ASSESSMENT OF CORAL REEF BIODIVERSITY IN THE CORAL SEA

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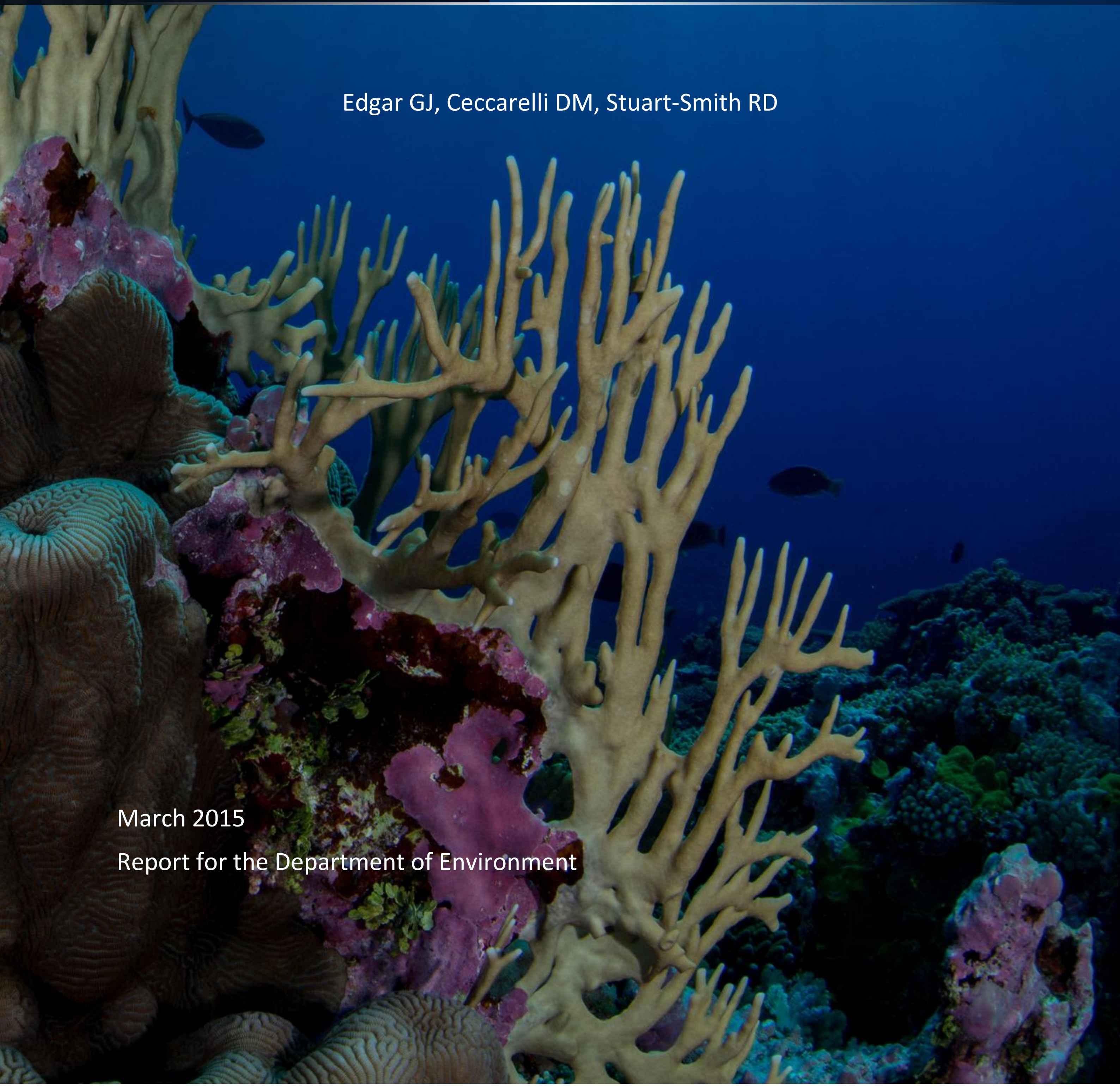

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Report for the Department of Environment

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Contents

List of acronyms

ACRONYM	EXPANDED
RLS	Reef Life Survey
IMAS	Institute of Marine and Antarctic Studies
CMR	Commonwealth Marine Reserve
IUCN	International Union for Conservation of Nature
GBR	Great Barrier Reef
GPS	Global Positioning System
EEZ	Exclusive Economic Zone
KEF	Key Ecological Features
UVC	Underwater Visual Census


Bird Reef

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Bird Reef

Executive summary

Australia's Coral Sea borders the Great Barrier Reef, Papua New Guinea, the Solomon Islands, Vanuatu, New Caledonia and the Tasman Front. Globally, the Coral Sea is considered to be among the last remaining 'pristine' seas with relatively low human impact. The remoteness of its coral reefs means that despite occasional ecological surveys, a comprehensive inventory of coral reef assemblages has been largely lacking. Much of the broader Coral Sea region lies within the Coral Sea Commonwealth Marine Reserve (CMR), which includes the former Coral Sea Conservation Zone, former Coringa-Herald National Nature Reserve, and former Lihou Reef National Nature Reserve.

Reef Life Survey (RLS) dive teams surveyed 160 sites on 17 Coral Sea reefs between September 2012 and July 2013, covering as many reef systems and wave exposure regimes within each reef as possible. RLS involves recreational divers trained to a scientific level of data-gathering to allow ecological surveys to be conducted across broad geographic areas in a cost-effective manner. Amongst Coral Sea sites investigated, 35 were in IUCN category Ia (which excludes commercial and recreational fishing), while all others were in IUCN IV or VI categories on reefs open to some commercial and recreational fishing.

This report and associated surveys were undertaken to greatly increase information on the distribution of marine biodiversity across the Coral Sea CMR, with major objectives: (i) to improve knowledge of the state of current biodiversity and the likely species or processes important for ongoing monitoring of the ecosystem health of the reserve, (ii) to place the Coral Sea CMR in the context of the broader region, and (iii) to provide a baseline that can assist in distinguishing future natural ecological change from that arising from management status.

Coral Sea reefs represent the only locations in Australian waters with fish and large mobile invertebrate species assemblages typical of oceanic Pacific islands. Although located within a few hundred kilometres from the Great Barrier Reef (GBR), reef communities on Coral Sea reefs are much more closely allied to those on the oceanic islands and atolls of Tonga, Samoa, Niue and Minerva Reef, which lie more than 2,500 km away. The Coral Sea hosts fewer species than the GBR but includes a distinct assemblage, rather than simply encompassing a subset of GBR species, indicating that a characteristic Coral Sea ecoregion exists within the Australian EEZ.

Coral Sea reefs comprise a globally-significant hotspot for reef sharks, with higher numbers sighted by divers than present at most locations worldwide. Reef shark density for the Coral Sea reefs was ranked 5th highest in comparison to all regions surveyed worldwide, following the Kermadecs, Elizabeth and Middleton Reefs, French Polynesia and the Marshall Islands. Sharks and large fishes were most abundant on central Coral Sea reefs, particularly locations protected from fishing, where larger grazers were also common. Reefs within marine national parks zoned as category IUCN Ia, including the Coringa-Herald and Lihou reef systems, supported higher fish biomass than comparable reefs where some fishing is allowed. Total fish biomass was estimated to be 70% higher, shark biomass 90% higher, and large predator biomass 50% higher in IUCN Ia zones than at comparable fished areas nearby.

Coral cover was relatively high on southern Coral Sea reefs such as Cato and Wreck Reefs (approximately 40%), where fragile branching corals were common, but tended to be much lower on central and northern reefs, probably because of frequent cyclone disturbance. Some central Coral Sea reefs, such as Holmes and Mellish Reefs, possessed coral cover as low as 7%. The exception was Osprey Reef, with over 30% coral cover, possibly because its geomorphology mirrors that of the southern reefs that have formed on the tops of seamounts. Coral assemblages of most reefs were dominated by encrusting corals, with some exceptions.

Central Coral Sea reefs with low coral cover tended to be dominated by calcified algae like *Halimeda* spp. and crustose coralline algae. Echinoderms and molluscs dominated the macroinvertebrate community on Coral Sea reefs in terms of abundance and also species richness. Grazing sea urchins were the most common invertebrate species. Bioerosion by urchins can lead to a net loss of carbonate, but sea urchin herbivory may also be important for creating free space for coral settlement. Some reefs also had high densities of giant clams, which have largely disappeared from many reefs across their range.

Reef fish communities were most diverse in the north, but coral-dependent species such as butterflyfishes tended to be more abundant in the southern reefs where the coral cover is highest. Abundance patterns were driven to a large extent by planktivorous and benthos-associated damselfishes, schooling wrasses, and small-bodied surgeonfishes, whilst biomass patterns were typically driven by the few large-bodied individuals, such as sharks, groupers, coral trout and large grazers. There was a clear distinction in the fish communities between the northern (north of Marion Reef) and southern reefs, not just in terms of species composition, but also at the level of functional groups.

Southern Coral Sea reefs remain a global stronghold for sea snakes, which are declining in many other parts of the world. Sea snakes were not observed on northern Coral Sea reefs despite high abundance on southern reefs. Sea turtles were observed on many reefs.

Overall, a primary ecological value provided by Coral Sea reefs is their distance from direct human pressures. Large-scale coral reef degradation is becoming ever more apparent worldwide, including on the Great Barrier Reef. The Coral Sea offers an environment that is closer to baseline condition than most other tropical regions, and thus provides a reference yardstick for assessing changes at locations elsewhere with similar wave-exposed coral reef environments but greater human-related stresses, including across the wider oceanic Pacific region.

Comprehensive monitoring of these same sites and reefs is recommended every three to five years using comparable methodology. This should include assessment of any decline in sea snake populations, ecological changes associated with direct and indirect effects of fishing in protected zones, and broad scale regional ecological shifts associated with changing climate. Monitoring could usefully be expanded to include additional methods specifically designed to estimate density and biomass of large-bodied predators.

Bird Reef

1 Introduction

This report and the surveys on which it is based were undertaken to greatly increase information on the distribution of marine biodiversity across the Coral Sea CMR, with major objectives: (i) to improve knowledge of the state of current biodiversity and the likely species or processes important for ongoing monitoring of the ecosystem health of the reserve, (ii) to place the Coral Sea CMR in the context of the broader region, and (iii) to provide a baseline that can assist in distinguishing future natural ecological change from that arising from management status.

The Indo-Pacific is the global centre of marine biodiversity. For coral reef organisms, species richness declines with increasing distance from the Coral Triangle region, an area of island archipelagos encompassing the waters of Indonesia, Papua New Guinea, the Solomon Islands, Malaysia and the Philippines. The area's geological history, biogeography and evolutionary processes have resulted in highly diverse reef systems hosting, for example, over 600 species of corals and 2000 species of fishes (Bellwood and Meyer 2009). These reefs, however, are also under great pressure from a burgeoning human population; over 350 million people live in the Coral Triangle alone, and many more in the broader Indo-Pacific region. Most rely to some degree on coral reefs for food, income and protection from storm-generated waves (Foale et al. 2013). Surveys in the region are numerous, especially in the central area (with less effort in more remote locations such as the Kermadecs and western and central Pacific island nations), but no previous survey has the scope to allow comparisons across the entire region.

The Australian Coral Sea lies to the east of the Great Barrier Reef and borders the EEZs of Papua New Guinea, the Solomon Islands, Vanuatu and New Caledonia. To the south, the Tasman Front provides a hydrographic boundary with the Tasman Sea. The Coral Sea is considered to be among the 4% of the ocean that remain least affected by human impacts, and is considered to be one of the last remaining 'pristine' seas (Ceccarelli *et al.* 2013; McKinnon *et al.* 2014). In its entirety, the Coral Sea covers ~4,791,000 km^2, with the Australian portion encompassing 972,000 km^2. Approximately 30 reefs, shoals and seamounts lie within the Australian Coral Sea, together representing less than 1% of the total area (Heap and Harris 2008), but hosting a high percentage of its biodiversity. Their wide distribution across the Coral Sea from the Great Barrier Reef to the fringing reefs of New Caledonia and elsewhere, suggest an important role as "stepping stones" between these areas on both evolutionary and ecological time scales (Ceccarelli *et al.* 2013).

During the Commonwealth Government's Marine Bioregional Planning Program, the Coral Sea was recognised as a distinctive area within the East Marine Region. The Coral Sea was declared a conservation zone in 2009 and proclaimed a Commonwealth MarineReserve (CMR) in 2012, and includes the two former reserves of Coringa-Herald and Lihou Reef. The reserve forms part of Australia's National Representative System of Marine Protected Areas (NRSMPA) and represents the region's biodiversity as it varies across provincial bioregions, depth ranges, large scale biological and ecological features and sea-floor features. The reserve covers approximately 989,842km square, encompassing the waters of the Coral Sea that fall within Australia's exclusive economic zone, and is divided into mulptiple management zones that are each assigned an IUCN category.

Two former Nature Reserves were incorporated into the Coral Sea CMR: the Coringa-Herald and Lihou Reef National Nature Reserves. These were proclaimed as IUCN category Ia reserves in 1982, and prohibited recreational and commercial fishing.

Key Ecological Features (KEFs) that were identified for the Coral Sea include the Tasmantid seamount chain and the reefs, cays and herbivorous fishes of the Queensland and Marion Plateaux.

There have been no integrated surveys that could characterise the geographic distribution of coral reef communities to date (Ceccarelli *et al.* 2013).

Systematic inventories to characterise flora and fauna of Coral Sea reefs have taken place sporadically in Australian waters since the 1960s, with efforts concentrated on a few reef systems. For instance, there have been at least 56 documents published about studies on the Herald Cays (Ceccarelli *et al.* 2013), but less than 10 studies were published on each of the 14 other reef systems in Australian waters (e.g. Kenn, Mellish and Frederick Reefs). Researchers still routinely find new species, new records, and range extensions (e.g. Randall and Walsh 2010). These discoveries include not just small or cryptic species, but also large iconic species such as the giant clam *Tridacna tevoroa*, which was discovered in Tonga and Fiji in 1990 and recorded for the first time on Lihou Reef in 2008 (Ceccarelli *et al.* 2009). Consequently, no comprehensive "Coral Sea species list" exists for any taxonomic group. Ecological coral reef surveys have been carried out by different teams using different methods and with different priorities. Existing knowledge indicates the possibility of a number of biogeographic provinces within the Coral Sea, but without the characterisation of species composition throughout the area, biogeographic patterns cannot be defined. The presence, abundance and distribution of a number of species of conservation significance also remain to be adequately established.

The level of functional connectivity between the main Coral Sea reefs is poorly characterised. Several gene flow studies have used Coral Sea samples in a larger Indo-Pacific context (e.g. Treml *et al.* 2008), but virtually none have focussed on the Coral Sea itself. Based on models of oceanographic circulation, and genetic analyses, larval transport is expected to occur westward from the Pacific towards the GBR, and the potential main means of this transport (the South Equatorial Current) also appears to separate northern and southern Coral Sea regions (Benzie 1998). The East Australian Current provides a connectivity pathway from the central Coral Sea to temperate waters to the south, and the North Queensland Current provides the northern pathway from the Coral Sea into the Solomon Sea. However, Coral Sea coral reefs are isolated habitat patches with large physical barriers (expanses of deep water) separating them. Further research including molecular analysis may indicate whether reef isolation has led to genetically distinct populations on individual reefs, especially for species with limited larval dispersal capabilities (Planes *et al.* 2001).

Oceanic coral reefs such as those in the Coral Sea are vulnerable to overexploitation and climate change impacts because they largely rely on self-seeding for sources for recruitment (Ayre and Hughes 2004). Their isolation from each other coupled with high exposure to cyclones and storms make them more vulnerable to natural catastrophic impacts and climate change than the contiguous and often larger, more complex reef systems of the GBR that have more sheltered habitat area (Graham *et al.* 2006), increasing the area's ecological fragility and the risk of local extinctions.

The Coral Sea's reefs and cays are also considered relatively undisturbed, with very low levels of fishing (Young *et al.* 2012). Prior studies have found coral cover to be low in exposed habitats and on smaller reefs, and higher in sheltered habitats and larger or interconnected reefs with lagoons. Existing estimates of reef-wide coral cover range from 7% (Coringa-Herald) to 60% (Osprey Reef)(Ceccarelli *et al.* 2013), although no estimates exist for most reefs. In many shallow habitats (slopes, reef flats and lagoons), the dominant benthic component is low-profile turf algae; this appears typical of reef habitats exposed to heavy wave action.

A species list of reef fishes was begun by Ayling and Ayling (1985), and updated during subsequent surveys (e.g. Ceccarelli *et al.* 2009; Oxley *et al.* 2004). It has suggested that fish assemblages generally represent a subset of fishes found on the Great Barrier Reef, with some notable exceptions that may be Coral Sea endemics.

Coral Sea cays are known nesting grounds for protected marine turtles (Harvey *et al.* 2005), and the seamounts in the southern portion of the area are thought to provide crucial feeding grounds for seabirds that nest on the Great Barrier Reef (Congdon *et al.* 2007). Previous surveys suggest that some Coral Sea reefs host large populations of reef sharks and sea snakes. The Coral Sea also serves as habitat for a large number of cetacean species, including the well-documented migration pathway of humpback whales (Ceccarelli et al. 2013).

The surveys aimed to address the geographic gaps in the sampling of major coral reef organisms across the Coral Sea, by conducting surveys across multiple reefs using consistent methodology and personnel. In addition to the broader aims stated above, this report specifically aims to:

- document substratum cover, macroinvertebrate and fish fauna across the region's reefs, including those in the Coral Sea CMR;
- assess the biogeographic affinities of Coral Sea reefs with those on the Great Barrier Reef and wider Indo-Pacific region;
- describe geographic distribution patterns of coral reef organisms to determine key potential drivers of coral reef biodiversity (e.g. latitude, reef size, exposure, depth) on northern, central and southern Coral Sea reefs (see Appendix 1);
- provide a baseline for the development of future monitoring, to assess biodiversity trends of shallow coral reefs in the Coral Sea;
- discuss potential threats to biodiversity in the region;
- assess any potential biological or ecological responses of biota to differing levels of protection within the Coral Sea CMR and surrounding waters; and
- provide information on the distribution and abundance of threatened and protected species.

2 Methods

Reef Life Survey (RLS) dive teams surveyed 160 sites on 17 Coral Sea reefs between September 2012 and July 2013 (Figure 1). Sites were chosen to encompass as much of the variability of shallow reef systems across the region as possible, covering as many reef systems and wave exposure regimes within each reef as possible; however, weather constraints often precluded access to wave-exposed locations and, for some reefs, also limited access to sites at distance from protected anchorages. Approximately 53% of transects were in sheltered areas, 29% in semi-exposed habitats, 12% in lagoons and 6% in fully exposed areas.

All 160 sites analysed were in the Coral Sea CMR, however, 35 were in areas zoned marine national park (IUCN Ia) (the previous Lihou Reef and the Coringa-Herald Reserves) which prohibits extractive uses, including fishing (Appendix 1).

Figure 1 Locations of reefs (labelled sites) where Coral Sea reef surveys were undertaken by RLS teams.

All surveys were conducted using the standardised underwater visual census methods applied globally by Reef Life Survey. Reef Life Survey (RLS) involves recreational divers trained to a scientific level of data-gathering to make it possible to conduct ecological surveys across broad geographic areas in a cost-effective manner. RLS divers partner with management agencies and university researchers to undertake detailed assessment of biodiversity on coral and rocky reefs globally.

A summary of these methods is provided here, but further details can be downloaded at: http://reeflifesurvey.com/files/2008/09/NEW-Methods-Manual_15042013.pdf. Divers and boat crew who participated in surveys all did so in a volunteer capacity.

Depth contours surveyed at a site were selected to encompass a wide depth range of 2- 20m, but recognising constraints associated with diving bottom time (<22 m depth), excessive swell at shallow depths at some sites, and the reef/sand edge, which was typically shallow at sheltered sites. Two transects were usually surveyed at each site, on predominantly coral reef habitat, and generally parallel at different depths. Underwater visibility and depth were recorded at the time of each survey, with visibility measured as the furthest distance at which large objects could be seen along the transect line, and depth as the depth (m) contour followed by the diver when setting the transect line. Each site was allocated an exposure category (Exposed, Semi-exposed, Sheltered or Lagoon), based on its position in relation to prevailing wind and swell. For most sites, more detailed exposure categories were assigned (Table 1). Three community components (large fishes, mobile invertebrates and cryptic fishes, and sessile organisms) were surveyed along each 50 m transect line.

Table 1 Scores defining exposure of sites to wave energy, vertical relief of the 3-dimensional reef structure, the angle of the slope and prevailing current strength.

Exposure score	Wave exposure	Relief	Slope	Currents
1	Sheltered, wind waves <1 m	<0.5 m	<1:10	none
2	Waves 1-3 m	0.5-1 m	1:10-1:4	weak
3	Ocean swell <3 m	1-2 m	1:4 -1:2	moderate
4	Open swell from prevailing direction	>2 m	>1:2	strong

2.1 Fish surveys (Method 1)

All fish species sighted within 5 m x 50 m blocks either side of the transect line were recorded on waterproof paper as divers swam slowly along the line. The number and estimated size-category of each species was also recorded. Size categories used were 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 400, 500, 625 mm, and above, which represent total fish length (from snout to tip of tail). All species sighted within the blocks were recorded, even for those with unknown identity. Digital photographs were used to later confirm identities with appropriate taxonomic experts, as necessary. In occasional circumstances when no photograph was available, taxa were recorded to the highest taxonomic resolution for which there was confidence (e.g. genus or family, if not species). Other large pelagic animals such as mammals, reptiles and cephalopods were also recorded during the Method 1 fish survey, but were excluded for analyses focusing on fishes. Species observed outside the boundaries of the survey blocks or after the fish survey had been completed were recorded as ‘Method 0’. Such records are a presence record for the time and location but were not used in quantitative analyses at the site level. ‘Method 0’ sightings were also made of invertebrates and any other notable taxonomic groups.

2.2 Macroinvertebrate and cryptic fish surveys (Method 2)

Large macroinvertebrates (echinoderms, and molluscs and crustaceans > 2.5 cm) and cryptic fishes were surveyed along the same transect lines set for fish surveys. Divers swam near the seabed, up each side of the transect line, recording all mobile macroinvertebrates and cryptic fishes on the reef surface within 1 m of the line. This required searching along crevices and undercuts, but without moving rocks. Cryptic fishes include those from particular, pre-defined families that are inconspicuous and closely associated with the seabed (and are thus disproportionately overlooked during general Method 1 fish surveys). The global list of families defined as cryptic for the purpose of RLS surveys can be found in the online methods manual. As data from Method 2 were collected in blocks of a different width to that used for Method 1 and were analysed separately from those data, individuals of cryptic fishes known to already be recorded on Method 1 were still recorded as part of Method 2. Sizes were estimated for cryptic fishes using the same size classes as for Method 1.

