis			2																			
C. weberi		4		3		5						2				1						
C. xanthochira										P												
C. xanthura	2	4				4	2	4	4													
Chrysiptera biocellata			4																			
C. glauca					P					P	1											
C. leucopoma								2			2	5				4	3	3	2		4	
C. starki										P												
C. taupou	4	2	4	3		3	3	3	3		3	2	3	4		1	2	1	2		3	
Dascyllus reticulatus		3	4	2		3	3		3					2		3		3				
D. trimaculatus						2																
Plectroglyphidodon dickii		3	2			4	2		2								1					P
P. imparipennis				3				3			4	4				3	3		1			P
P. johnstonianus		3	2			3	3		1		2	2		3		1						
P. lacrymatus	4	4	3	3		4	4	2	2			2		3		1	1	3	3		4	
P. leucozonus								3			2	3										
P. phoenixensis				1				3	2		4	2									2	
Pomacentrus bankanensis		1		2		2		2			1	2	2	1		2	2				2	
P. chrysura					P					P					P					P		P
P. coelestis				4		3		5			4	2				3	3					
P. imitator	4	3	2	3		3	4		3				3	4			1	2	5		4	
P. pavo					P					P												
P. vaiuli	6		5	6		5	4	3	4		3	4	4	4		4	3	4	4		5	
Pomachromis richardsoni	5			2		2		5	4		6	6	5	4		5	6		2		4	
Stegastes albifasciatus					P																	
S. fasciolatus	3	4	3	4		5	3	4	4		5	4	4	4		3	3	2	2		4	
S. nigricans			5																			
Pseudochromidae																						
Cypho purpurascens					P															P		

	NE Herald					SW Herald					Coringa (SW)					Chilcott					Magdelaine	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
Pseudochromis paccagnellae										P												
Scaridae																						
Bolbometopon muricatum	2		1					3												P		
Calotomus carolinus		1	2	2		3		3	2				2	2		1		1	2		2	
Cetoscarus bicolor	2	2	2			2		2										1				
Chlorurus frontalis									2										2			
c. microrhinos	2	3	3			2	2	2	3				1	3				2	2		3	
c. rubrioviolaceus		3		2		3		2	2		2		2	2			1		1		2	
c. sordidus	4		4			3	4	4	2					2				3	3		3	
Hipposcarus longiceps	1	2	2	3			3	4			3		4	3		2	2	1	2		2	
Scarus altipinnis	3	4	3			2	3	1					2	3			2	2	3		4	
S. chameleon	3		3			3	3	1						1				3	3			
S. dimidiatus																				P		
S. forsteni		2				3		3	3													
S. frenatus		3				3		2	3					2					2			
S. longipinnis	4	4		3		4	4	3					2	4			1	2	1		2	
S. niger	3		2				4	2	1										2			
S. oviceps			2																	P		
S. psittacus			2	4		3		4							T	2	2	3			2	
S. schlegeli	2											2	4	2			3	3	3		3	
Scombridae																						
Gymnosarda unicolor										P												
Scorpaenidae																						
Sebastapistes cyanostigma																2						
Serranidae																						
Belonoperca chabanaudi																					1	
Cephalopholis argus	1					2									P							P
C. urodeta	1	2	2	3		3	3	3	3		3	3				1		2	1		1	
Epinephelus fasciatus							1			P												
E. hexagonatus										P												
E. merra			3				2						1	2				3	2		1	
E. polyphekadion			1																			
E. spilotoceps			1													1						
Grammistes sexlineatus				1				1					1									
Plectropomus laevis	1	2	3			3	2	1	2					2		2	1	1	1		1	
Pseudanthias pascalus		4					4	3														
P. squamipinnis				3		2																
P. tuka										P												
Serranocirrhitus latus										P												
Variola louti						2																
Siganidae																						
Siganus argenteus				1										3				3			2	
S. punctatus													1	2								
S. spinus													2									
Sphyraenidae																						
Sphyraena barracuda																				P		
Synodontidae																						
Saurida gracilis										P												
Synodus variegatus							1													P		
Tetraodontidae																						
Arothron hispidus			2																			
A. nigropunctatus	2		3	3		3	2	2	2		2	2	2	2		1	2		1		2	
A. stellatus											1											
Canthigaster bennetti			4	1									2	1		1					4	
C. janthinoptera													1						1			

	NE Herald					SW Herald					Coringa (SW)					Chilcott					Magdelaine	
SPECIES	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	2	3	4	Inc.	1	Inc.
C. valentini	2	2					1						2	1				2	1			
Tripterygiidae																						
Enneapterygius spp.	2	2																				
Zanclidae																						
Zanclus cornutus	2	3	3	1		3	3	3	3		2	3	3	3		2	1	3	2		2	

APPENDIX 3: UNDERWATER PHOTOGRAPHS

A selection of underwater photographs showing the present status of the Coringa-Herald National Nature Reserve benthic community.