2.3 Photo-quadrats of benthic cover (Method 3)

Information on the percentage cover of sessile animals and macroalgae along the transect lines set for fish and invertebrate surveys were recorded using photo-quadrats taken every 2.5 m along the 50 m transect. Digital photo-quadrats were taken vertically-downward from a height sufficient to encompass an area of approximately 0.3 m x 0.3 m. In total, images were available and processed for 252 of the 314 transects investigated for fishes and benthic invertebrates.

The percentage cover of different macroalgal, coral, sponge and other attached invertebrate species was obtained from photo-quadrats by recording the functional group observed under each of five points overlaid on each image, such that 100-110 points were counted for each transect. To provide a percentage cover estimate for that transect, the number of points counted for each functional group was divided by total points less undefined shadow and tape areas. Mean and maximum rugosity values were also estimated for each transect from photo-quadrats, on a scale of 1 to 4, as follows: 1) flat smoothly-curved seabed, occasional projecting rocks when present, not rising more than 5 cm; 2) smoothly-curved seabed with cracks and ridges (with rounded edges) rising vertically 5-20 cm but not undercut; 3) dissected reef surface with cracks and ridges (with some angular edges) rising vertically 20-50 cm and with small undercuts; and 4) highly-dissected reef with extensive (>0.5 m) undercuts.

Functional groups for photo-quadrat processing comprised the standard 50 categories applied in broad-scale analysis of RLS data (Appendix 2), which are aligned with the CATAMI classification system (CATAMI Technical Working Group 2013). With greater time investment by a specialist operator than was achievable for this report, higher taxonomic resolution analyses are possible using the photo-quadrat set for groups such as corals and algae. Images have been archived and are available for processing at any resolution through the future.

2.4 Statistical analyses

Collection of detailed data on fishes, including species-level identities, length classes and abundance information, allow the calculation of species-specific biomass estimates. The RLS database includes coefficients for length–weight relationships obtained for each species from Fishbase (www.fishbase.org) (in cases of missing length-weight coefficients, these are taken from similarshaped species). When length–weight relationships were described in Fishbase in terms of standard length or fork length rather than total length, additional length-length relationships provided in Fishbase allowed conversion to total length, as estimated by divers. For improved accuracy in biomass estimates, the bias in divers' perception of fish size underwater was additionally corrected using the mean relationship provided in Edgar *et al.* (2004), where a consistent bias was found amongst divers that led to underestimation of small fish sizes and overestimation of large fish sizes. Note that estimates of fish abundance made by divers can be greatly affected by fish behaviour for many species (Edgar *et al.* 2004); consequently, biomass determinations, like abundance estimates, can reliably be compared only in a relative sense (i.e. for comparisons with data collected using the same methods) rather than providing an accurate absolute estimate of fish biomass for a patch of reef.

2.4.1 UNIVARIATE ANALYSES

A range of univariate metrics were calculated from survey data: total fish abundance, fish species richness, abundance of fish functional groups, total fish biomass, abundance and biomass of large fishes (> 25cm), and percent cover of corals and other key benthic organisms. All metrics represent mean values per 500 m^2 transect area for Method 1 fishes, 100m^2 transect area for Method 2 fishes and invertebrates, and percent cover of benthic organisms from photo-quadrats. Analysis of Variance (ANOVA) with appropriate transformations was conducted on the above metrics, with Reef as a fixed factor. While Reef would normally be considered a random factor in biogeographical studies with a subset of reefs sampled, we considered it fixed for this application because we surveyed almost the full set of Coral Sea reefs, and each reef is of specific interest in its own right. To adequately test the effects of protection within IUCN Ia zones (hereafter: Reserve status) in a balanced design, a set of sites zoned to allow some fishing was selected to match the reef size and approximate site exposure (to control for coarse habitat characteristics) of all IUCN Ia sites. The effect of Reserve status was tested in a separate analysis on the reduced dataset, with Reserve status as a fixed factor. For this analysis, Reef was included as a random factor nested within Reserve status.

2.4.2 MULTIVARIATE ANALYSES

Biogeographic relationships at an ocean scale were assessed using a combined fishes and invertebrates dataset that incorporated both the 5-m wide Method 1 (fishes) and 1-m wide Method 2 (mobile invertebrates) data. Because Method 1 data were collected over five times the area of Method 2, those data were reduced to the equivalent of a 1 m x 50 m area by converting Method 1 data to a string of single abundance records for each species at each site, then randomly removing 80% of individuals from each block. The two data sets were then combined after removal of cryptic fish families from Method 1 surveys that were duplicated using Method 2.

Relationships between Coral Sea sites in percent cover of sessile biota, reef fish and invertebrate communities were initially analysed using non-metric Multi-Dimensional Scaling (MDS). These were run using the PRIMER+PERMANOVA program (Anderson *et al.* 2008). This analysis reduces multidimensional patterns (e.g. with multiple species or functional groups) to two dimensions, showing patterns of similarity between sites. MDS was used to investigate differences in community structure between reefs.

Data were converted to a Bray-Curtis distance matrix relating each pair of sites after square root transformation of raw data. The transformation was applied to downweight the relative importance of the dominant species at a site, and so allow less abundant species to also contribute to the plots. MDS was followed up with PERMANOVA (to test the significance of differences between reefs), SIMPER (to determine which species or groups were contributing to these differences) and

Multivariate ANOVA (MANOVA) to test the significance of difference between fish and benthic functional groups.

To test the influence of reef area (data obtained from UNEP-WCMC, WorldFish Centre, WRI, TNC (2010)), depth and wave exposure on benthic and fish community structure, a generalised linear mixed effects model (GLMM) was used to determine the best explanatory variables for key benthic components and fish functional groups, using the statistical package *R*. Reef, Depth and Exposure were treated as fixed factors, with Site as a random factor. Model selection for GLMMs was based on minimisation of Akaike Information Criterion. The top model based on AIC values is presented. For sites with detailed exposure scores (Table 1), Principal Components Analysis (PCA) was used to determine the influence of different exposure regimes on the fish community.

3 Results

3.1 Regional patterns

Based on MDS analysis of fish and invertebrate data from 13 Indo-Pacific coral reef regions, the Coral Sea fauna was most similar to assemblages recorded in Niue, Minerva Reefs, American Samoa and Tonga. These regions shared high densities of the grazers *Acanthurus nigrofuscus* and *Ctenochaetus striatus*, and the farming damselfish *Pomacentrus vaiuli*. Elizabeth and Middleton Reefs shared a very similar subtropical / temperate fauna to each other that was distinct from elsewhere. The Great Barrier Reef linked closely with the broader Coral Triangle region of the Solomons, Vanuatu, PNG and Indonesia, as characterised by highly diverse tropical coral reef fish assemblages (Figure 2).

The Coral Sea and the Great Barrier Reef possess distinct coral reef faunas, both for fishes and invertebrates (Figure 3). Species that were more common in the Coral Sea and rarer on the GBR included the grazing sea urchin *Echinostrephus* sp., the planktivorous damselfishes *Chromis iomelas*, *C. agilis*, *C. chrysura* and *C. margaritifer*, the grazers *Acanthurus nigrofuscus* and *Ctenochaetus striatus*, the omnivores *Pomacentrus philippinus*, *Plectroglyphidodon johnstonianus* and *Pomacentrus vaiuli*, the benthic carnivores *Forcipiger flavissimus*, *Thalassoma lutescens*, *Anampses neoguinaicus* and *Gomphosus varius*, and the obligate corallivore *Chaetodon pelewensis* (not all species are shown in the Figure; some had correlation values < 0.5). The central and southern GBR had sites that were most closely aligned with the general Coral Sea data cloud; inshore and Torres Strait sites were least similar to the Coral Sea.

Shark species recorded in the Coral Sea included grey reef shark *Carcharhinus amblyrhynchos*, silvertip shark *C. albimarginatus*, Galapagos shark *C. galapagensis* and whitetip reef shark *Triaenodon obesus*. The Coral Sea was the fifth-highest (0.51 ± 0.06 individuals per 500m^2) when compared to equivalent survey data from other Indo-Pacific localities (Figure 4), even when including *C. melanopterus*, which was not observed on our surveys in the Coral Sea. Shark densities in the Coral Sea were surpassed only by the Kermadec Archipelago (3.7 ± 1.01 individuals per 500m^2), Elizabeth and Middleton Reefs (1.7 ± 0.44 individuals per 500m^2), French Polynesia (0.9 ± 0.2 individuals per 500m^2) and the Marshall Islands (0.87 ± 0.33 individuals per 500m^2). ANOVA showed that Coral Sea shark densities were significantly lower than the Kermadecs and Elizabeth and Middleton; they were significantly higher than the North West Shelf, the GBR, Ningaloo Reef and Indonesia (Tukey Unequal N HSD; $p < 0.05$). Many Indo-Pacific localities had no sharks recorded.

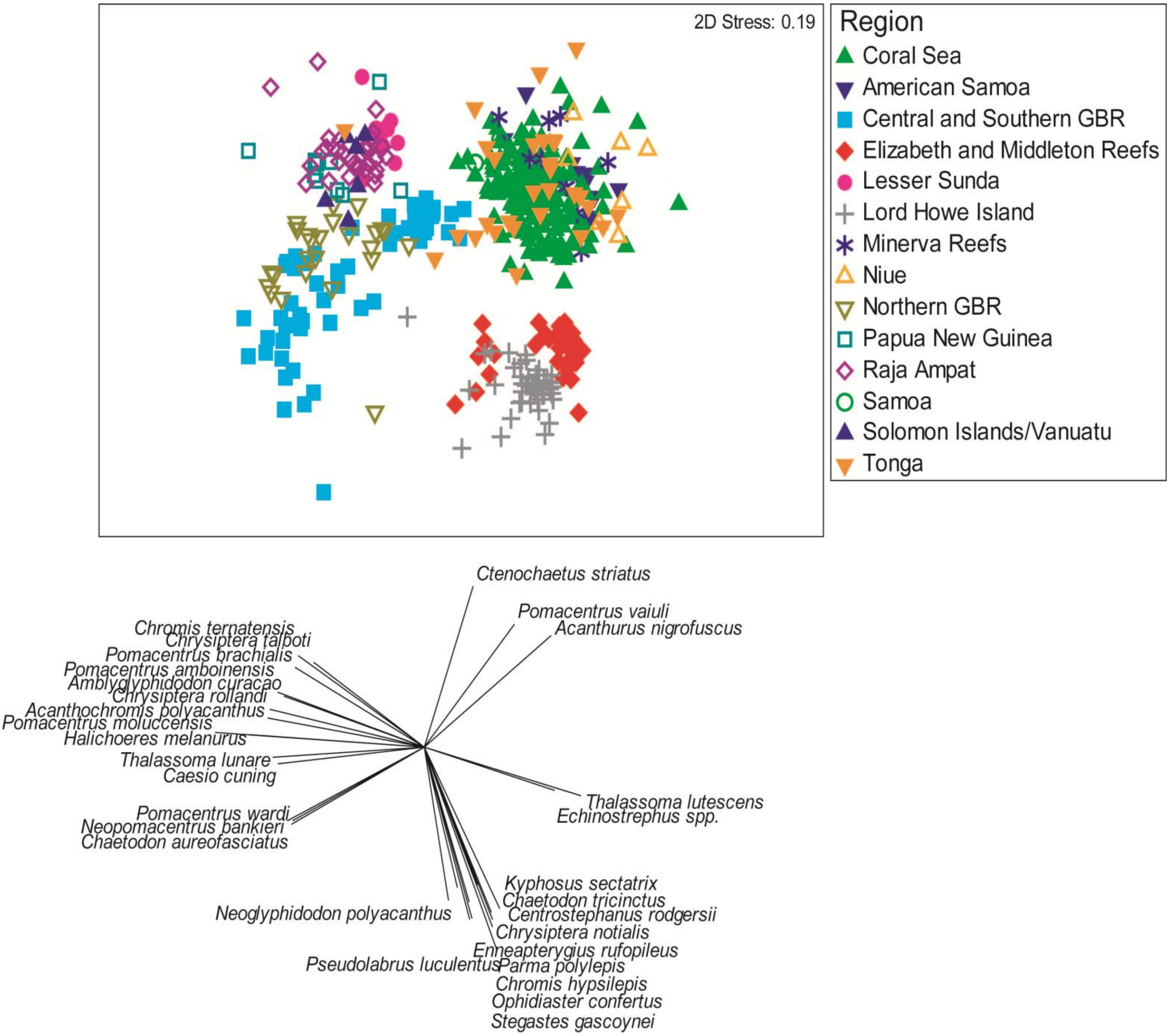

Figure 2 MDS of fish and invertebrates from combined Method 1 and Method 2 data. Log (x+1) transformed, Bray-Curtis similarity matrix, major western Pacific coral reef regional comparison. Vectors shown are those with a correlation value of at least 0.5.

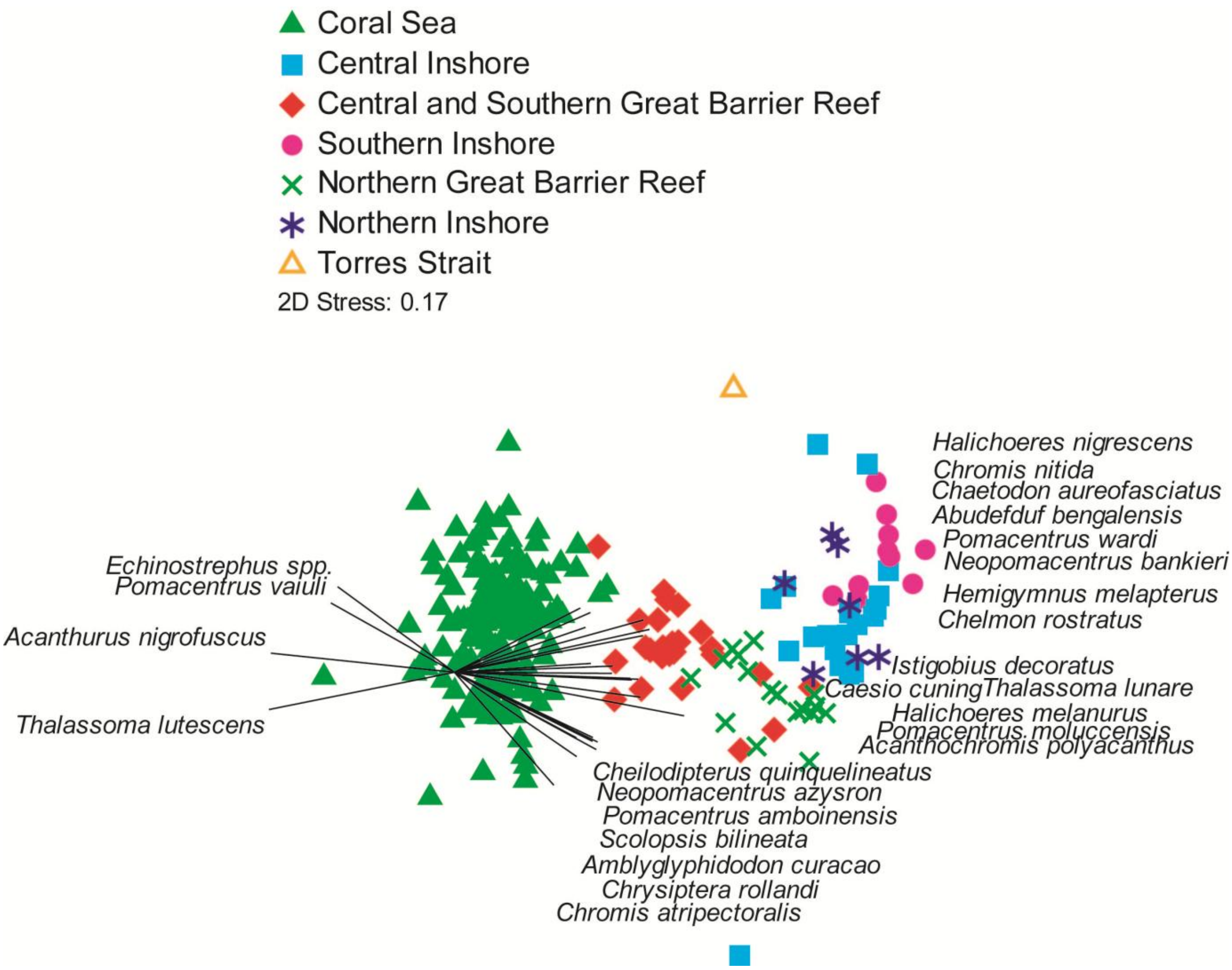

Figure 3 MDS of fish and invertebrates from combined M2 and M1 data. Log (x+1) transformed, Bray-Curtis similarity matrix, Coral Sea compared with inshore, offshore, northern, central and southern GBR. Vectors shown are those with a correlation value of at least 0.5.

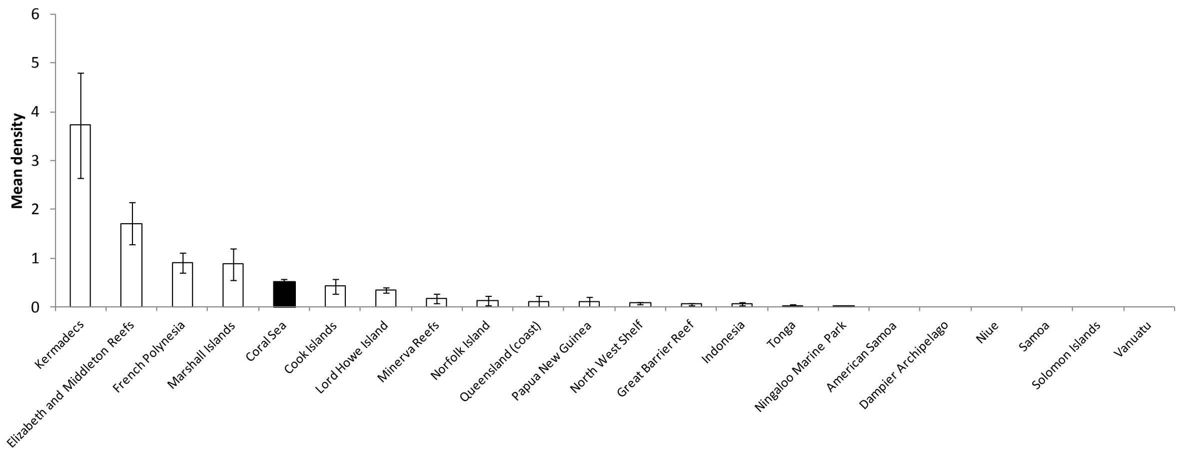

Figure 4 Mean density (individuals per 500 m^2) of reef sharks recorded using Method 1 across 22 regions of the Indo-Pacific. The Coral Sea is highlighted in black. Error bars = ± 1 SE.

3.2 Benthic community

The surveyed Coral Sea reef sites had an average coral cover of 18% (± 1.1% SE). Overall, the reefs were dominated by crustose coralline algae, and live coral cover was similar to the cover of calcified algae (e.g. *Halimeda* spp.) and non-calcified algae (including turf) (Figure 5). Turf made up 86% of the non-calcified algal cover, with only a small coverage of fleshy macroalgae. Abiotic substrata (bare rock, sand, rubble and dead coral) made up 13% (± 0.9% SE) of the analysed photo-quadrats.

Individual reefs had distinct benthic communities when considered as groups of species with similar ecological roles, or functional categories (MANOVA Pillai's Trace = 2.01, $F_{128,1880} = 4.9$, $p < 0.001$; Figure 6). Osprey Reef and the southernmost reefs (Wreck and Cato) had the highest cover of live hard coral (36%, 39% and 43%, respectively), whilst central Coral Sea reefs (Holmes to Mellish) had between 7% and 18% live hard coral cover. High cover of crustose coralline algae (between 20% and 30%) was recorded at all reefs except Osprey, Marion and Saumarez Reefs, where it ranged between 8% and 11%. Turf and calcified algae tended to be highest on central Coral Sea reefs, with lower cover on northern (Osprey Reef) and southern reefs (Kenn, Wreck and Cato). These southern reefs tended to have higher soft coral cover than reefs further north. Sponges were generally found in low cover, with greater representation of sponges on individual reefs north of Flinders Reef, but with very high variability between locations.

Of the different hard coral categories identified during benthic surveys, the most frequent growth forms were encrusting and branching corals (Figure 7). Notable distribution patterns across reefs were an increasing trend in branching coral cover with increasing latitude and a disproportionately high cover of tabular corals on Marion Reef (8%, compared with < 2% on each of the other reefs) (Figure 8).

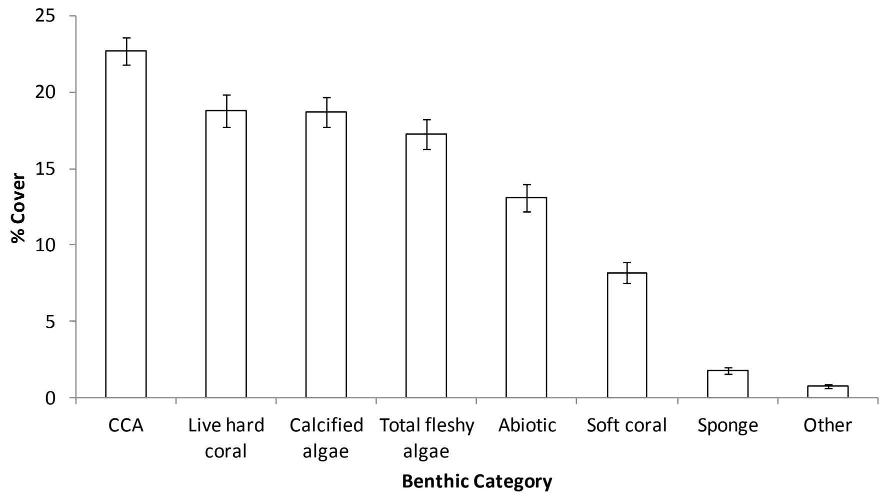

Figure 5 Percent cover of major benthic organisms across all surveyed Coral Sea sites. CCA: crustose coralline algae; Total fleshy algae includes filamentous algae and turf; Abiotic substratum includes dead coral. Error bars = ±1 SE.

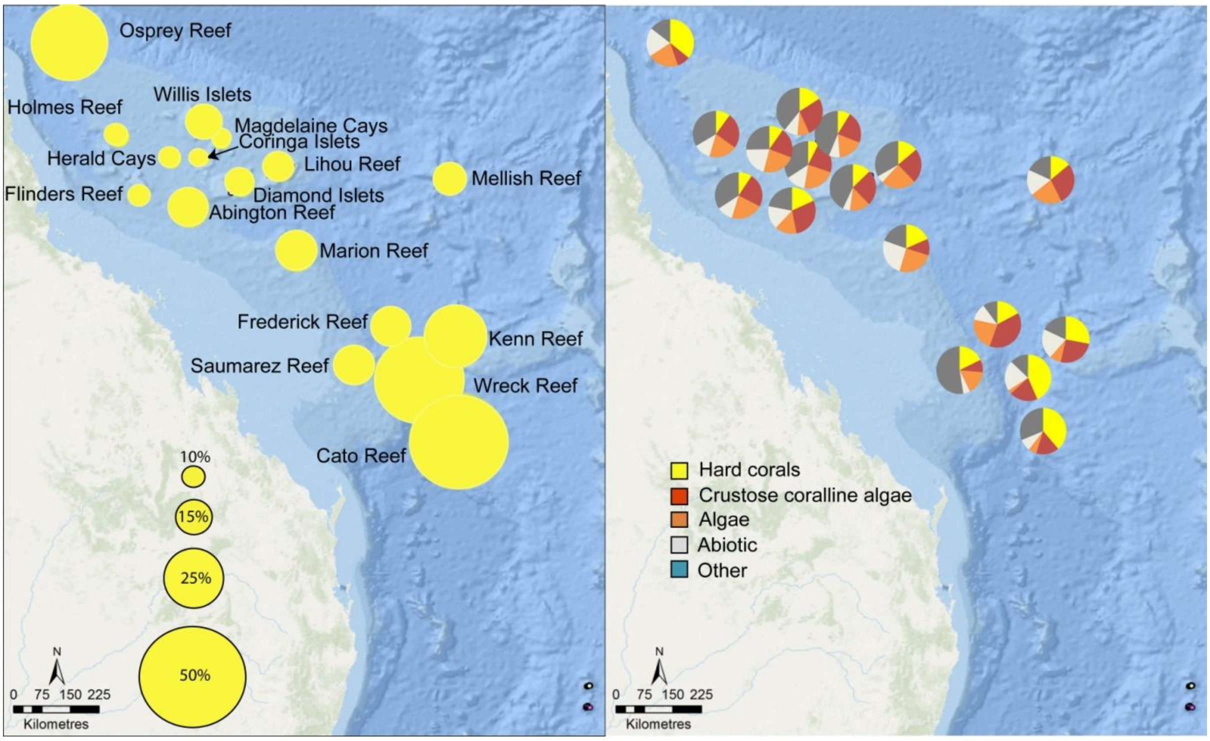

Figure 6 Distribution of percentage cover of live coral (left map, with bubble sizes scaled to percentage coral cover) and major benthic categories across surveyed Coral Sea reefs (right map).

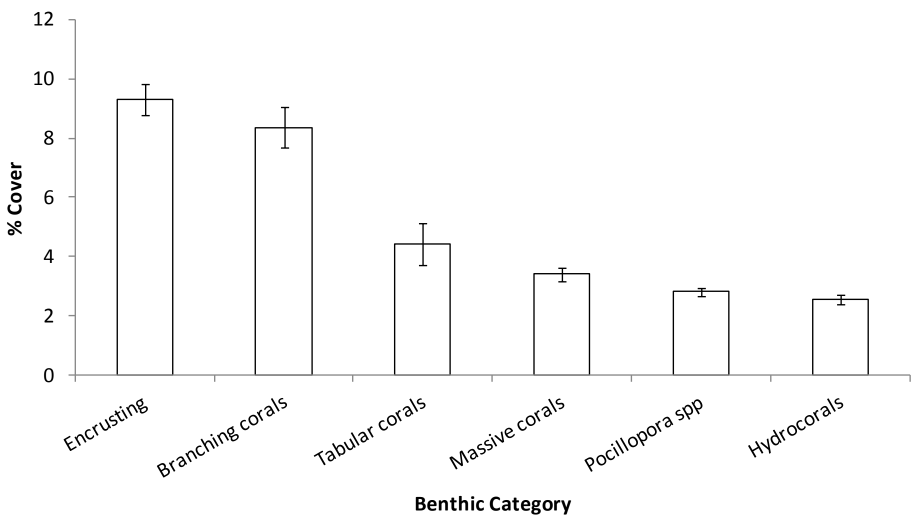

Figure 7 Percent cover of coral growth forms across all surveyed Coral Sea sites. Error bars = ±1 SE.

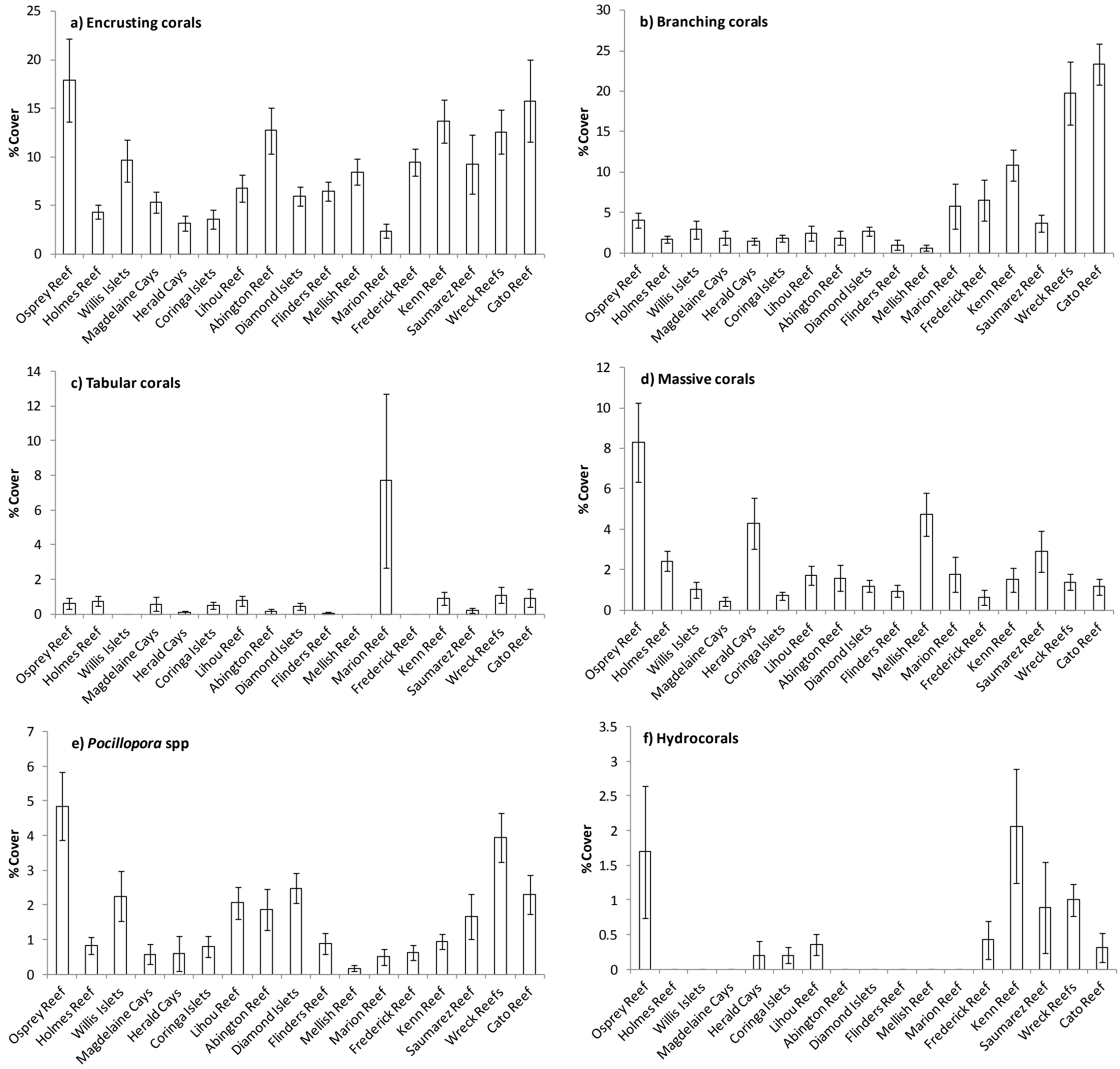

Figure 8 Distribution of percentage cover of coral growth forms across surveyed Coral Sea reefs. (x-axis: left to right = north to south). Note differences in the y axes. Error bars = ±1 SE

3.3 Benthic community drivers

General linear mixed models (GLMMs) showed how different reef organisms were influenced by different environmental gradients. Generally, the following four patterns could be discerned: 1) latitude was a key correlate of variations in the cover of live hard corals, algae, sponges, soft corals, and algal turf; 2) wave exposure best explained changes in abiotic substrata; 3) reef area was a significant determinant of sponge cover; and 4) fine scale rugosity was the strongest correlate of live coral cover. Additionally, variability in the cover of calcified algae was a function of both exposure and longitude (Table 2). Live and soft coral cover increased with increasing latitude, while fleshy algae, calcified algae and sponges showed the opposite trend (Figure 9). Depth had little influence on the benthic community.

A negative correlation was evident between calcified algae and rugosity (estimated from photo-quadrats; Figure 10). A subset of sites had detailed exposure scores relating to wave energy, vertical relief, slope angle, and currents; PCA showed that sites with higher values of some of these scores had a dominance of low-relief turf algae and a low cover of live corals. PC1 defined the separation of sites with high crustose coralline algal cover from those with higher cover of soft corals; PC2 represented the sites that had either high live hard coral cover or a dominance of turf. High relief sites tended to have more live hard coral and calcified and coralline algae; sites with low vertical relief, gentle slope and strong currents tended to be dominated by turf (Figure 11).

Table 2 Summary of optimal generalised linear models (GLMMs) for predicting benthic community components. Separate models are shown for key benthic categories. Models presented are those with the lowest values of Akaike Information Criterion that evaluate the influence of exposure, depth, latitude, longitude and reef size. Significant predictors are in bold (α=0.05). df: degrees of freedom; wAIC: AIC weights.

Variable	Model	df	AIC	wAIC
Live hard coral cover	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	196.9	0.907
Algal cover	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	243.9	0.741
Fleshy algae	Null	3	229.0	0.943
Calcified algae	**Exposure** + Depth + Latitude + **Longitude** + Reef Area	7	270.8	0.469
Sponges	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	129.1	0.943
Abiotic	**Exposure** + Depth + Latitude + Longitude + Reef Area	6	308.2	0.973
Soft coral	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	251.8	0.813
Algal turf	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	308.9	0.860
Crustose coralline algae	Null	3	232.6	0.564

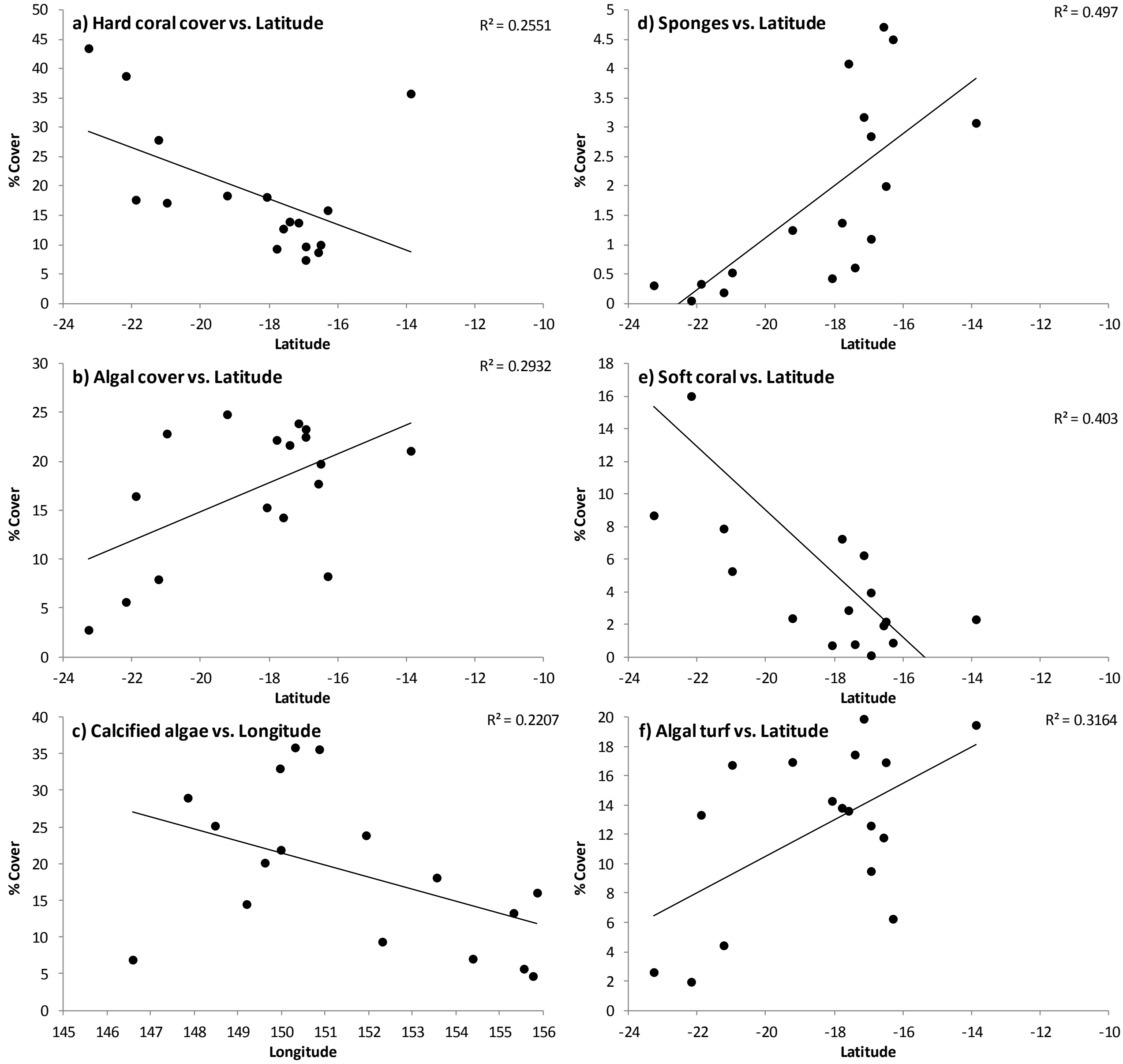

Figure 9 Relationships between benthic categories, latitude and longitude.

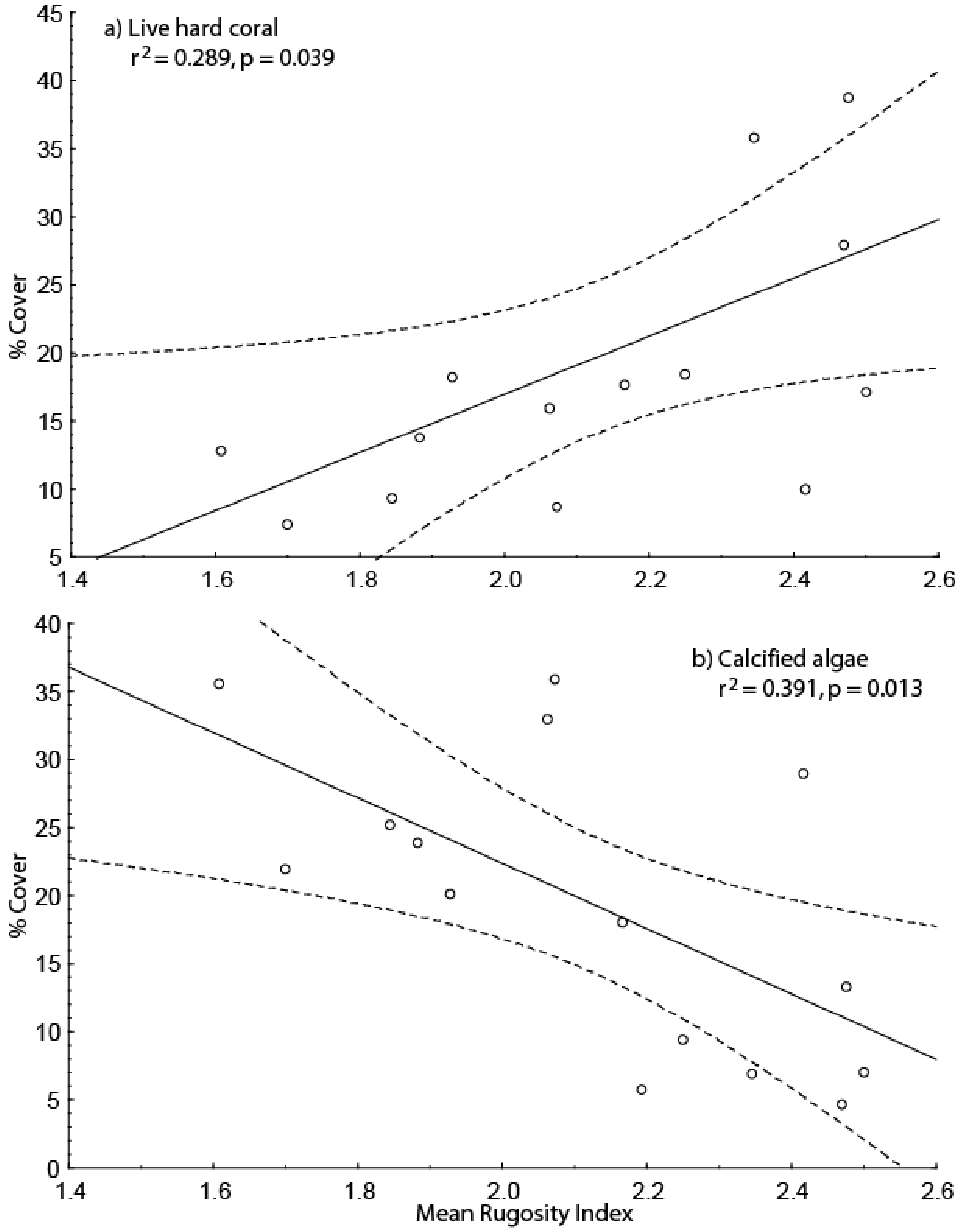

Figure 10 Relationship between mean rugosity and a) live hard coral cover, and b) calcified algal cover. Dotted lines: 95% Confidence Intervals for reef-level slope estimates

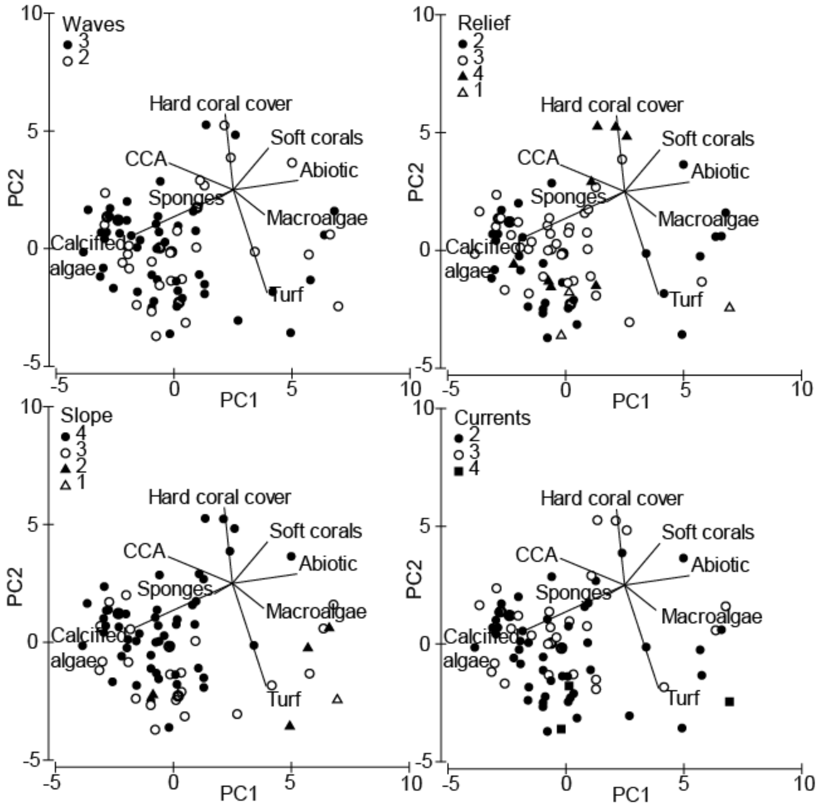

Figure 11 Principal Components Analysis biplot of benthic community relative to different measures of exposure. PC1 accounts for 34.7% of the variability, PC2 for 19.9% (cumulative = 54.6%). For definition of scores refer to Table 1.

3.4 Macroinvertebrates and cryptic fishes

The 1-m wide transects yielded 156 macroinvertebrate species, including 21 crustaceans, 77 molluscs and 56 echinoderms. Echinoderms dominated the Coral Sea macroinvertebrate fauna along transects in both abundance and species richness (Figure 12). The abundance and species richness of pooled invertebrates varied across the 17 Coral Sea reefs surveyed ($F_{16,294} = 4.7$, $p < 0.001$ for abundance, $F_{16,294} = 3.2$, $p < 0.001$), but there were no clear latitudinal patterns (Figure 13). The lowest macroinvertebrate abundance was found on the Magdelaine Cays, and on Mellish, Marion and Wreck Reefs. Surprisingly, species richness on these reefs was comparable to most other reefs – Marion Reef even had among the highest species richness of macroinvertebrates. The highest abundance was found on Saumarez Reef, followed by Lihou, Flinders and Kenn Reefs. The highest species richness was found on Osprey and Marion Reefs (Tukey HSD).

The abundance and species richness of crustaceans, molluscs and echinoderms varied significantly across reefs.

3.4.1 CRUSTACEANS

Crustacean abundance and species richness were generally low compared to other taxa, and distributed unevenly across reefs. Slightly higher abundance was found on Willis Islet, and species richness was higher on northern reefs than southern reefs. No other latitudinal patterns were evident.

3.4.2 MOLLUSCS

Mollusc abundance was also highly variable between reefs, but species richness was more uniform across all reefs.

3.4.3 ECHINODERMS

Echinoderm abundance was an order of magnitude higher than the other two taxa, but species richness was only slightly higher (Figure 14). Correspondingly, the echinoderm spatial abundance and species richness patterns most closely reflected those of the pooled macroinvertebrate abundance and species richness (Table 3).

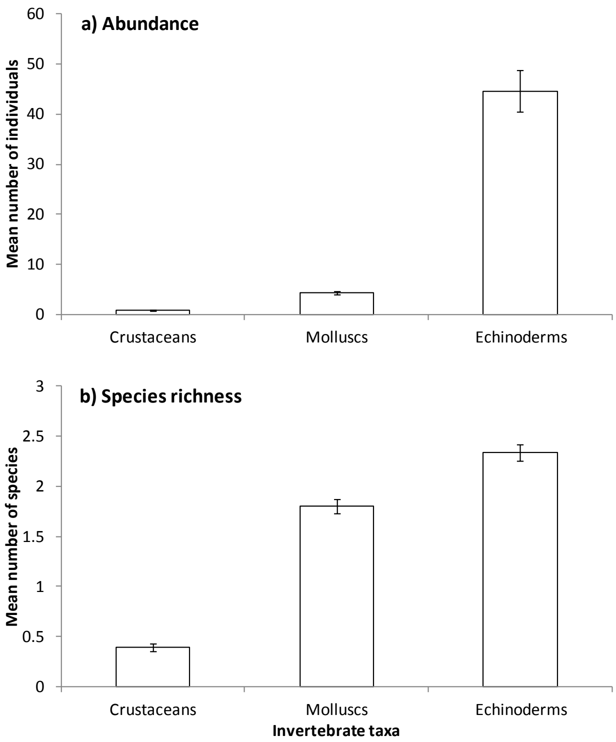

Figure 12 The three major taxonomic groups of invertebrates recorded on Coral Sea reefs. a) Abundance – mean number of individuals per transect, b) Species richness – mean number of species per transect. Error bars = ±1 SE.