Figure 1. Shallow exposed front reef showing lack of benthic organisms at some sites. This is probably the result of storm wave impact.

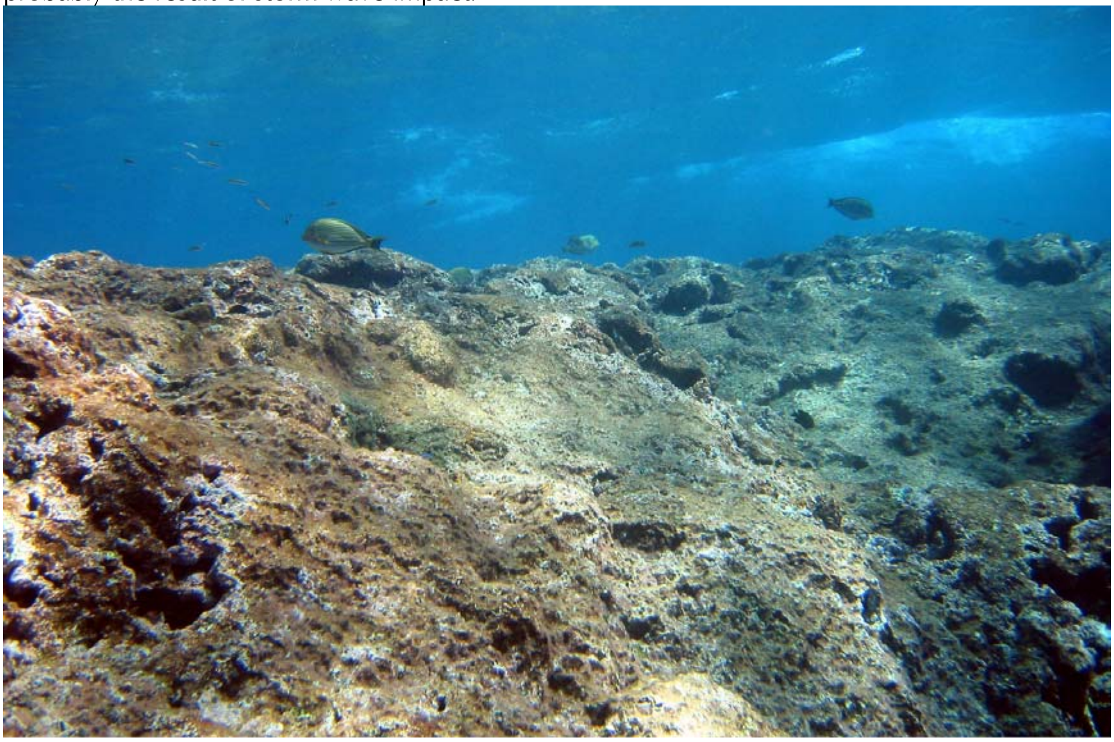

Figure 2. Shallow exposed front site with patchy acroporid and pocilloporid corals.