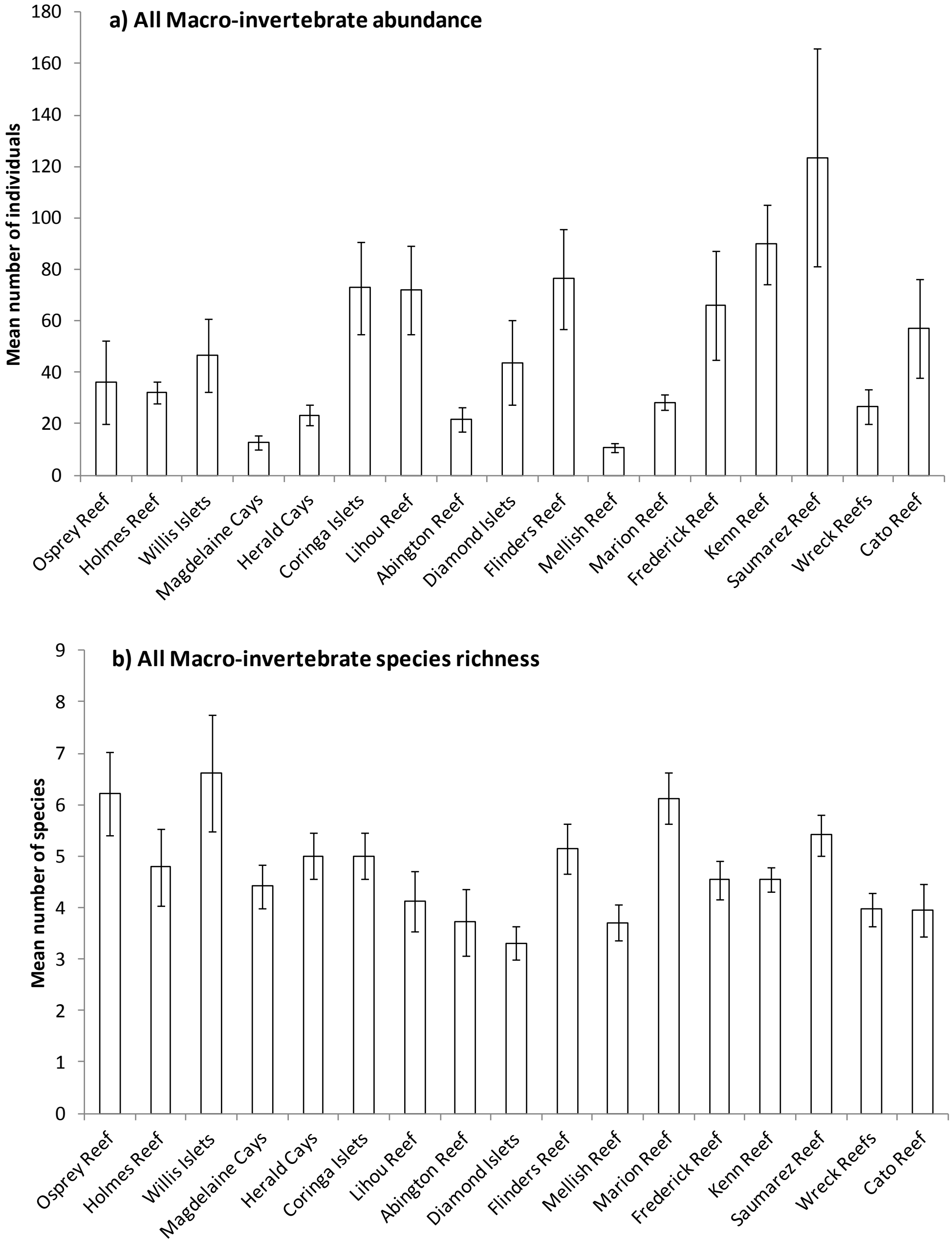

Figure 13 Pooled invertebrate fauna on individual Coral Sea reefs (x-axis: left to right = north to south). a) Abundance – mean number of individuals per transect, b) Species richness – mean number of species per transect. Error bars = ±1 SE.

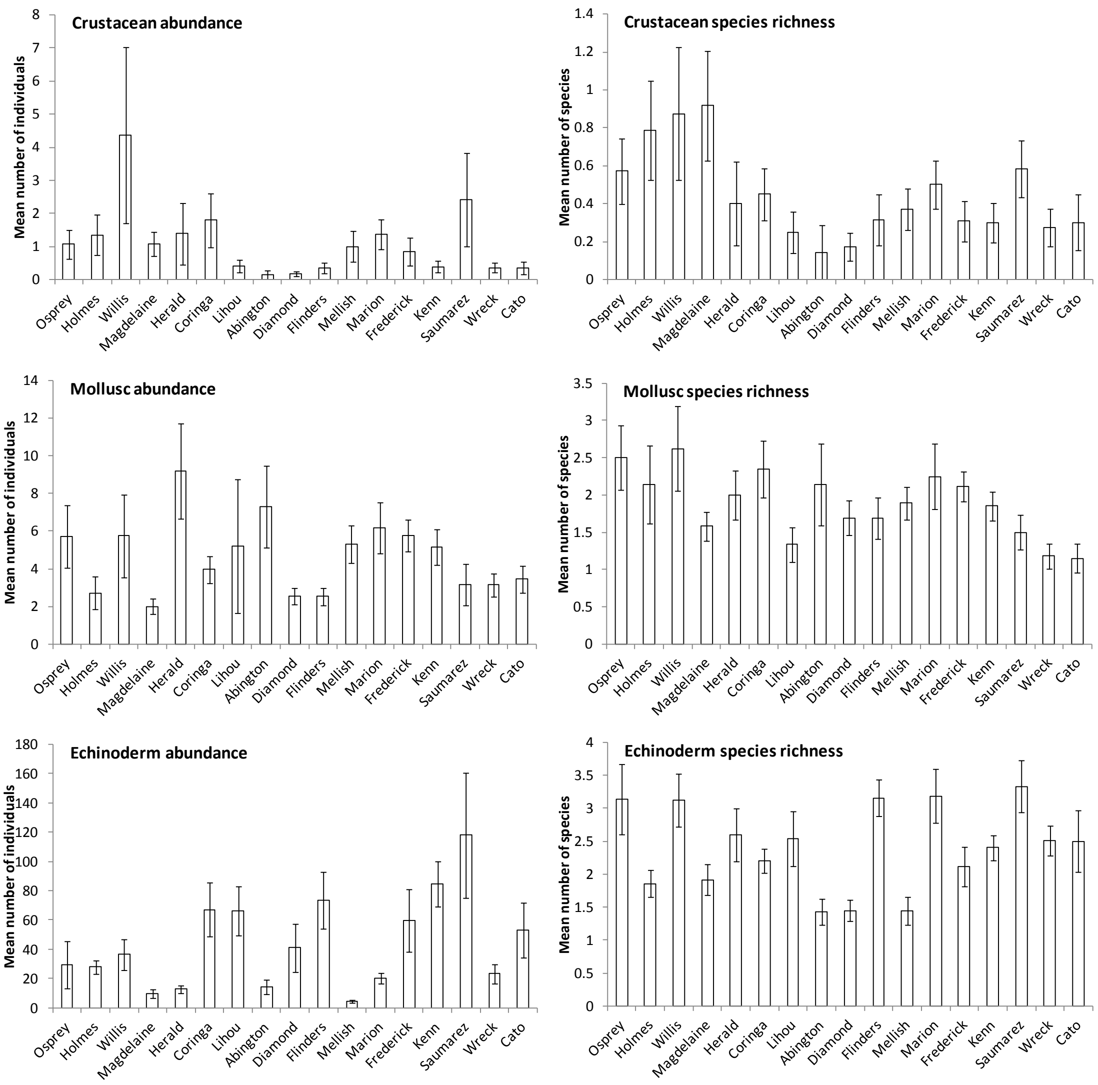

Figure 14 Abundance and species richness of different invertebrate phyla across surveyed Coral Sea reefs. Error bars = ±1 SE. Note differences in the y-axes.

Table 3 Results of General Linear Model testing for difference between reefs in the abundance and species richness of the three major macroinvertebrate phyla.

Variable	F_{df}	Sig.
Crustacean abundance	$2.13_{16,294}$	<0.005
Crustacean species richness	$1.76_{16,294}$	<0.05
Mollusc abundance	$2.75_{16,294}$	<0.001
Mollusc species richness	$2.01_{16,294}$	<0.05
Echinoderm abundance	$5.59_{16,294}$	<0.001
Echinoderm species richness	$3.67_{16,294}$	<0.001

Multidimensional Scaling (MDS) revealed clear distinctions between some reefs based on macroinvertebrate faunas (PERMANOVA $F_{16,141} = 4.5$, $p<0.05$). SIMPER tests showed that the southern reefs had some of the highest dissimilarity values, indicating invertebrate assemblages that were very different from those of other reefs (especially Marion, Kenn and Cato Reefs), ranging between 88 and 95%. Groupings that stood out were reefs with high proportions of the grazing sea urchin *Echinostrephus* sp. (Herald, Lihou, Abington, Flinders, Willis, Holmes, Saumarez), those with greater proportions of sea urchins *Diadema savignyi* and *Echinothrix calamaris* (Wreck, Kenn, Cato, Frederick), and those with larger representations of the hermit crab *Dardanus lagopodes* (Marion Reef), the clam *Tridacna maxima* (Diamond Islets) and a combination of the clam *T. squamosa*, the sea urchin *Diadema setosum* and the nudibranch *Chromodoris annae* (Osprey, Marion). No latitudinal gradient was evident (Figure 15).

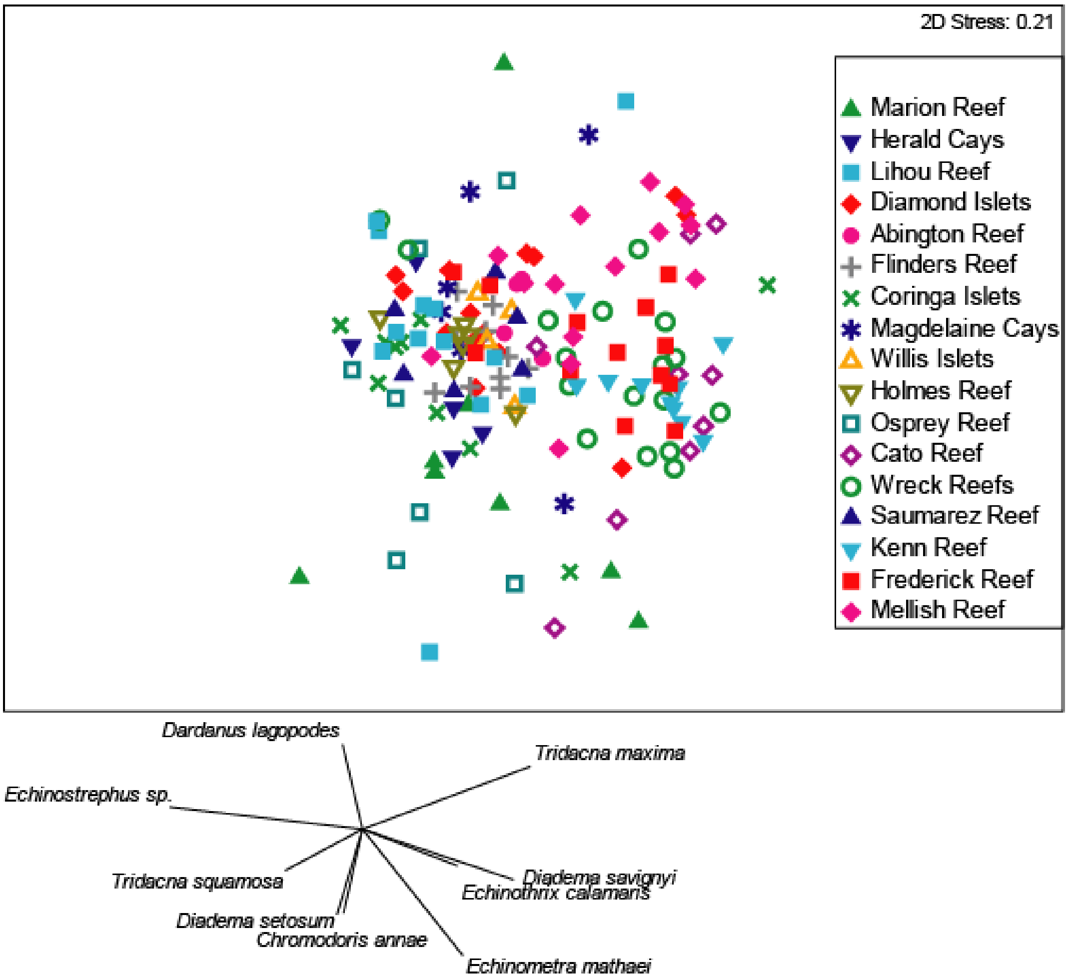

Figure 15 Multidimensional Scaling plot on square-root transformed Bray-Curtis similarity matrix of macroinvertebrate communities on the surveyed Coral Sea reefs. Symbols represent multivariate site means. Vectors are shown for species with a correlation of at least 0.3.

The 1-m wide transects yielded 83 identified species of cryptic fishes, including 33 benthic carnivores, 20 planktivores, 17 piscivores, 6 omnivores, 5 herbivores, 2 corallivores and 2 species that target the scales and skin of other fishes. Osprey Reef had a significantly higher abundance and species richness of cryptic fishes than all other reefs (Figure 16, Table 4). The reefs surveyed differed significantly in the composition of functional groups of cryptic fishes (MANOVA Pillai's Trace = 1.01, $F_{96,1764} = 5.8$, $p < 0.05$).

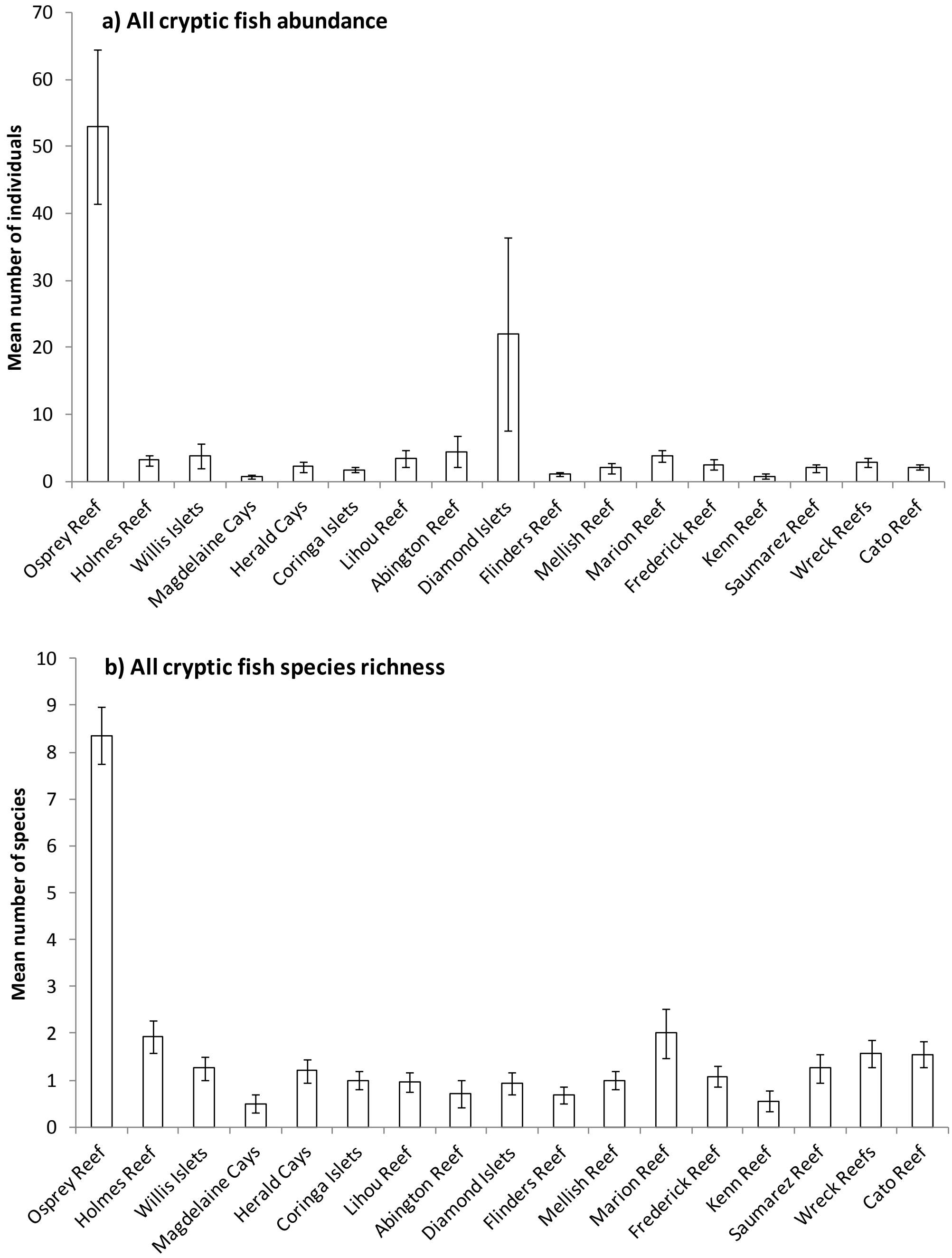

Figure 16 Pooled cryptic fishes recorded on 1-m belt transects on individual Coral Sea reefs (x-axis: left to right = north to south). a) Abundance – mean number of individuals per transect, b) Species richness – mean number of species per transect. Error bars = ±1 SE.

Table 4 Results of General Linear Model testing for difference between reefs in the abundance and species richness of all species.

Variable	F_{df}	Sig.
Abundance (all cryptic fish)	$10.25_{16,294}$	<0.001
Species richness (all cryptic fish)	$10.32_{16,294}$	<0.001

3.5 Fish community

Method 1 fish surveys yielded 507 identified species of fish (Appendix 3), including 38 omnivores, 77 grazers, 90 planktivores, 65 piscivores, 173 benthic carnivores, 33 corallivores, 15 farming damselfishes, and 16 other. The 16 species included miscellaneous trophic groups, such as spongivores, cleaners and fishes that feed on the scales and flesh of other fishes (e.g. *Plagiotremus laudandus*). This adds considerably to the only two previous species lists compiled, for the reefs of the former Coringa-Herald Commonwealth Marine Reserve (372) and Lihou Reef (343) (Ceccarelli *et al.* 2009; Ceccarelli *et al.* 2008).

Reefs in the central Coral Sea had the highest abundances of reef fishes ($F_{16,297} = 5.42$, $p < 0.001$), but species richness showed a declining trend with increasing latitude ($F_{16,297} = 5.24$, $p < 0.001$; Figure 17). Particularly low abundances were recorded on Osprey, Marion, Wreck and Saumarez Reefs (Tukey's Unequal N HSD showing the greatest disparity between these reefs and others), whilst Holmes Reef, the Magdelaine Cays and Abington Reef had particularly high abundance. Holmes Reef and the Herald Cays were particularly species-rich. Biomass was very high on the Magdelaine Cays, a IUCN Ia reef system, and particularly low on Kenn and Cato Reefs ($F_{16,297} = 6.99$, $p < 0.001$; Figure 17). The abundance and biomass of large fishes (> 25cm TL) was highly variable, with particularly high density on Flinders Reef and very low density on Cato, Wreck and Osprey Reefs. The proportion of sharks was highest on the central reefs and on Wreck Reef, and the number of large grazers exceeded all other functional groups together on Flinders Reef, the Willis Islets, Marion Reef, Mellish Reef, Saumarez Reef and Cato Reef (Figure 18).

The density of different functional groups also varied between reefs (MANOVA Pillai's Trace = 1.47, $F_{128,2376} = 4.16$, $p < 0.001$; Figure 19). The distribution of planktivore densities closely matched the between-reef patterns of overall fish density. Farmers and omnivores tended to occur in higher densities north of Marion Reef, while corallivores tended to increase with increasing latitude, in line with coral cover.

MDS of fish functional groups suggested that Coral Sea reefs could tend towards greater proportions of one of three groups: reefs dominated by corallivores and macroalgal browsers (e.g. the southern reefs), reefs with higher representation of excavating and scraping parrotfishes (e.g. Holmes and Osprey Reefs), or reefs with a relatively even assemblage of the remaining functional groups (e.g. the Herald Cays; Figure 20). Adjacent reefs tended to share a similar complement of functional groups; northern reefs and southern reefs formed separate groups, with Osprey Reef an outlier (PERMANOVA $_{F16,142} = 3.08$, $p < 0.05$; see also Appendix 4).

Fish species assemblages also distinguished southern reefs from northern reefs, but with Mellish closer to the northern reefs, Marion intermediate, and Osprey as a distinctive outlier (Figures 20, 21). Key fish species that distinguished the southern reefs included the large piscivores *Aprion virescens* and *Variola louti*, several wrasses (*Anampses* spp. and *Thalassoma* spp.), planktivorous damselfishes (*Chromis atripectoralis* and *C. flavomaculata*) and the corallivore *Chaetodon melannotus*. Northern reefs had high proportions of benthic carnivores (goatfish *Parupeneus* spp., various wrasses) and small mesopredators (*Epinephelus merra*). Abington and Mellish Reefs tended to host larger proportions of the planktivorous damselfishes *Chromis agilis*, *C. atripes* and *C. iomelas*, the obligate corallivore *Chaetodon lineolatus*, the piscivore *Aphareus furca*, and humpheaded wrasse *Cheilinus undulatus*.

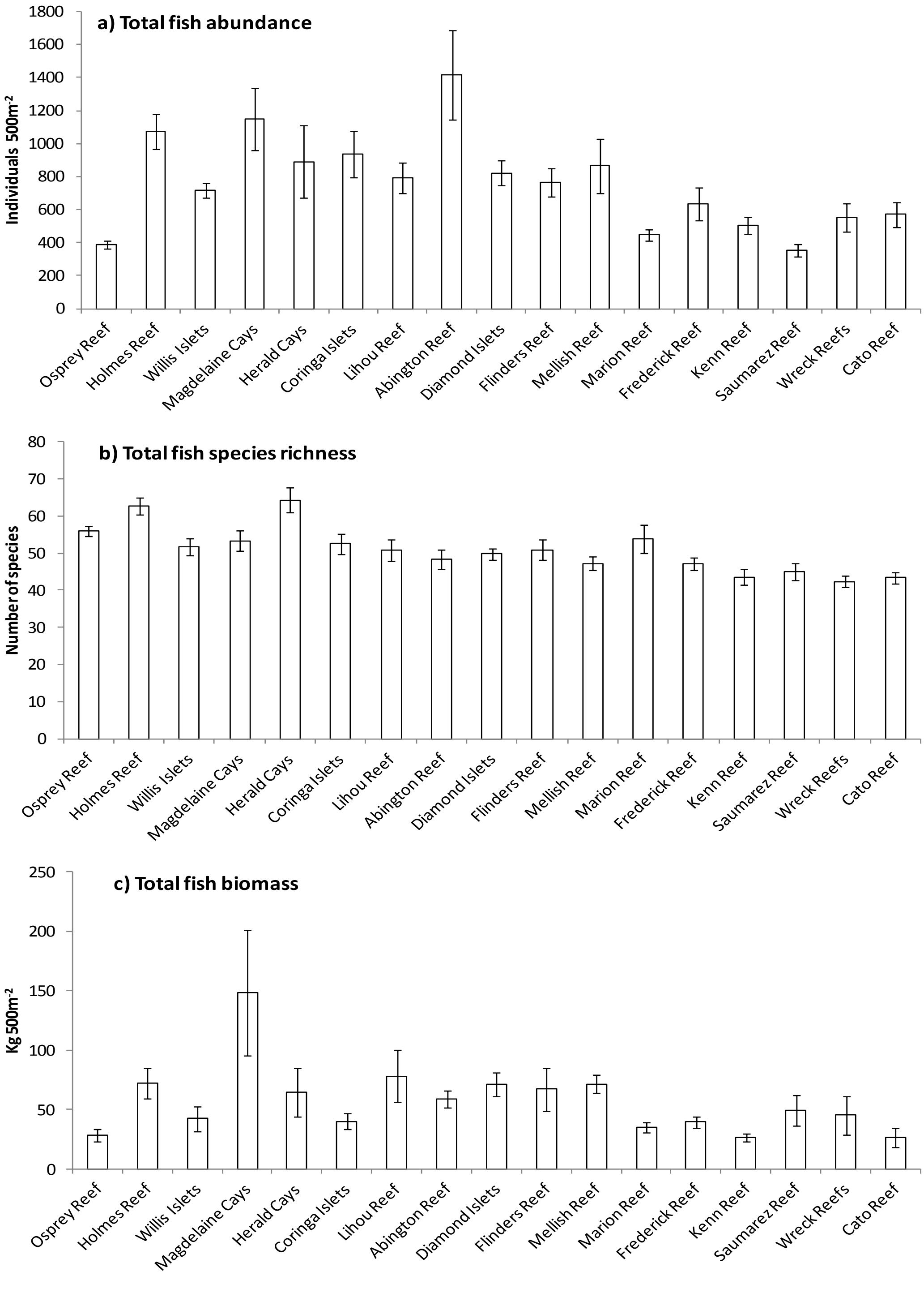

Figure 17 Pooled fish species recorded in 5 m blocks along transects on individual Coral Sea reefs (x-axis: left to right = north to south). a) Abundance – mean number of individuals per transect, b) Species richness – mean number of species per transect., c) Biomass – mean kg of all individuals per transect. Error bars = ±1 SE.

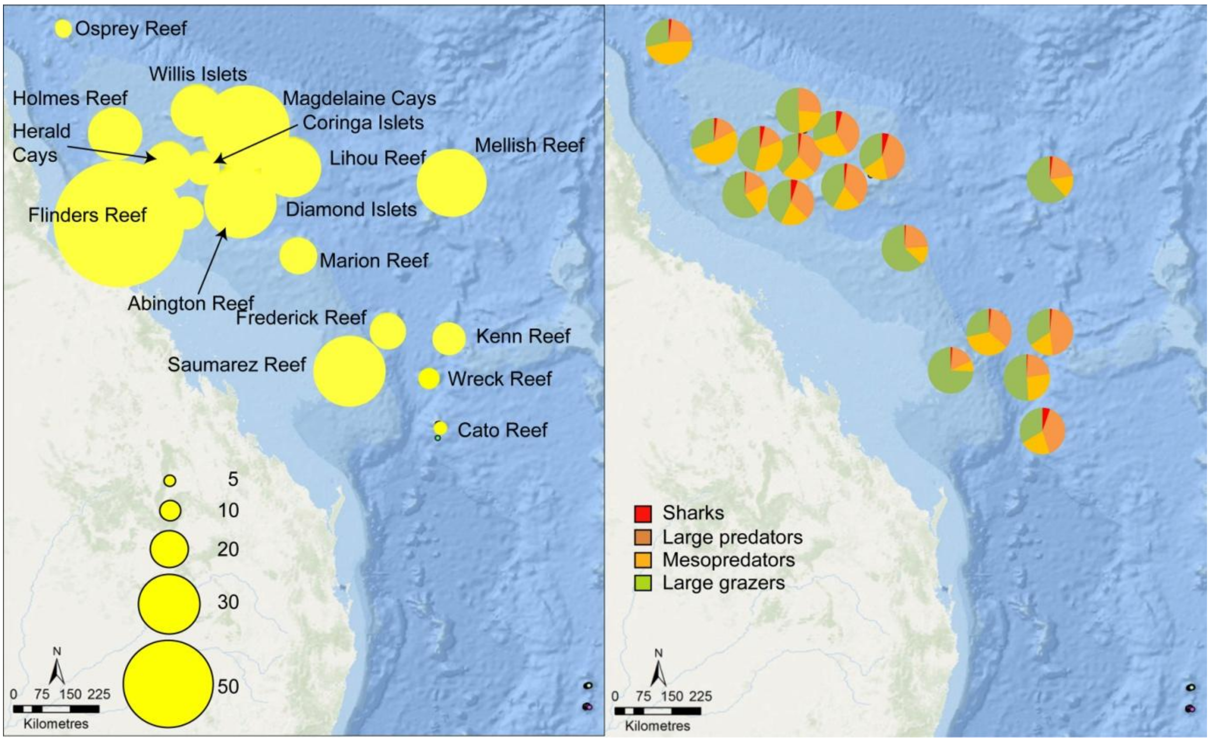

Figure 18 Large fishes (>25 cm TL) recorded in 5 m blocks along transects on individual Coral Sea reefs. Left map: total density of large fishes, scaled by density; right map: proportions of sharks, large predators, mesopredators (small serranids and lutjanids) and large grazers (surgeonfishes, rabbitfishes, parrotfishes and drummers) relative to other large fishes.

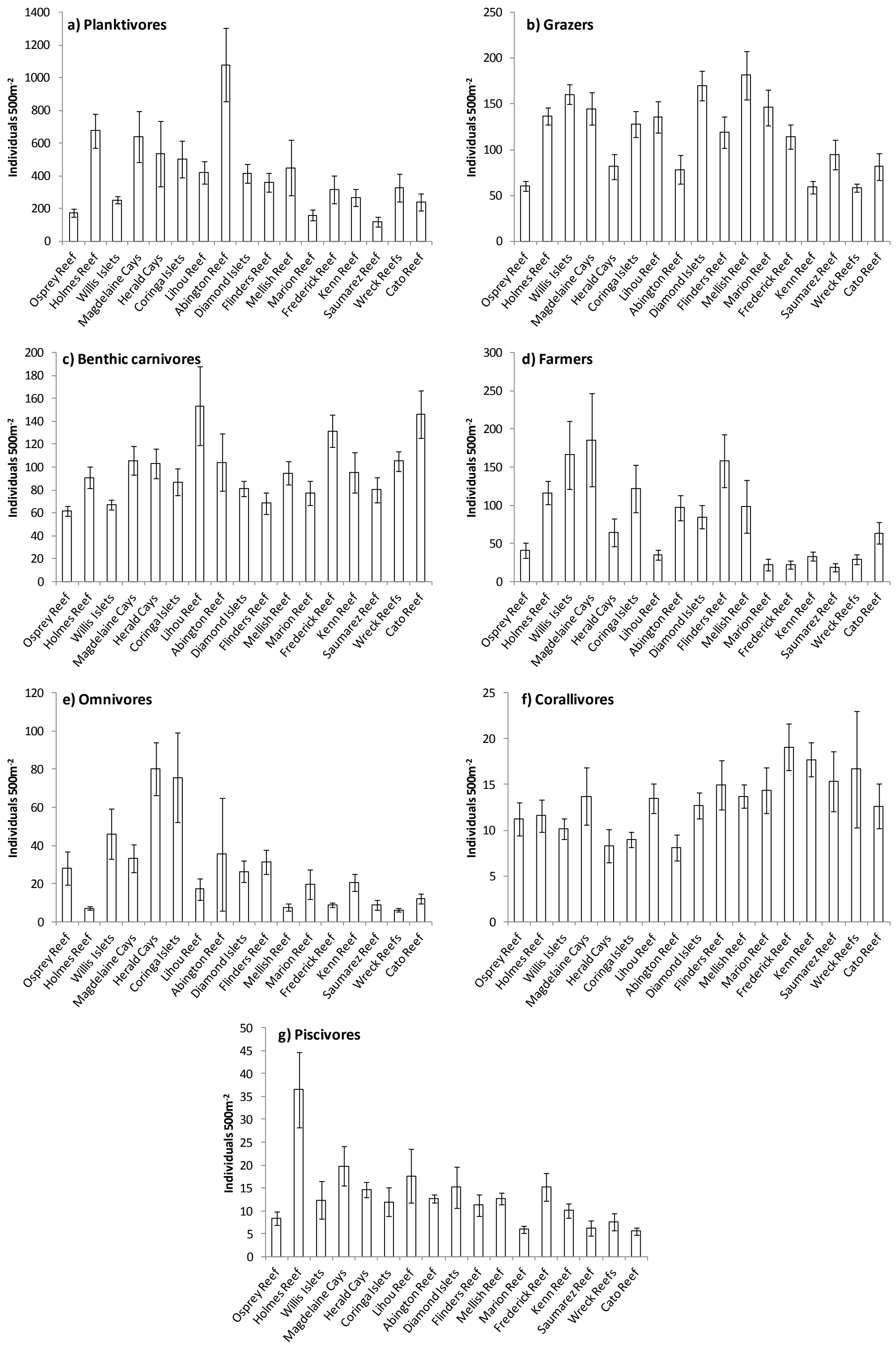

Figure 19 Abundance of different fish functional groups across surveyed Coral Sea reefs. Error bars = ±1 SE. Note differences in the y-axes.

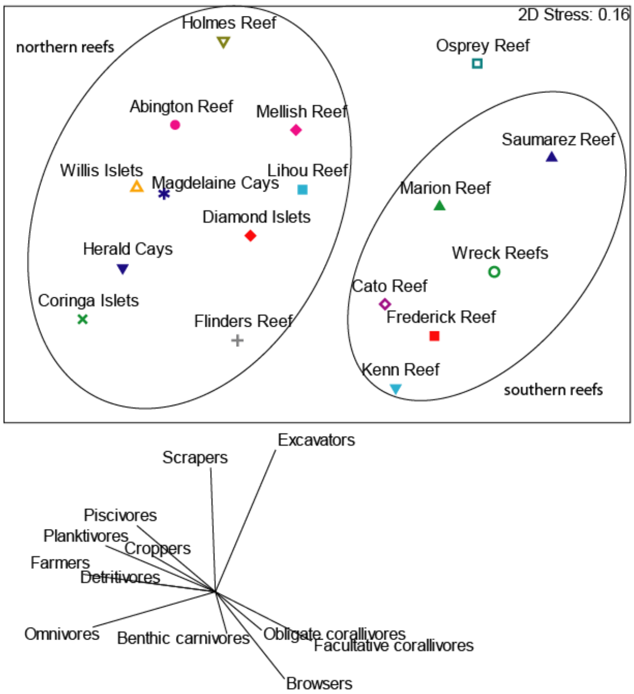

Figure 20 Multidimensional Scaling plot on log (x+1) transformed Bray-Curtis similarity matrix of abundance of fish functional groups on the surveyed Coral Sea reefs. Symbols represent multivariate reef means.

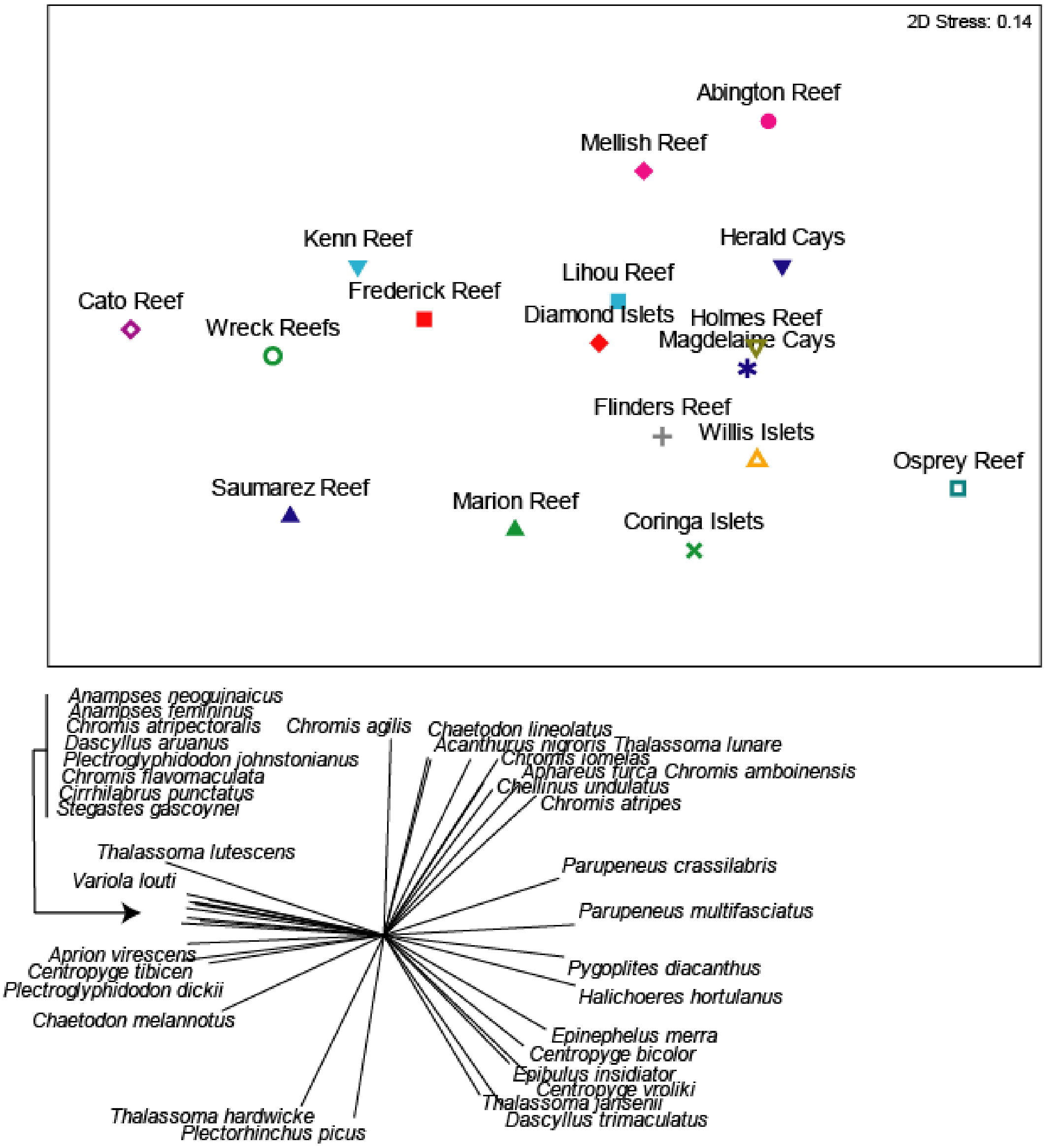

Figure 21 Multidimensional Scaling plot on log (x+1) transformed Bray-Curtis similarity matrix of abundance of fish species on the surveyed Coral Sea reefs. Symbols represent multivariate reef means.

3.6 Fish community drivers

GLMMs indicated latitude was a key correlate of variation in the density of pooled fishes and grazers (and particularly croppers and excavators); detritivore densities were affected by both exposure and latitude, and piscivore densities varied with a combination of latitude and depth (Table 6). Longitude also affected some components of the fish community, either as the single explanatory factor (indeterminate farmers, all farmers combined and fish species richness), or together with depth (omnivores, planktivores) and exposure (intensive farmers). Depth alone was the best factor to explain densities of extensive farmers.

Fish species richness declined with increasing latitude and longitude, and total fish density increased with increasing depth to 16 metres (Figure 22). The longitudinal decline in species richness could be related to the orientation of the coastline and shelf, where more northern and species-rich sites have lower longitude values for equivalent distance from the coast. Corallivores and macroalgal browsers increased with increasing latitude, whist farming damselfishes declined. Reef area appeared to have little influence on the density and species richness of reef fishes; only turf croppers showed a positive correlation with increasing reef size. Depth had a negative influence on corallivore densities and a positive influence on indeterminate farmers (Figure 22).

Correlations between fish functional groups and fine-scale benthic variables (hard coral cover, algal cover and rugosity from photo-quadrats) were generally weak; the strongest relationships were declines in omnivores, piscivores, grazers and farming damselfishes with increasing rugosity and/or coral cover, and a positive correlation between obligate corallivores and rugosity (Figure 23). Sites with the lowest vertical relief, gentlest slope and highest current exposure tended to host a more depauperate fish community than sites with intermediate values, but no clear site groupings were identified according to broad physical variables (Figure 24).

Table 5 Summary of optimal generalised linear models (GLMMs) for predicting reef fish community components. Separate models are shown for key fish functional groups. Models presented are those with the lowest values of Akaike Information Criterion that evaluate the influence of reef, exposure and depth. Significant predictors are in bold (α=0.05). df: degrees of freedom; wAIC: AIC weights.

Metric	Variable	Model	df	AIC	wAIC
Density	All fishes	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	19.5	0.829
	Omnivores	Exposure + **Depth** + Latitude + **Longitude** + Reef Area	5	445.4	0.922
	Croppers	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	323.9	0.945
	Browsers	Null	3	392.1	0.851
	Detritivores	**Exposure** + Depth + **Latitude** + Longitude + Reef Area	7	423.5	0.503
	Scrapers	Null	3	259.7	0.569
	Excavators	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	297.9	0.671
	All grazers	Exposure + Depth + **Latitude** + Longitude + Reef Area	4	74.7	0.674
	Planktivores	Exposure + **Depth** + Latitude + **Longitude** + Reef Area	5	432.4	0.302
	Piscivores	Exposure + **Depth** + **Latitude** + Longitude + Reef Area	5	236.4	0.569
	Facultative corallivores	Null	3	158.1	0.958
	Obligate corallivores	Null	3	236.7	0.829
	All corallivores	Null	3	49.1	0.805
	Ideterminate farmers	Exposure + Depth + Latitude + **Longitude** + Reef Area	4	594.6	0.658
	Extensive farmers	Exposure + **Depth** + Latitude + Longitude + Reef Area	4	567.3	0.347
	Intensive farmers	**Exposure** + **Depth** + Latitude + **Longitude** + Reef Area	8	459.4	0.901
	All farmers	Exposure + Depth + Latitude + **Longitude** + Reef Area	4	501.0	0.759
Species richness	All fishes	Exposure + Depth + Latitude + **Longitude** + Reef Area	4	612.1	0.904

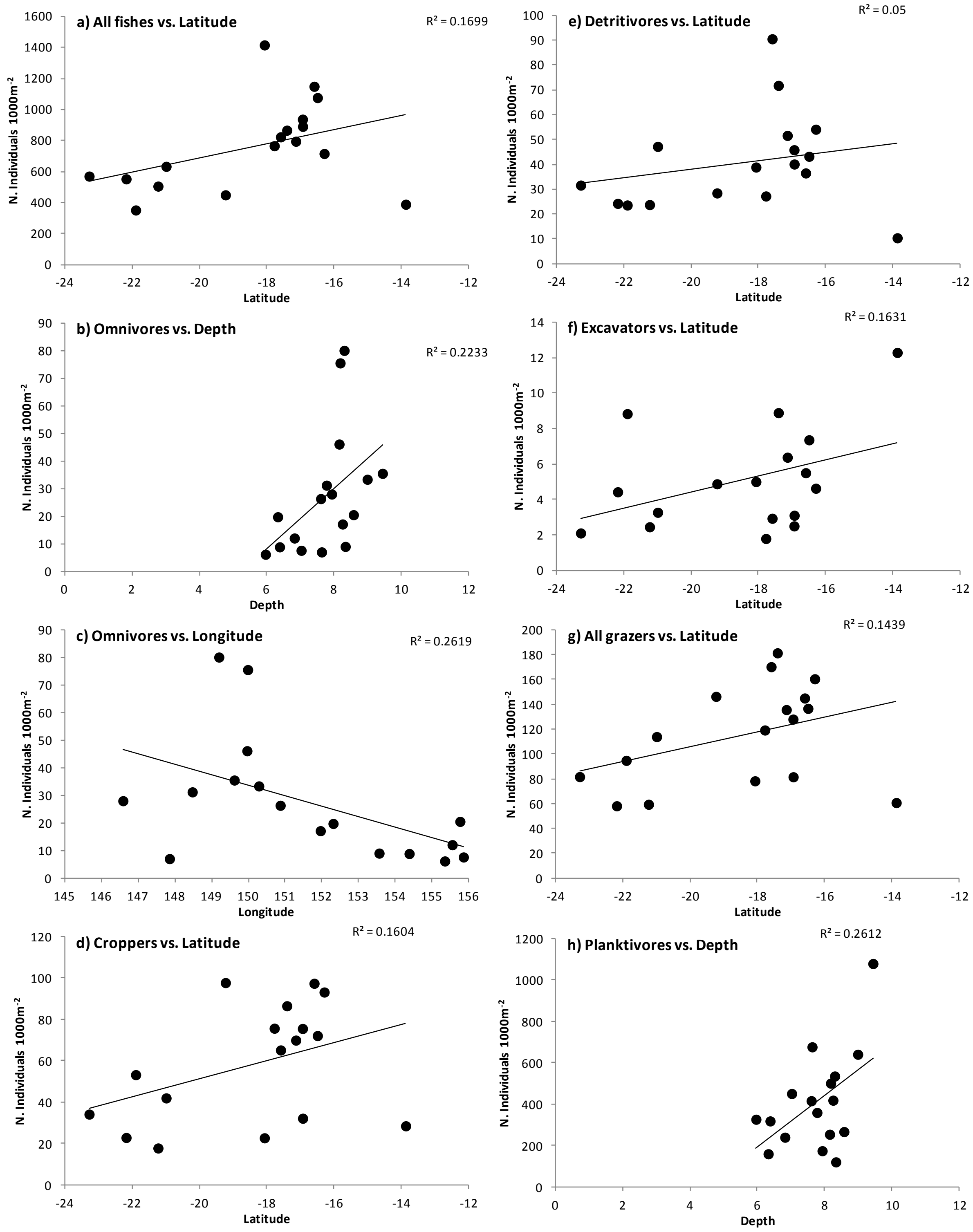

Figure 22 Fish density and species richness by key physical metrics.