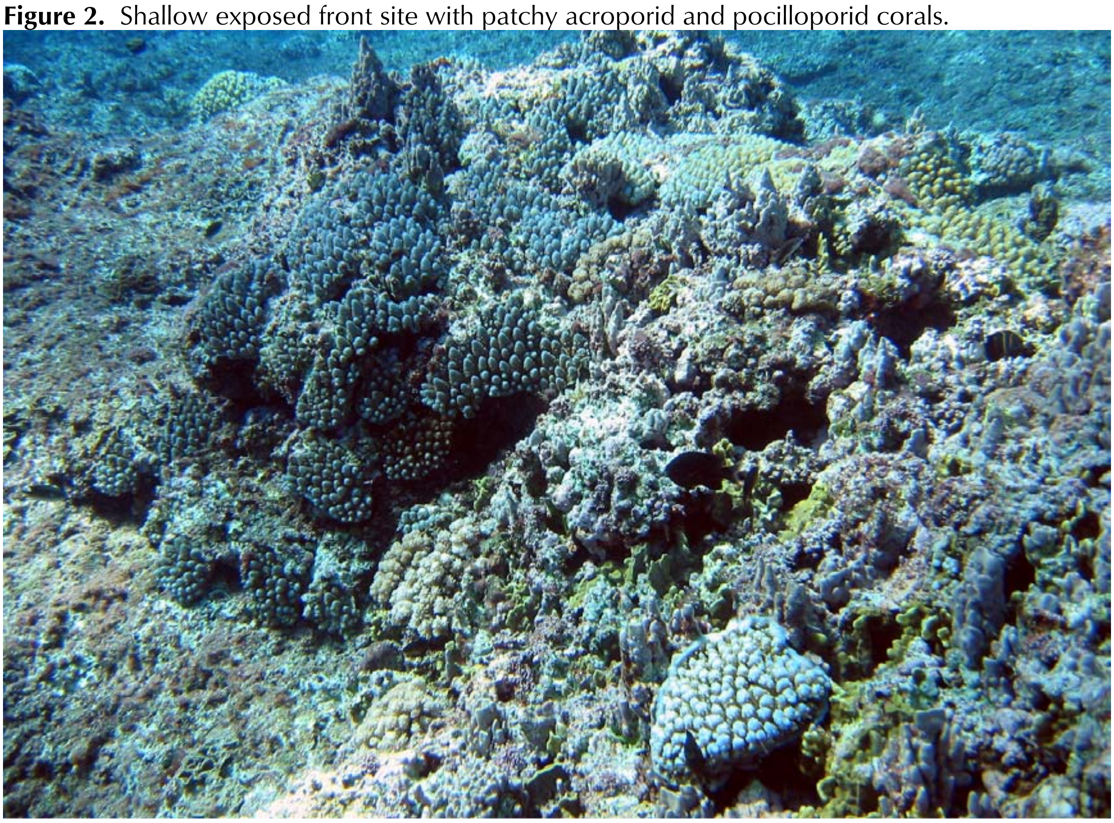

Figure 3. General view of the deep exposed front site habitat. Note the lack of noticeable hard coral colonies.

Figure 4. Section of the deep exposed front reef community showing sponges (grey) and soft corals (brown). Sponge cups are 5-10 cm across.

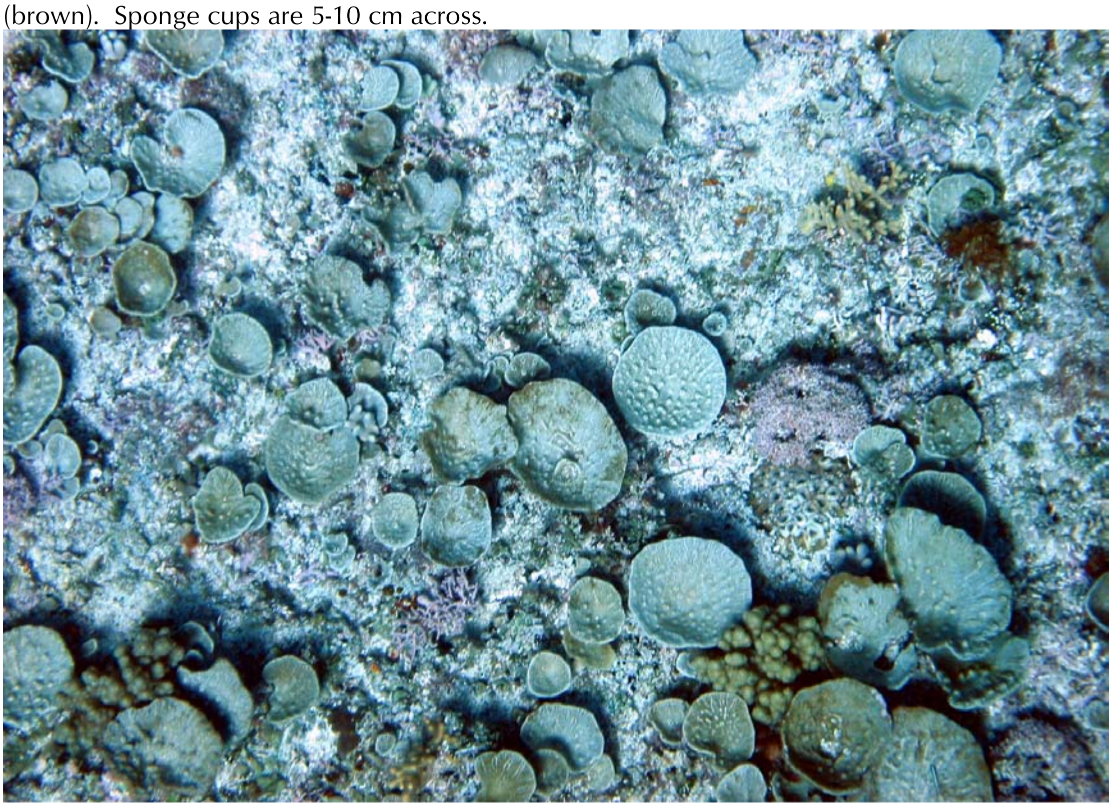

Figure 5. Deep exposed front reef community showing thallous algae and sponges.