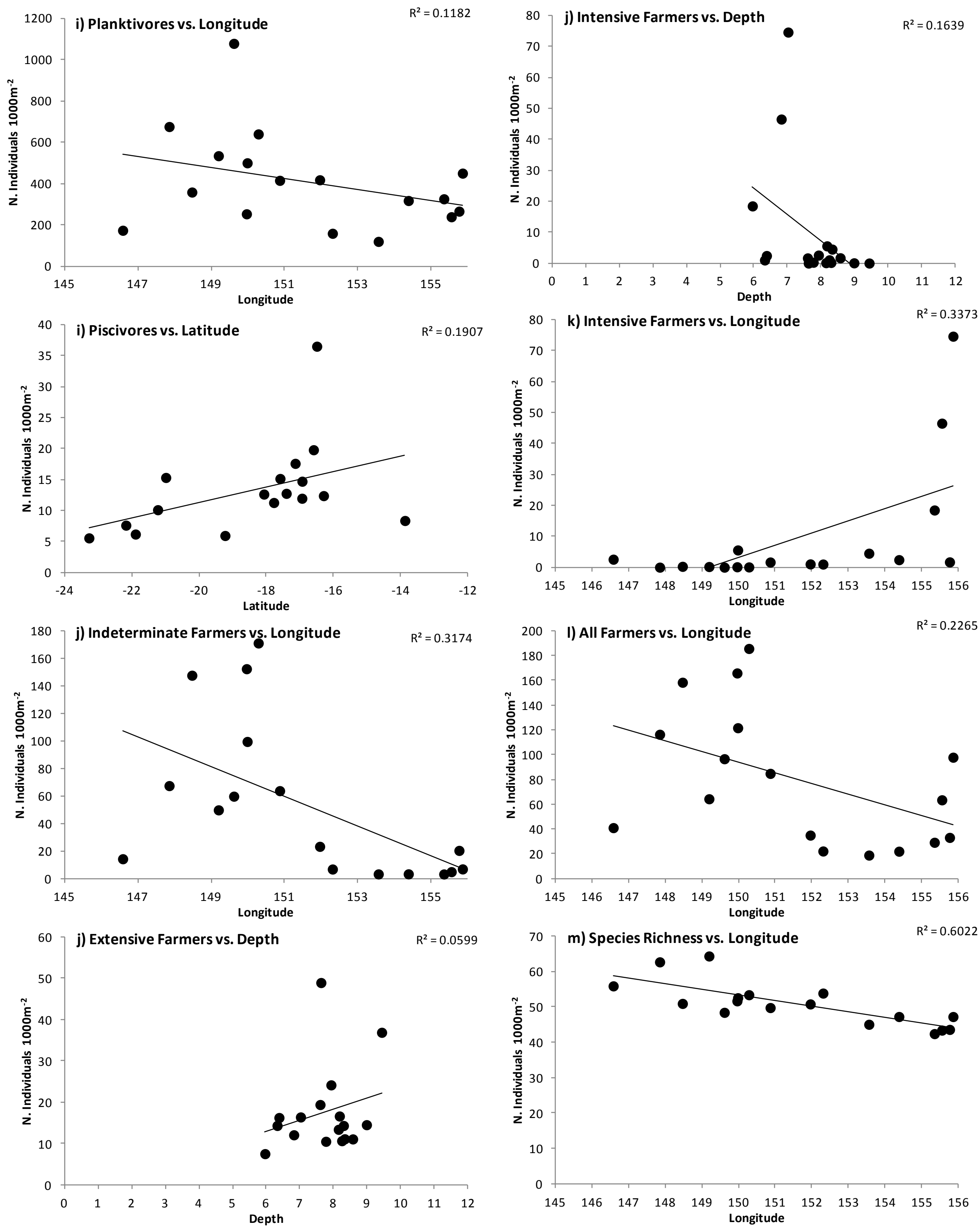

Figure 22 (continued). Fish density and species richness by key physical metrics.

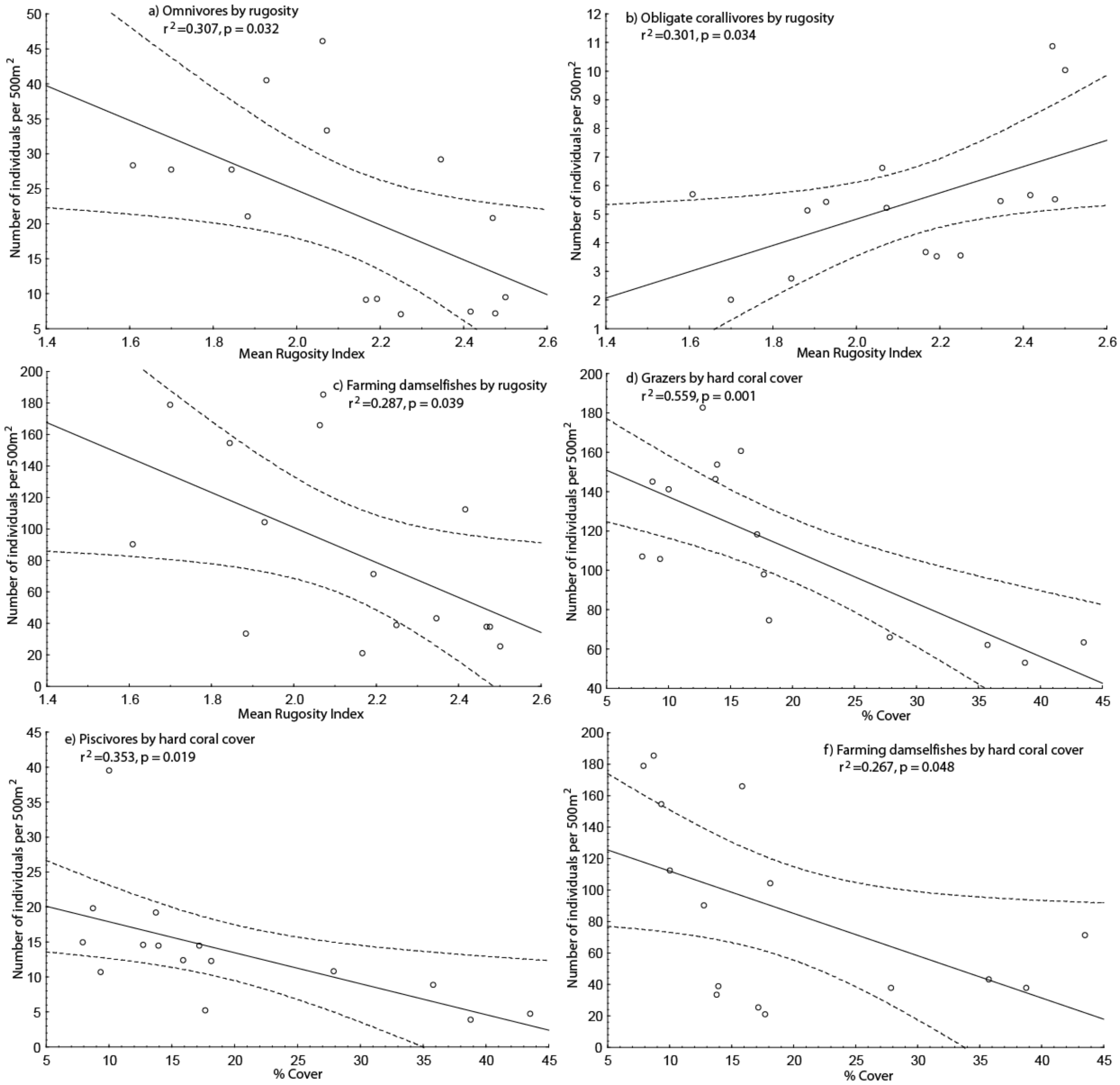

Figure 23 Relationships between croppers / grazers, obligate corallivores, hard coral cover and rugosity for relationships that are significant. Dotted lines: 95% Confidence Intervals for site-level slope estimates.

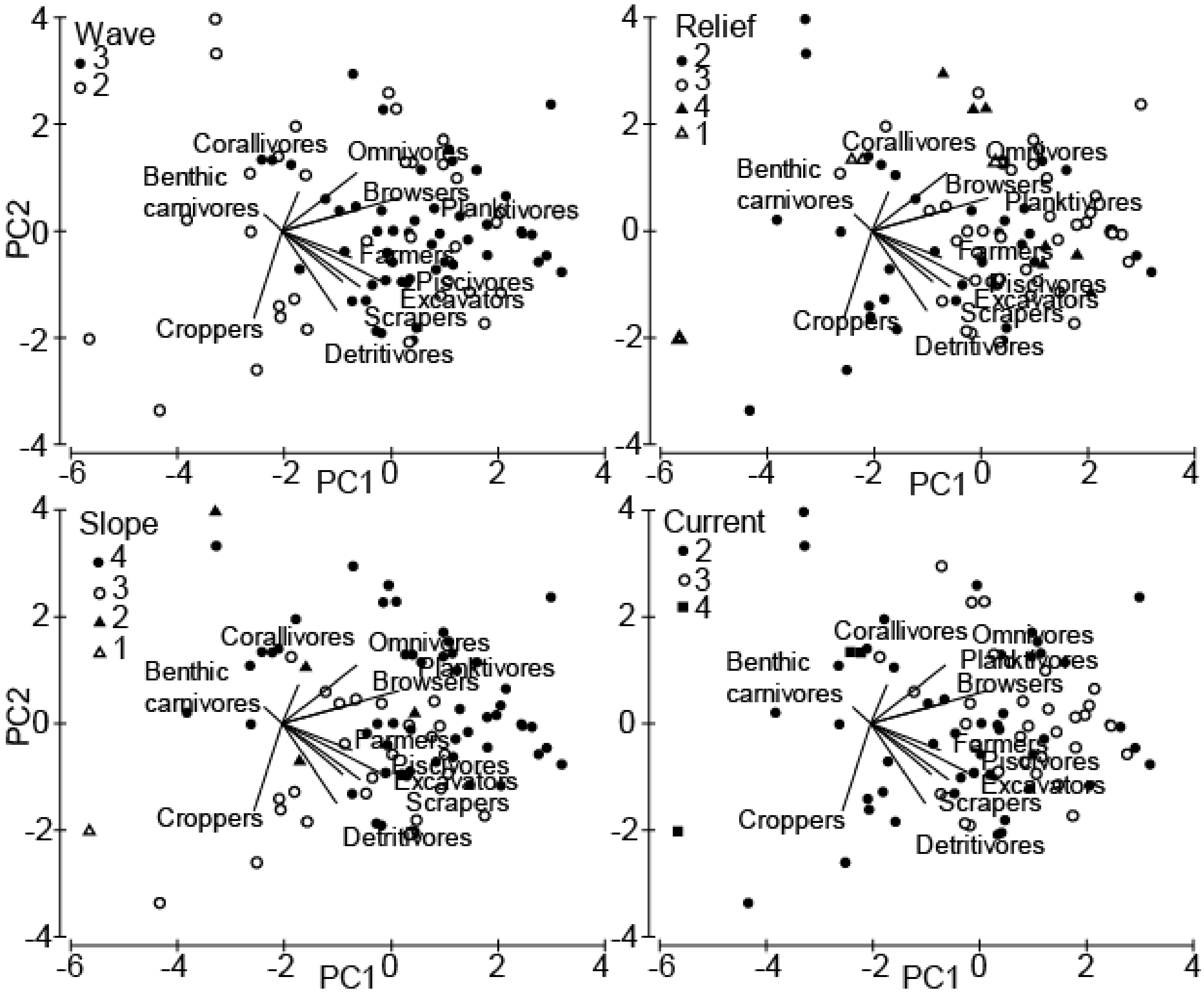

Figure 24 Principal Components Analysis biplot of fish functional groups relative to different site environmental metrics. PC1 accounts for 28.5% of the variability, PC2 for 17.5% (cumulative = 46%). For definition of scores refer to Table 1.

3.7 Reserve status effects – Benthos

Protected reefs (i.e. former Coringa-Herald and Lihou Nature Reserves, which have been managed as IUCN Ia since 1982) and unprotected reefs that currently remain open to fishing within the CMR had approximately similar compositions of benthic categories (MANOVA Pillai's Trace = 0.07, $F_{8,105} = 0.94$, p = 0.49, NS; Figure 25). Some reefs tended towards a dominance of calcified algae, crustose coralline and sponges (e.g. Diamond Islets, Lihou Reef, Holmes Reef), or greater live corals of all morphologies (e.g. Osprey Reef, Cato Reef, Wreck Reefs; Figure 26). Some individual sites had pronounced benthic community characteristics, such as high proportions of algae (e.g. Site CS83 on Mellish Reef) or live corals (e.g. CS6, Marion Reef).

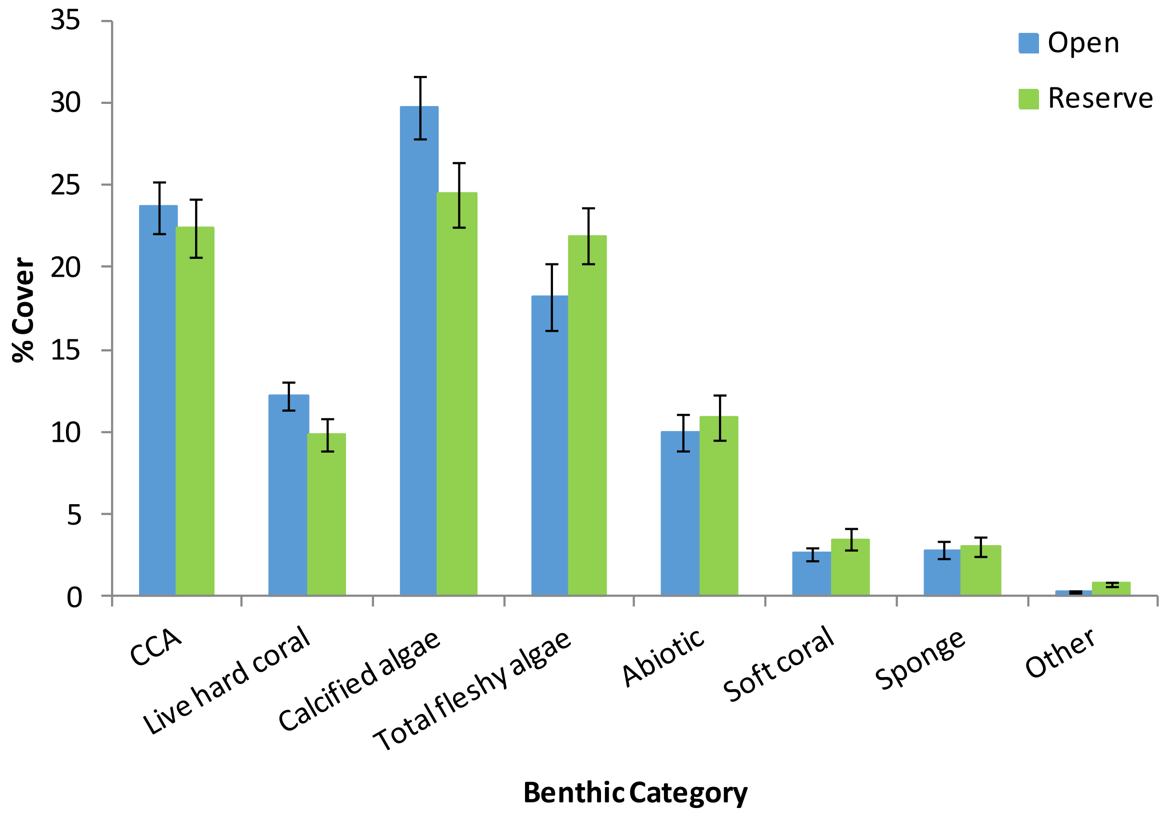

Figure 25 Difference in percentage cover of broad benthic categories between open (to fishing) and Reserve (IUCN Ia) reefs. Error bars = ±1 SE.

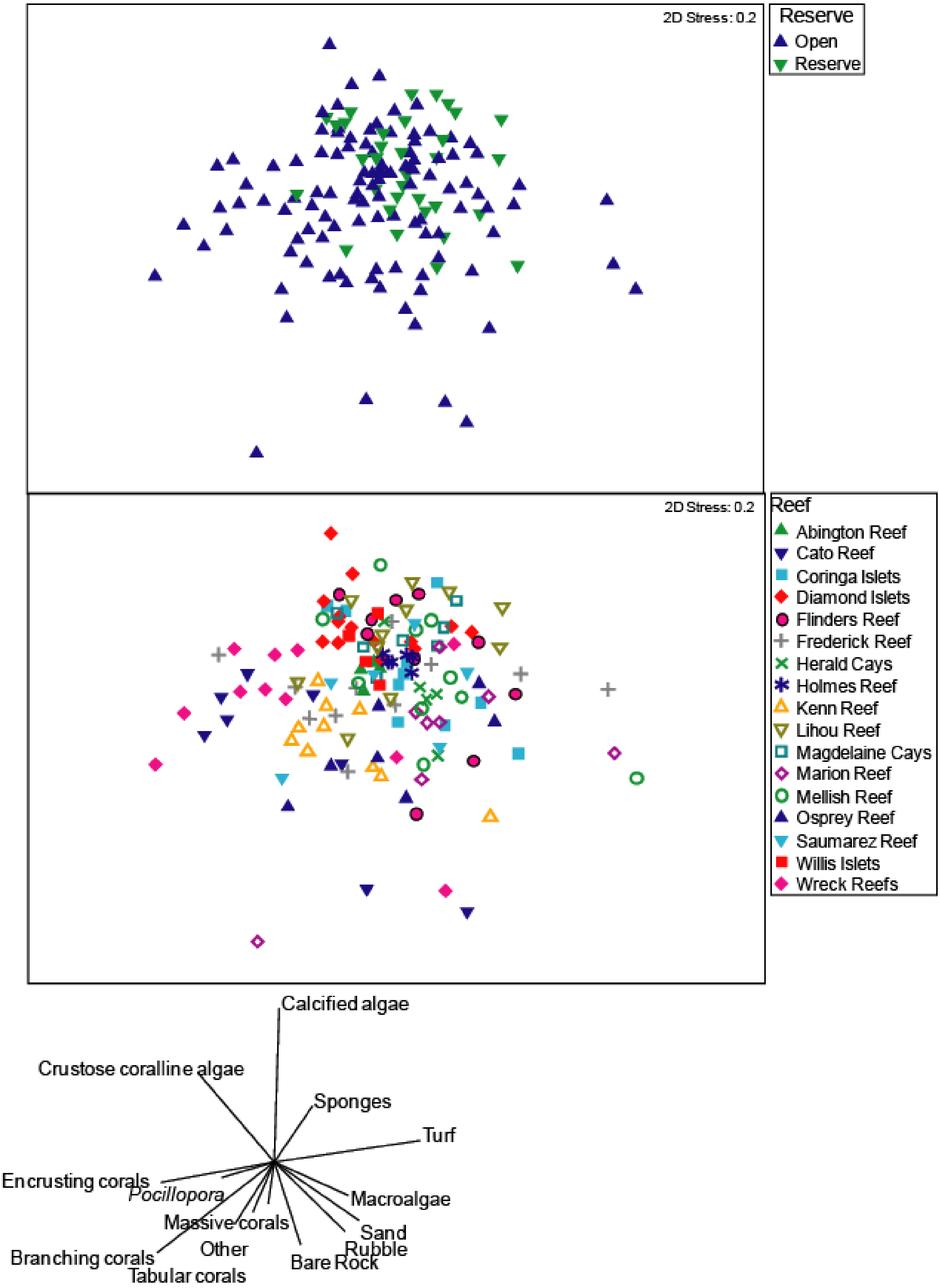

Figure 26 Multidimensional scaling plot on square-root transformed Bray-Curtis similarity matrix of benthic biota on the surveyed Coral Sea reefs. Symbols represent multivariate site means.

3.8 Reserve status effects – Fishes

Reefs protected within IUCN Ia zones showed a trend of higher species richness and biomass of pooled fishes than similar nearby unprotected reefs (Figure 27). For large fishes and large predators, density was similar between IUCN Ia and unprotected reefs, but there was a trend (Table 5) for higher densities of sharks and lower densities of mesopredators and large grazers to be present on IUCN Ia reefs (Figure 28). A total of 71% more large fish biomass was estimated for IUCN Ia reefs compared to similar reefs outside these zones where fishing is allowed. An increase in biomass of 47% and 94% was also estimated for large predators and sharks, respectively. Nevertheless, because of high variability between sites, this result was at the margins of statistical significance, depending on test and transformation applied (Table 5).

Planktivores were by far the most abundant group of fish recorded on all reefs combined, followed by grazers, benthic carnivores and farming damselfishes (Figure 29). Functional group composition varied significantly between IUCN Ia reefs and fished reefs (MANOVA Pillai's Trace = 0.15, $F_{7,121} = 3.1$, $p < 0.01$), with higher densities of omnivores and benthic carnivores on IUCN Ia reefs (Table 5).

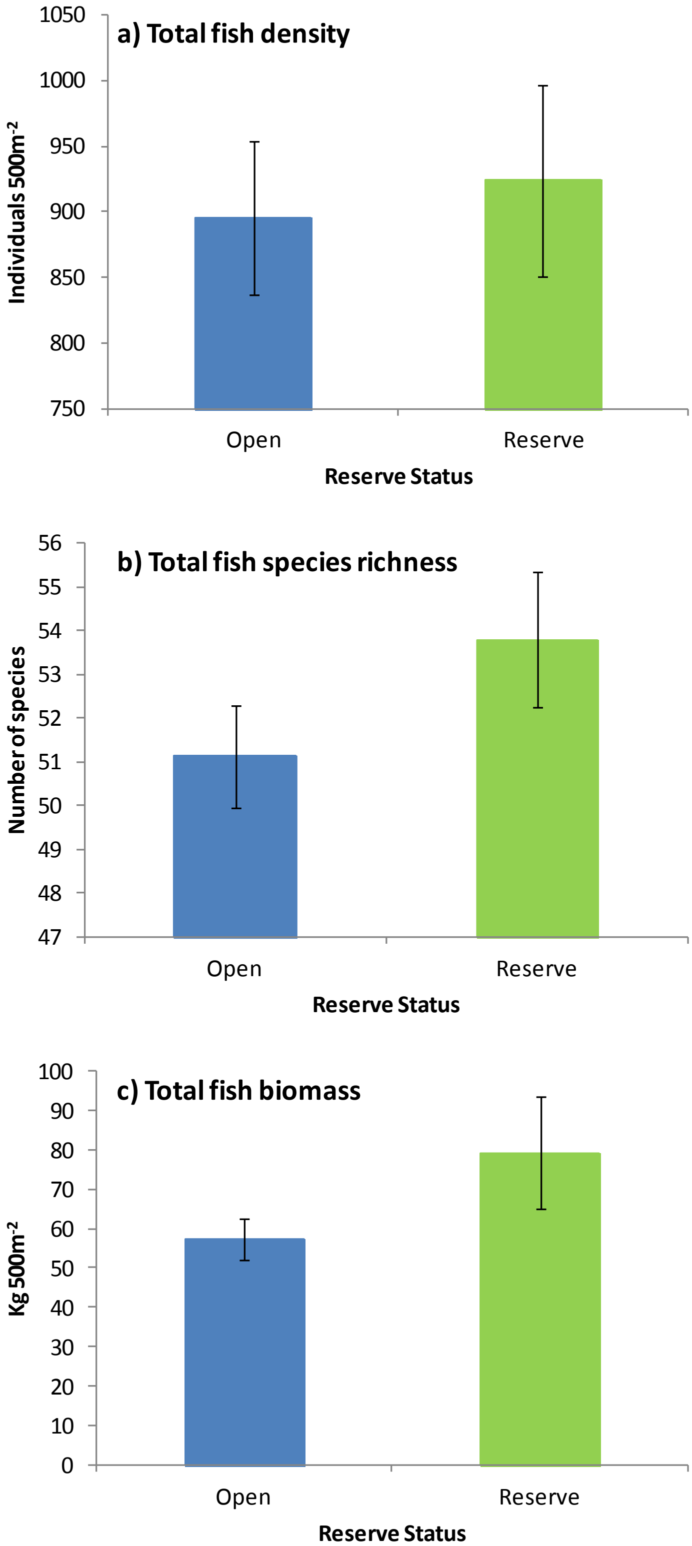

Figure 27 Pooled fish species recorded in 5 m blocks along transects on IUCN Ia (Reserve) and comparable fished (Open) Coral Sea reefs. a) Abundance – mean number of individuals per transect, b) Species richness – mean number of species per transect, c) Biomass – mean kg of all individuals per transect. Error bars = ±1 SE.