Figure 6. General view of more sheltered back reef or flank community showing sponges and *Porites lichen*.

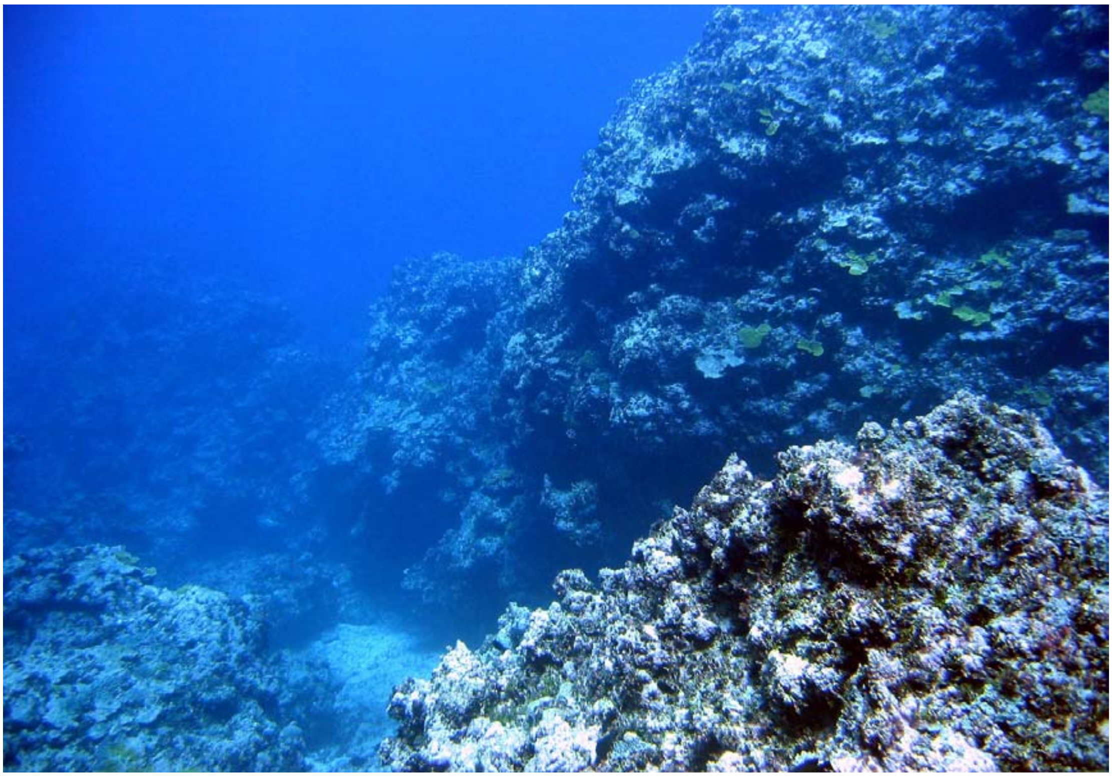

Figure 7. Partly dead *Porites lichen* colonies showing probable impact of recent bleaching episodes. Note *Halimeda* plants around edges.

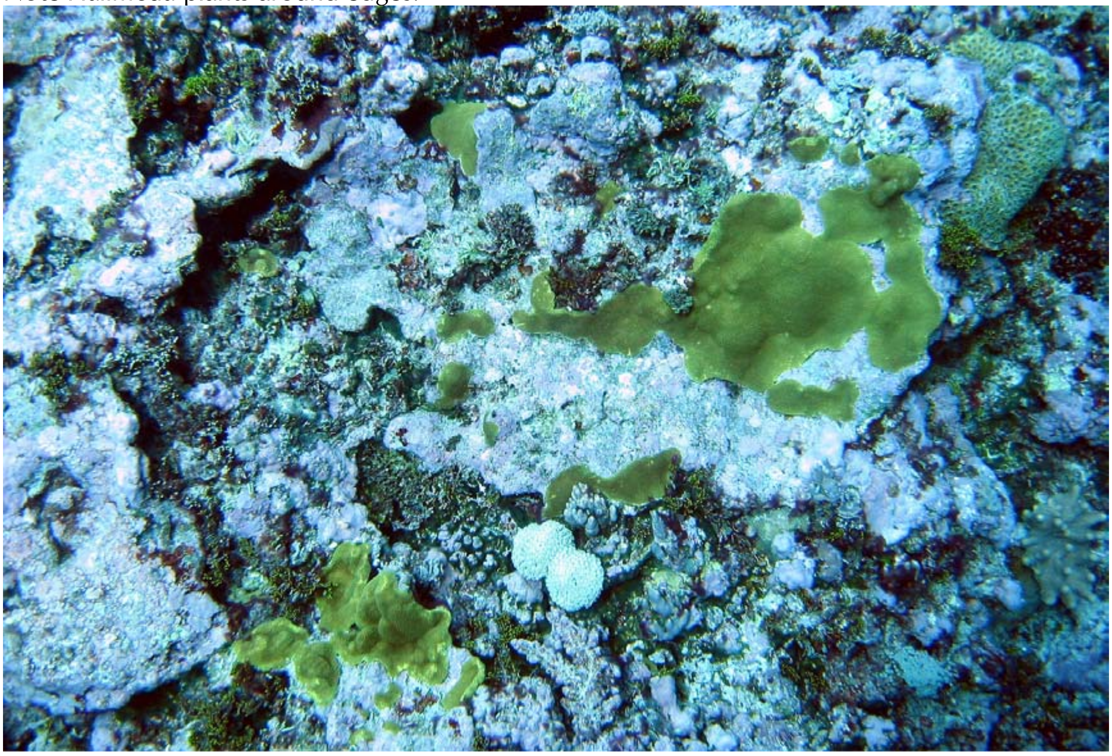

Figure 8. Dense sponges and *Porites lichen* in the back reef habitat.

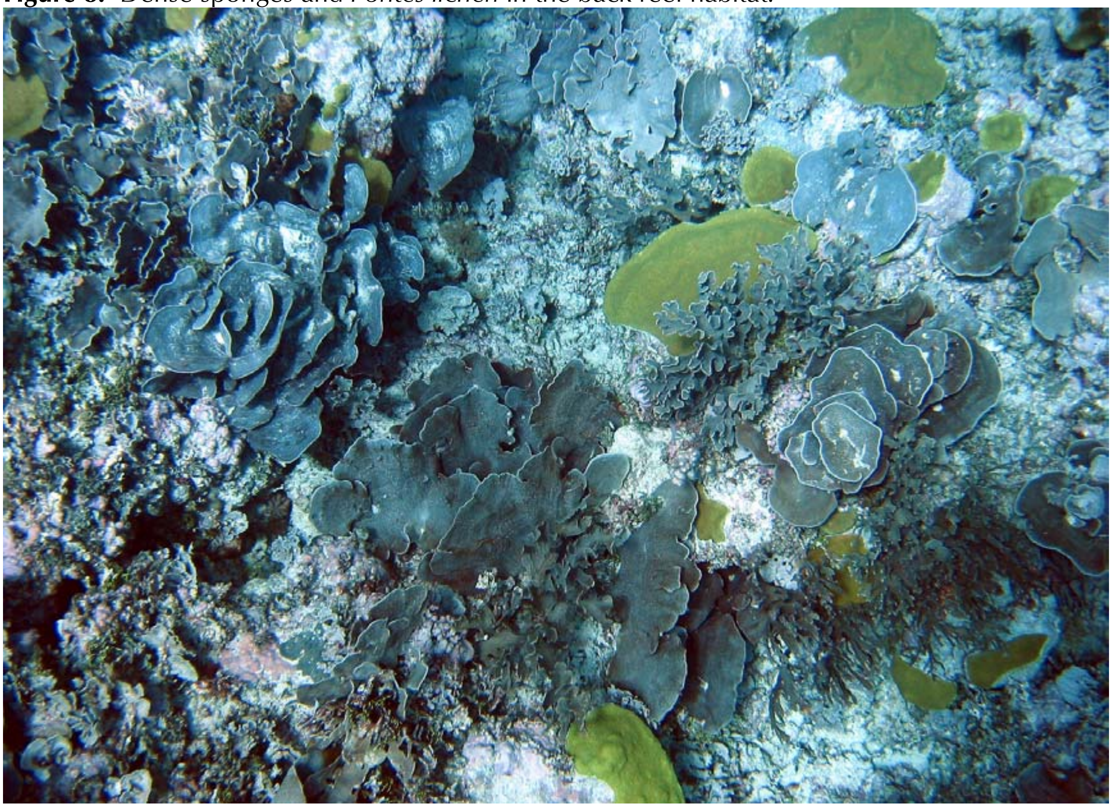

Figure 9. Dead standing *Acropora* colonies from recent bleaching episode.