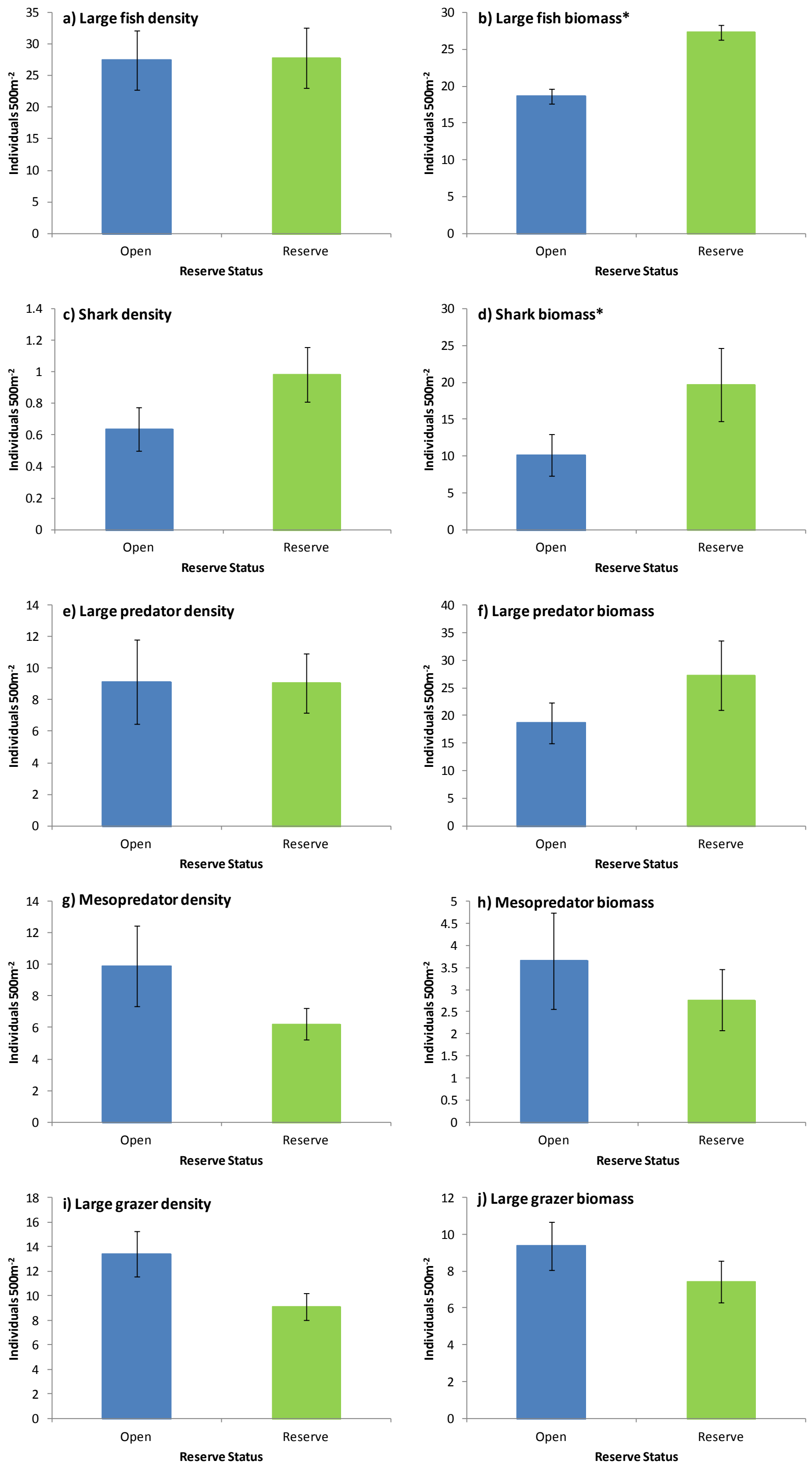

Figure 28 Large fishes (> 25 cm TL), sharks, large predators, mesopredators (small serranids and lutjanids) and large grazers recorded in 5 m blocks along transects on fished (Open) and IUCN Ia (Reserve) Coral Sea reefs. Left column: Abundance – mean number of individuals per transect; right column: Biomass – mean kg of all individuals per transect. * Indicates that the difference between open and reserve values is significant at the level of $p < 0.05$. Error bars = ±1 SE.

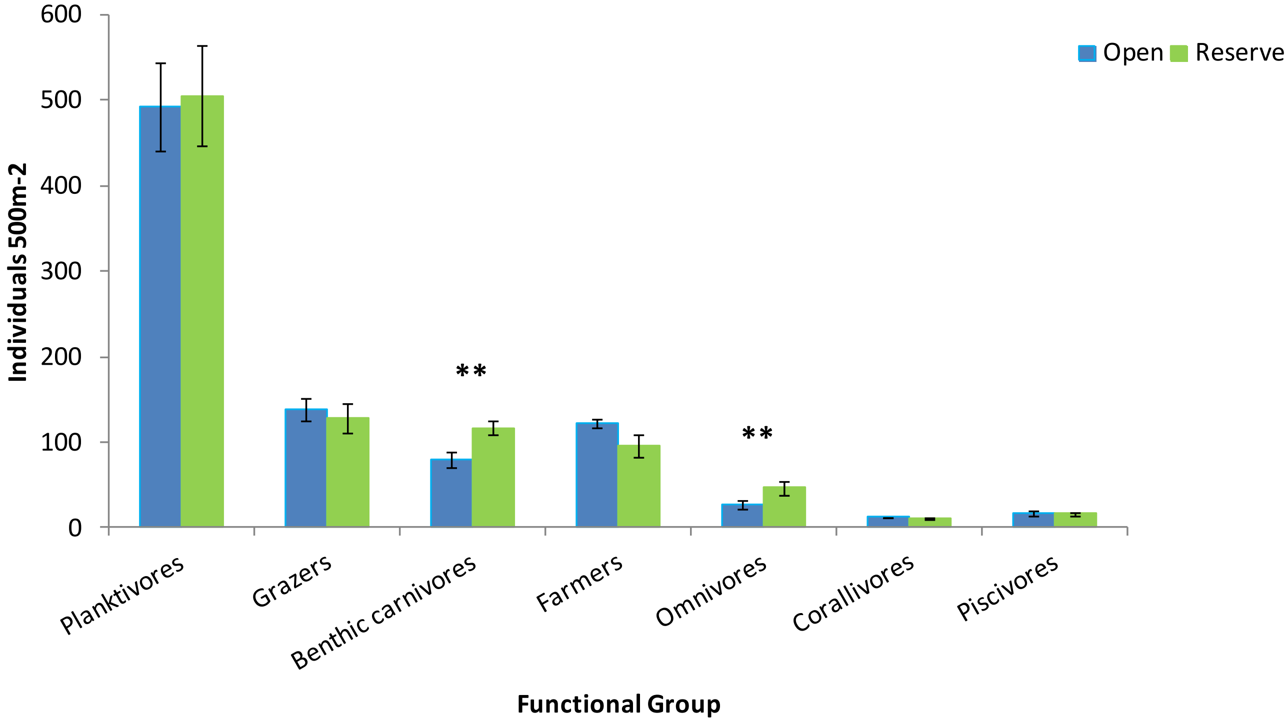

Figure 29 Abundance of fish functional groups on fished (Open) and IUCN Ia (Reserve) Coral Sea reefs. ** Indicates that the difference between open and reserve values is significant at the level of $p < 0.01$. Error bars = ±1 SE.

Table 6 Results of General Linear Model testing for difference between IUCN Ia and fished reefs in the abundance and species richness of functional groups. Bold style indicates a significant difference between IUCN Ia and fished reefs. Species richness and density were log(x+1) transformed, and biomass was log(x+10) transformed.

Metric	Variable	$F_{1,127}$	P
Species richness	All fishes	2.6	0.11
Density	All fishes	1.97	0.05
	Large fishes (> 25cm TL)	0.17	0.68
	Sharks	3.16	0.08
	Large predators	1.71	0.19
	Mesopredators	0.09	0.76
	Large grazers	0.48	0.49
	Planktivores	0.48	0.49
	Grazers	0.58	0.45
	Benthic carnivores	*6.26*	*0.01*
	Farmers	0.33	0.57
	Omnivores	*7.23*	*0.01*
	Corallivores	1.56	0.21
	Piscivores	0.07	0.78
Biomass	All fishes	0.02	0.88
	Large fishes (> 25cm TL)	*4.79*	*0.03*
	Sharks	*5.16*	*0.02*
	Large predators	3.43	0.06
	Mesopredators	0.68	0.41
	Large grazers	0.09	0.76

3.9 Threatened and Protected species

Species listed under the EPBC Act and/or international conservation legislation (CITES, Bonn Convention, IUCN Red List) that were recorded during the surveys include sea snakes (*Aipysurus laevis*, *Emydocephalus annulatus*, *Acalyptophis peronii* and *Aipysurus duboisii*), green turtle *Chelonia mydas*, hawksbill turtle *Eretmochelys imbricata* and flatback turtle *Natator depressus* (all listed as vulnerable under the EPBC Act). Additionally, 37 humphead wrasse (*Cheilinus undulatus*, listed on the IUCN Red List (IUCN 2010) as 'Endangered') and several species of grouper (*Epinephelus fasciatus, E. lanceolatus, E. maculatus, E. merra, E. polyphekadion and E. tauvina*), two of which (*E. polyphekadion* and *E. lanceolatus*) are listed as 'Near Threatened' or 'Vulnerable' on the Red List, were also recorded. The few rays recorded included the spotted eagle ray *Aetobatus narinari*, the ribbontailed stingray *Taeniura lymma* ('Near Threatened'), and the blotched fantail ray *Taeniura meyeni* ('Vulnerable'). No patterns were evident between different reefs in the sightings of rays on transects.

Marion Reef was the northernmost reef with turtle and sea snake sightings. Turtle sightings were few, with only one or two individuals recorded on each of the southern reefs. Sea snakes were more numerous (166 individuals sighted inside and outside transects), with a major separation between southern reefs, where common, and northern reefs, where absent. Highest densities were concentrated on Marion Reef. High densities also occurred on Saumarez, Frederick, Cato and Wreck Reefs (Figure 30). The most common species sighted was the olive sea snake *Aipysurus laevis*; on three of the reefs this was the only species recorded. *Emydocephalus annulatus* was recorded in the region only at Marion and Frederick Reefs – the latter being where the most sea snake species were observed.

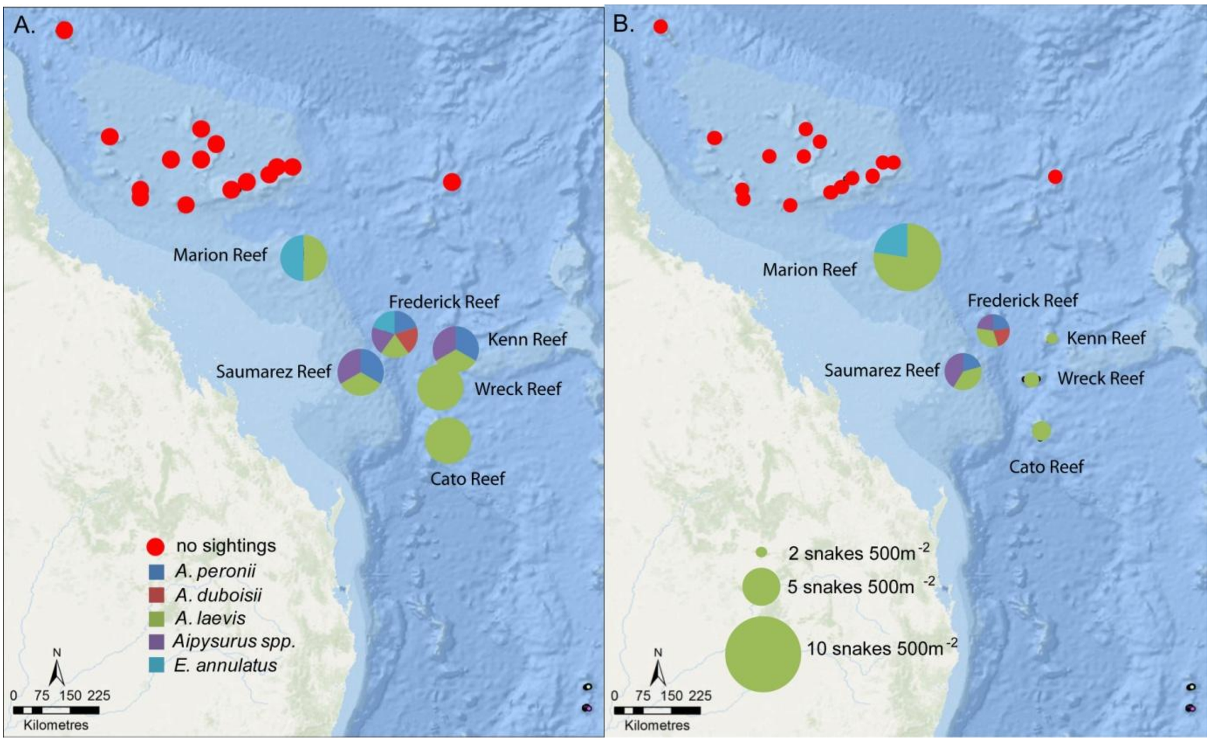

Figure 30 Distribution of sea snake species across Coral Sea reefs. A. All reefs with sea snake sightings using all methods, with unscaled species composition. B. Sea snakes recorded using M1, with bubbles scaled according to mean sea snake density (per 500 m^2) on each reef (circle diameter = density x 2).

4 DISCUSSION

4.1 Regional comparison

These surveys of reef fish and invertebrate communities show that Coral Sea reefs host faunal communities unique within Australian waters. A particularly important result of biogeographic analyses was that Coral Sea reefs were found to be closely aligned with isolated West Pacific oceanic reefs, more so than with GBR reefs, despite the order of magnitude difference in distance (2,500-4,000 km versus 200 km), and a lack of evidence of direct genetic connectivity in recent gene flow studies (Treml *et al*. 2008). Similarly isolated reefs off Australia's NW shelf share reef fauna with Indonesia and the broader Indo-Australasian archipelago, as does the Great Barrier Reef. Biologically, the Coral Sea appears to form part of the Pacific Plate rather than the Australian Plate that extends northwards to New Guinea and eastern Indonesia. A defining feature of Coral Sea reefs and remote Pacific Islands is that the shallow-water biota must arrive by long distance dispersal and inhabit a reduced set of habitat types, with relatively few options for shelter. Small surgeonfishes (*Acanthurus nigrofuscus* and *Ctenochaetus striatus*), damselfish (*Pomacentrus vaiuli*), sea urchins (*Echinostrephus* sp.), and schooling wrasses are predominant species on Coral Sea and Pacific Island reefs, highlighting an assemblage adapted to strong wave conditions (Binning *et al.* 2014) and low-relief topography (Graham and Nash 2013). By contrast, amongst the GBR biota are species endemic to the continental plate, species with low dispersal ability, and species with juvenile stages dependent on estuarine, seagrass and sheltered fine sediment habitats. Such species are largely absent in the Coral Sea.

A rigorous biogeographic comparison of the GBR and Coral Sea had not previously been possible because of a lack of taxonomically-rich data collected with a standardised methodology. As previous surveys suggested, the Coral Sea hosts fewer species than the GBR (e.g. Ceccarelli *et al.* 2008); however, rather than simply being a subset of GBR species, a characteristic Coral Sea species ecoregion exists. For example, the Coral Sea macroinvertebrate assemblage frequently included high densities of grazing sea urchins, while grazing invertebrates do not have a strong defining influence on community structure across as many of the sites surveyed in the GBR. Within each trophic group, different species dominated the Coral Sea community compared to the GBR.

Collectively, Coral Sea reefs host a group of Pacific reef-associated species that are less frequently found together in Australian waters, and that lack healthy self-reproducing populations in other IUCN Ia zones. While similar habitat types are present within Australia's EEZ amongst the offshore reefs off Western Australia, those tropical reefs have a distinctly Indo-Australian archipelago rather than Pacific character in their species composition (e.g. Gaither *et al.* 2011); this makes the Coral Sea reefs unique within Australian waters.

Apex predators such as sharks are rapidly disappearing from the world's oceans (Myers and Worm 2003); in many cases they are used as indicators of "healthy" marine ecosystems (e.g. Graham *et al.* 2010). In particular, oceanic reefs furthest away from human influence have been suggested to support a locally "inverted biomass pyramid", where large apex predators dominate (Friedlander and DeMartini 2002; Sandin *et al*. 2008). This study shows that the Coral Sea supports reef shark densities similar to remote locations with little or no human exploitation, suggesting that despite a history of fishing on most Coral Sea reefs (reviewed in Ceccarelli *et al*. 2013), food web structure appears largely intact.

4.2 Patterns of biodiversity and community structure

Individual reefs have distinctive ecological characteristics, suggesting a varied set of ecological values extending across the Coral Sea. Many reefs are dominated by low-relief carbonate pavement overgrown with calcified and turf algae, with substantial cover of crustose coralline algae. Central Coral Sea reefs of the Queensland Plateau generally had low coral cover; the only reefs in this area with coral cover > 15% are Willis Islet (15.9%) and Abington Reef (18.1%). In contrast, the only reef south of Marion Reef with coral cover < 15% is Mellish Reef (13.9%); the highest coral cover estimates (> 30%) were recorded on Wreck Reef and Cato Reef in the south, and also Osprey Reef, the northernmost reef surveyed. This high cover of encrusting coral at Osprey may be due to the reef's geomorphology, which was more similar to the pinnacles typical of the southern Coral Sea than the reef complexes characteristically found on the Queensland Plateau. Coral assemblages of most reefs were generally dominated by encrusting corals. The exceptions were the Herald Cays, where massive corals were dominant, Cato Reef with a high percent cover of branching corals, Kenn Reef and Wreck Reef, with a similar representation of encrusting and branching corals, and Marion Reef, which had higher cover of branching and tabular corals (Figure 31).

(a) Encrusting coral, Coringa-Herald, 2007

(b) Massive coral, Coringa-Herald, 2007

(c) Branching coral, Lihou Reef, 2008.

(d) Tabular coral, Lihou Reef, 2008.

Figure 31 Examples of coral growth forms.

Echinoderms dominated the macroinvertebrate community on Coral Sea reefs in terms of abundance, and both echinoderms and molluscs were particularly species-rich. The low number of crustaceans present in surveys probably resulted from the cryptic nature of many members of this subphylum, rather than low richness.

The dominant species of invertebrates sampled were sea urchins of the genera *Echinostrephus*, *Diadema* and *Echinometra*; these are common tropical grazers and surface bioeroders. Bioerosion by echinoids is usually greater on exposed reefs, potentially leading to a net loss of carbonate; on the other hand, herbivory by sea urchins may be important for creating free space for coral settlement and growth, especially in areas with low rates of fish herbivory (Bronstein and Loya 2014). Some reefs also had high densities of tridacnid clams (Mellish and Abington Reefs), but only the Herald Cays had significant densities of the giant clam *Tridacna gigas*. This species is harvested throughout the Indo-Pacific, has largely disappeared from many reefs throughout its range and is currently listed as “Vulnerable” by the IUCN (Wells 1996); seemingly healthy densities within a Commonwealth Marine Reserve in the Coral Sea may provide a source population for surrounding reefs.

Despite their relatively low coral cover, many of the central Coral Sea reefs had high abundance and richness of reef fish species. Holmes Reef, the Magdelaine Cays and Abington Reef all had densities in excess of 1,000 individuals per 500 m^2; Holmes Reef and the Herald Cays hosted over 60 species per 500 m^2. Some of the southern reefs, by contrast, had densities at or below ~500 individuals per 500 m^2 (e.g. Marion, Saumarez and Kenn Reefs).

Cryptic fish species that were dominant on more than one reef included arc-eye hawkfish *Paracirrhites arcatus*, black-sided hawkfish *P. forsteri*, epaulette soldierfish *Myripristis kuntee*, red-streaked blenny *Cirripectes stigmaticus*, blackstriped combtooth blenny *Ecsenius fourmanoiri* and spotted fringefin goby *Eviota guttata*. Cryptic fishes are typically neglected from most non-destructive survey methods, and most reef fish survey or monitoring programs only include a selection of non-cryptic, diurnal species for which density estimates are likely to be most robust (English *et al.* 1997). Regardless, cryptic species should be regarded as an important focal group for field surveys as they are an integral component of coral reef trophodynamics, and typically possess much higher rates of endemism than more conspicuous fishes (Paulin and Roberts 1993). Dedicated sampling has highlighted their high numerical abundance on coral reefs, and their significant contribution to the conversion and recycling of primary production (Depczynski and Bellwood 2003). Dedicating a component of underwater visual census methods to searching for cryptic fishes, as undertaken for RLS surveys, represents an appropriate non-destructive, cost-effective way for including this faunal group in marine reserve biodiversity assessment and monitoring. Yet the limitations must be recognised, that species which recurred in most samples tend to be those visible through careful searching, commonly resting on the substratum (rather than within crevices). Further limitations may include detectability through observer bias or subratratum type (cryptic fishes being more easily detedcted against certain surfaces, and on less complex substrata).

Non-cryptic fishes ranged widely in abundance and biomass, with some reefs having particularly high (e.g. Abington Reef) or low (e.g. Saumarez Reef) abundance or biomass (e.g. high: Magdelaine Cays; low: Kenn Reef). Abundance patterns were driven to a large extent by planktivores (especially species of the genus *Chromis*), which typically occur in large schools, especially in habitats with high water movement. Benthos-associated damselfishes (e.g. *Pomacentrus vaiuli*, *P. philippinus*), schooling wrasses (e.g. *Thalassoma amblycephalum*), and small-bodied surgeonfishes (e.g. *Acanthurus nigrofuscus*) can also occur in high densities, influencing overall density estimates; these appear to be typical Coral Sea reef fish species. In contrast, biomass patterns are typically driven by few large-bodied individuals, such as sharks, groupers and coral trout (e.g. *Plectropomus laevis*), and large grazers (e.g. *Bolbometapon muricatum*).

The primary driver for broad-scale variability in the surveyed communities was latitude, with a general increase in coral cover and coral-associated fishes, and a concomitant decline in algal cover and grazing fishes. One driver of this difference may be that reefs north of approximately 19°S experience a greater frequency of tropical cyclones, which have been one of the most important causes of large-scale coral decline on the Great Barrier Reef (De'ath *et al.* 2012). During the past 20 years, 22 tropical cyclones with a trajectory inside the Coral Sea region have affected reefs north of 19°S (roughly coinciding with the latitude of Marion Reef, south of which coral cover was significantly higher than to the north), compared with 14 cyclones that have passed south of Marion Reef (http://www.bom.gov.au/cyclone/history/#reports). Of the cyclones affecting southern reefs, only one was a severe category 5 cyclone, and its trajectory remained primarily over the continental shelf and the GBR. Fish abundance and species richness declined with increasing latitude, in line with global marine latitudinal gradients and the increasing distance away from the Coral Triangle centre of marine biodiversity (Roberts *et al.* 2002; Sanciangco *et al.* 2013). Additionally, a division of the fish species composition between northern and southern reefs – with the point of division roughly around the latitude of Marion Reef – suggests the presence of at least two bioregions within the Coral Sea.

The distinct characteristics of northern and southern reef fish faunas are most likely driven by a combination of reef geomorphology and the influence of major currents. The southern reefs are mostly the pinnacles of isolated seamounts at the northern end of the Tasmantid Seamount Chain, whilst the northern reefs formed on high points of the major carbonate plateaux during lower sea levels, and have maintained pace with sea level rise to form emergent present-day reefs and cays (Davies *et al.* 1989). The exception is the northern-most reef, Osprey Reef, which is an isolated pinnacle more similar to the seamount reefs of the south. In fact, Osprey Reef is an outlier in the grouping of reefs according to fish functional groups; hosting a combination of northern / tropical species and species typical of steep-sided pinnacle reefs (Graham and Nash 2013). The influence of the major jets of the South Equatorial Current that flow from east to west through the Coral Sea and divide against the Australian continental shelf at about the latitude of the southern Queensland Plateau may also reduce the mixing of species between the northern and southern portions of the Coral Sea, effectively creating a dispersal barrier (Ceccarelli *et al.* 2013).

The distinction between northern and southern reefs was even stronger when the functional groups of fishes were considered, suggesting differences in food webs and associated ecological processes on northern and southern reefs. Southern reefs were dominated by corallivores and browsers (fishes that graze on fleshy macroalgae, as opposed to low-lying algal turf), whereas northern reefs had a greater variety of trophic groups, including piscivores, planktivores, farming damselfishes and grazers. The higher coral cover of the southern reefs explains the greater importance of corallivores (Wilson *et al.* 2009). Despite the latitudinal decline in algal cover, enough primary production evidently exists to sustain large populations of browsing fishes. Grazing fish are widely considered to be a functionally important component of the reef fish fauna and a critical element in the maintenance of healthy coral assemblages by removing competing macroalgae (Bellwood *et al.* 2004; Burkepile and Hay 2011; Mumby *et al*. 2006). Protection of grazing fishes is seen as an important goal in the management of coral reefs; they are considered a component of one of the key ecological features, or KEFs, within the East Marine Region (Dambacher *et al.* 2011).

4.3 Performance of existing Commonwealth Marine Reserves

Reefs in long-term IUCN Ia zones (Coringa-Herald and Lihou Reef) had proportionally greater values of key attributes of the fish community relative to similar fished reefs. Total fish biomass was estimated to be 70% higher, shark biomass 90% higher, and large predator biomass 50% higher in the IUCN Ia zones. However, because of high habitat variability between sites and reefs, these estimates were at the margins of statistical significance, depending on test and transformation applied. Further surveys are needed to accurately measure the contribution of protection to increased fish biomass and further recovery of fish communities in the central Coral Sea area. Repeat surveys will be particularly useful in this regard as changes in animal numbers at a site through time are typically much lower than variability between sites (Edgar and Barrett 2012), consequently much more powerful statistical tests of protection can be applied.

Observed ecological differences between IUCN Ia reefs and those open to fishing agreed well with expectations. While the methods used were not specifically designed to provide robust estimates of large wide-ranging predators—longer and wider transects are usually advocated for that purpose (Ayling and Choat 2008)—the biomass of species groups such as predators targeted by fishers was enhanced in Coral Sea IUCN Ia zones. Elsewhere, well-enforced marine reserves have repeatedly been shown to greatly enhance total biomass and size of fished species within boundaries (Edgar *et al.* 2014; Graham *et al.* 2011; Russ *et al.* 2008). To be most effective in recovery of fish biomass, marine reserves need large size, an extended period of protection, a no-take policy, good enforcement, and physical habitat barriers (Edgar *et al.* 2014). Long-term Commonwealth Marine Reserves (IUCN Ia zones) in the Coral Sea are exceptional in the global context in their potential to meet all of these standards.

Our surveys did not show any significant difference in coral cover or other habitat characteristics between IUCN Ia reefs and those open to fishing in similar latitudes with similar wave exposure regimes. This was not surprising given that Australian fisheries avoid destructive fishing practices that physically damage reefs. Furthermore, when marine reserves contribute to change in benthic communities, this is usually a consequence of a “trophic cascade”, where the removal of top predators has flow-on effects through the food web to primary producers and habitat engineers (Mumby *et al.* 2006). It is probable that, given the complexity of coral reefs, the 20 year period since fishing prohibitions were enacted in reserves was probably too short for trophic effects to clearly manifest through reef food webs. While recovery of top predators in reserves is likely to affect all levels of the food web through the long-term, such indirect effects typically require multi-decadal time periods to become apparent (Babcock *et al.* 2010). Thus, through the long-term, coral populations in protected zones may show relative increases in cover (Selig and Bruno 2010), and possibly enhanced resilience to disturbance, largely through the maintenance of herbivorous fish populations. Such changes remain to manifest detectably, and research in other parts of the world suggest these to be context-dependent. Future surveys should specifically aim to test predictions associated with trophic cascades associated with return of top predators.

4.4 Ecological values and vulnerability

4.4.1 SEA TURTLES

This survey provides a first quantitative indication of sea turtle and sea snake occurrence on many of Coral Sea reefs. Previous information exists on nesting turtles on the northern reefs, but no previous reports have documented turtles frequenting the southern reefs. Six of the world's seven species of marine turtle are known to occur in the Coral Sea: green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*), loggerhead turtle (*Caretta caretta*), leatherback turtle (*Dermochelys coriacea*), flatback turtle (*Natator depressus*) and Olive Ridley turtle (*Lepidochelys olivacea*); three of these species were sighted during RLS surveys (green, hawksbill and flatback turtles). Coral Sea cays provide nesting habitat for a number of marine turtles, especially the green turtle (Harvey *et al.* 2005). Green turtles from the Coral Sea cays form a distinctive genetic group that appears in the Papua New Guinea/Torres Strait harvest (Moritz *et al.* 2002), while other green turtle population migrate through the Coral Sea between inshore Queensland foraging grounds and nesting beaches in New Caledonia and Vanuatu. The strong evidence for southward migration of turtle hatchlings along the East Australian Current (Boyle *et al.* 2009) suggests connectivity throughout the Coral Sea reef system.

4.4.2 SEA SNAKES

Anecdotal evidence and published articles (Heatwole *et al*. 1978) have suggested high sea snake numbers on Coral Sea reefs in the past, however, this is a first estimate of the densities of sea snakes and their distribution. Southern Coral Sea reefs possessed very high densities of sea snakes, especially the olive sea snake *Aipysurus laevis;* however, no sea snakes were observed on northern reefs, with a sharp line biogeographically dividing northern and southern regions. Reefs with sea snakes present typically included multiple species.

The apparent absence of sea snakes from northern Coral Sea reefs may reflect a historical pattern, or it may be a recent phenomenon. Alarming and unexplained declines in sea snake populations have recently occurred in other parts of the world (Lukoschek *et al.* 2013), and local extinctions reported from parts of the Great Barrier Reef (Lukoschek *et al.* 2007). Our dataset provides a baseline for tracking future trends in sea snake abundance across the region, and, if future local extinctions do occur, then these reef community-level data should also provide insight into potential causes and consequences. For example, if population decline follows increased abundance of a particular fish predator then the survey data should reflect this.

Coral Sea reefs probably provide some refuge for eastern Australian sea snake populations through isolation, and also because the southern reefs may fall outside environmental bounds of whatever causative agent is responsible for population loss. Marine protected areas may or may not safeguard sea snakes from dramatic declines measured recently (Lukoschek *et al.* 2013).

Overall, a primary ecological value provided by Coral Sea reefs is their relatively natural state, free from substantial direct human threats. Large-scale coral reef degradation is becoming ever more apparent worldwide (Halford and Caley 2009; Polidoro and Carpenter 2013). Coral cover in the GBR has declined by 50% in the last 27 years (De'ath *et al.* 2012), and more than half of the world's reefs are now considered severely degraded, with one-third of the world's 845 species of reef-building corals at elevated risk of extinction (Carpenter *et al.* 2008). By contrast, Coral Sea reefs have a low human footprint and exist in a setting that remains relatively pristine (Halpern *et al.* 2012). The Coral Sea thus offers an environment that is closer to natural condition than most other tropical seas. In future, relatively unimpacted reefs such as those of the Coral Sea are likely to provide refugia for coral reef populations, as well as representing invaluable scientific yardsticks for assessing the magnitude of global changes induced by human activities.

(a) *Aipysurus laevis*, Olive seasnake

(b) *Acalyptophis peronii*, spiny headed seasnake

(c) *Aipysurus duboisii*, Dubois' seasnake

(d) *Emydocephalus annulatus*, turtle-headed seasnake

Figure 32 Seasnakes of the Coral Sea

4.4.3 RECOMMENDATIONS

Comprehensive monitoring of Coral Sea reefs is recommended every three to five years. This should include assessment of any decline in sea snake populations, ecological changes associated with direct and indirect effects of fishing in protected zones, and broad scale regional ecological shifts associated with changing climate.

If available resources allow only a reduced set of sites to be monitored on future occasions, sites covered should include reefs within each of the southern, central and northern regions to span the geographic extent of the Coral Sea, and both the IUCN Category Ia protected reefs and also reefs open to fishing. The specific site list for monitoring needs to be guided by the final zoning for the Coral Sea CMR (currently in review). This may require the addition of new sites in order to provide suitable fished reference locations for sites in protected zones, with surveys at such sites completed as soon as possible, preferably before any changes to onground changes in protected are enacted. Thus, a key recommendation is is that the locations for future monitoring activities of shallow reefs in the Coral Sea CMR are informed by the combination of the sites surveyed for this report and the final zoning scheme.

Ideally, future monitoring will emply the same methods as used here, to provide complete comparability and the most powerful means to detect change. However, methods could usefully be expanded to include additional surveys designed to estimate density and biomass of large-bodied predators. An appropriate method for such surveys is timed swims, where the density and size of large predators are counted in fixed time intervals of, for example, 10 minutes. Timed swims are preferably calibrated for distance by towing a recording GPS behind the diver.

Research priorities to guide the monitoring and evaluation should include development and selection of a suite of indicators which inform on changes in reef condition and biodiversity value of relevance to the performance of sanctuary zones, as well changes associated with warming and storms.

Further research questions of relevance to managers when determining the condition of biodiversity in the Coral Sea, identifying key threats, and understanding management options include:

- Investigation of factors limiting seasnake distributions, including assessment of ecological data for associations among species and functional groups, as well as with environmental data. This may require collection of additional habitat or environmental data, which may be piggy-backed with, or included in reef monitoring.
- Detailed habitat mapping.
- Detailed mapping of distribution and impact of natural disturbances, including cyclones and the influence of reef size and georgraphic complexity in influencing the role of storms in shaping reef habitat and communities. This should ideally include comparison with the Great Barrier Reef and other coral reef systems to allow the Cora Sea reefs to be considered in the broader regional geographic context.
- Broader analyses which use the Coral Sea CMR as a reference yardstick for assessing changes at locations with similar wave-exposed coral reef environments but greater human-related stresses. In this way, monitoring of the Coral Sea CMR can provide much wider benefits for MPA and off-reserve management of marine biodiversity.

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Appendices

APPENDIX 1

List of sites and Reserve Zoning.

Reef	Site name	Orientation	Blocks	IUCN Ia
Abington Reef	Abington Reef central	Central	4	
Abington Reef	Abington Reef Dark Gutter	Central	4	
Abington Reef	Abington Reef Passage	Central	4	
Abington Reef	Abington Reef SW point	Central	4	
Cato Reef	Cato Bommies	Southern	4	
Cato Reef	Cato East	Southern	10	
Cato Reef	Cato Entrance	Southern	4	
Cato Reef	Cato Lagoon 1	Southern	4	
Cato Reef	Cato Lagoon South	Southern	4	
Cato Reef	Cato NE	Southern	5	
Cato Reef	Cato North	Southern	4	
Cato Reef	Cato Passage	Southern	5	
Cato Reef	Cato Wreck	Southern	4	
Coringa Islets	Chilcott Bommie	Central	5	✓
Coringa Islets	Chilcott Islet bommie	Central	4	✓
Coringa Islets	Chilcott Islet Haven	Central	4	✓
Coringa Islets	Chilcott Islet inshore reef	Central	4	✓
Coringa Islets	Chilcott Islet SW inner reef	Central	4	✓
Coringa Islets	Chilcott Islet SW outer reef	Central	4	✓
Coringa Islets	Chilcott NE	Central	5	✓
Coringa Islets	Chilcott South	Central	5	✓
Coringa Islets	South West Islet Bommie	Central	5	✓
Coringa Islets	SW South West Islet	Central	6	✓
Diamond Islets	Central Diamond Islet	Central	4	
Diamond Islets	Central Diamond Islet Bald Bommie	Central	6	
Diamond Islets	Diamond Cay Islet	Central	4	
Diamond Islets	East Diamond Islet lagoon	Central	5	

Diamond Islets	East Diamond Islet NW	Central	5	
Diamond Islets	East Diamond Islet Swim	Central	6	
Diamond Islets	East Diamond Islet Tower	Central	3	
Diamond Islets	South Diamond Islet	Central	4	
Diamond Islets	South Diamond Islet Swim Through	Central	4	
Diamond Islets	South Dimond Milky	Central	4	
Diamond Islets	Tregosse Reef	Central	4	
Diamond Islets	Tregrosse Abundance	Central	5	
Diamond Islets	Tregrosse Outlier Reef	Central	4	
Diamond Islets	Tregrosse Outlier Reef Down	Central	4	
Diamond Islets	Tregrosse Reef Cricket Pitch	Central	5	
Flinders Reef	Flinders Cay Storm Bommie	Central	4	
Flinders Reef	Flinders Reef Bommie	Central	4	
Flinders Reef	Flinders Reef Entrance	Central	3	
Flinders Reef	Flinders Ribbon Reef South Cay	Central	4	
Flinders Reef	Flinders Ribbon Reef South Cay E bommie	Central	4	
Flinders Reef	Flinders Ribbon Reef South Cay SW	Central	4	
Flinders Reef	Flinders S Cay Bommie	Central	4	
Flinders Reef	South Flinders Horseshoe centre	Central	4	
Flinders Reef	South Flinders Horseshoe NW	Central	4	
Flinders Reef	South Flinders Horseshoe SW	Central	4	
Frederick Reef	Frederick Bosom	Southern	5	
Frederick Reef	Frederick Leo	Southern	5	
Frederick Reef	Frederick Lighthouse	Southern	5	
Frederick Reef	Frederick Passage	Southern	6	
Frederick Reef	Frederick Ridge Rock	Southern	5	
Frederick Reef	Frederick Split Rocks	Southern	5	
Frederick Reef	Fredrick Central Bommie	Southern	4	
Frederick Reef	Fredrick central reef	Southern	5	
Frederick Reef	Fredrick Observatory Cay	Southern	4	
Frederick Reef	Fredrick Reef north bommie	Southern	6	
Frederick Reef	Fredrick Reef SW	Southern	5	
Frederick Reef	North Fredrick Bommie	Southern	4	
Frederick Reef	Quay West Bommie	Southern	4	
Herald Cays	NE Herald Back Reef	Central	6	✓
Herald Cays	NE Herald Bommie	Central	5	✓
Herald Cays	NE Herald Cay Central	Central	6	✓

Herald Cays	NE Herald Cay NE	Central	5	✓
Herald Cays	NE Herald Cay SW	Central	6	✓
Holmes Reef	Holmes N Cay anchorage	Central	4	
Holmes Reef	Holmes N Cay bommie	Central	4	
Holmes Reef	Holmes Reef Cay Buoy Wall	Central	5	
Holmes Reef	Holmes Reef South Cay Swim through	Central	5	
Holmes Reef	Holmes South Cay Inner Reef	Central	4	
Holmes Reef	Holmes South Cay South Inner Reef	Central	4	
Holmes Reef	Holmes South Cay South Reef	Central	4	
Kenn Reef	Kenn Break	Southern	5	
Kenn Reef	Kenn Cave	Southern	6	
Kenn Reef	Kenn Labyrinth	Southern	6	
Kenn Reef	Kenn Reef anchorage bommie	Southern	4	
Kenn Reef	Kenn Reef bommie	Southern	4	
Kenn Reef	Kenn Reef North Cay	Southern	4	
Kenn Reef	Kenn Reef North Cay bommie	Southern	4	
Kenn Reef	Kenn Reef Pipeline	Southern	5	
Kenn Reef	Kenn Reef rubble	Southern	4	
Kenn Reef	Kenn Twin Bommies	Southern	5	
Lihou Reef	Lihou Cay bommie	Central	5	✓
Lihou Reef	Lihou Flatlands	Central	4	✓
Lihou Reef	Lihou Gardens	Central	5	✓
Lihou Reef	Lihou Kingy	Central	5	✓
Lihou Reef	Lihou North east	Central	4	✓
Lihou Reef	Lihou outer bank	Central	5	✓
Lihou Reef	Lihou Ribbon Cay	Central	4	✓
Lihou Reef	Lihou Shark Wall	Central	5	✓
Lihou Reef	Lihou Staircase	Central	6	✓
Lihou Reef	Lihou Turtle Islet	Central	2	✓
Lihou Reef	Lihou Turtle Islet SW	Central	2	✓
Lihou Reef	Lihou west	Central	4	✓
Lihou Reef	Turtle Marathon	Central	5	✓
Magdelaine Cays	Magdelaine Cay gulch	Central	4	✓
Magdelaine Cays	Magdelaine Cay SW	Central	4	✓
Magdelaine Cays	Magdelaine Cays Rip Bommie	Central	5	✓
Magdelaine Cays	Magdelaine Islet inner reef north	Central	4	✓
Magdelaine Cays	Magdelaine Islet point	Central	4	✓

Magdelaine Cays	Magdelaine Islet South	Central	4	✓
Magdelaine Cays	Magdelaine Reef Cruise Ship	Central	4	✓
Marion Reef	Brodie Cay NW	Southern	5	
Marion Reef	Brodie Cay SE	Southern	5	
Marion Reef	Carola Cay	Southern	4	
Marion Reef	Long Reef West	Southern	5	
Marion Reef	Paget Cay Bommie	Southern	4	
Marion Reef	Paget Cay South	Southern	4	
Marion Reef	Paget Cay South East	Southern	4	
Marion Reef	Weather Station Inner Reef	Southern	5	
Mellish Reef	Mellish bommie	Southern	4	
Mellish Reef	Mellish Crossroads Bommie	Southern	6	
Mellish Reef	Mellish Drainholes	Southern	5	
Mellish Reef	Mellish dropoff	Southern	5	
Mellish Reef	Mellish Grassland	Southern	5	
Mellish Reef	Mellish Grouper Cave	Southern	4	
Mellish Reef	Mellish Herald Beacon Cay East	Southern	5	
Mellish Reef	Mellish lagoon east	Southern	3	
Mellish Reef	Mellish lagoon entrance	Southern	5	
Mellish Reef	Mellish Lion Rock	Southern	4	
Mellish Reef	Mellish NW Dungeons	Southern	4	
Mellish Reef	Mellish overflow	Southern	4	
Mellish Reef	Mellish SW	Southern	5	
Mellish Reef	Mellish Wall	Southern	5	
Osprey Reef	Inner Osprey East	Southern	4	
Osprey Reef	Inside Osprey NE	Southern	4	
Osprey Reef	Osprey Admiralties	Northern	4	
Osprey Reef	Osprey Castle	Northern	4	
Osprey Reef	Osprey Pass	Northern	4	
Osprey Reef	Osprey Pass Channel	Northern	4	
Osprey Reef	Osprey Pass South	Northern	4	
Saumarez Reef	Saumarez egg sea snake	Southern	6	
Saumarez Reef	Saumarez olive sea snake	Southern	6	
Saumarez Reef	Saumarez stripe sea snake	Southern	4	
Saumarez Reef	Saumarez SW	Southern	5	
Saumarez Reef	Saumarez SW Islet	Southern	4	

Saumarez Reef	Saumarez SW reef cay	Southern	4	
Willis Islets	South Willis islet anchorage bommie	Central	4	
Willis Islets	South Willis Islet bommie	Central	4	
Willis Islets	South Willis islet south	Central	4	
Willis Islets	Willis Islet Dark Wall	Central	4	
Wreck Reefs	Bird Inner West	Southern	2	
Wreck Reefs	Bird Lagoon	Southern	6	
Wreck Reefs	Bird North Bommie	Southern	6	
Wreck Reefs	Bird NW Bommie	Southern	6	
Wreck Reefs	Bird Reef Hole	Southern	5	
Wreck Reefs	Booby Rock	Southern	4	
Wreck Reefs	Hilton Pool	Southern	4	
Wreck Reefs	North Wreck Reef	Southern	6	
Wreck Reefs	NW Wreck Reef	Southern	5	
Wreck Reefs	Porpoise Anchorage	Southern	5	
Wreck Reefs	Porpoise Lagoon	Southern	4	
Wreck Reefs	Porpoise NE	Southern	5	
Wreck Reefs	Porpoise North	Southern	6	
Wreck Reefs	Shag Rock	Southern	5	
Wreck Reefs	West Islet Passage	Southern	5	
Wreck Reefs	Wreck North	Southern	6	
Wreck Reefs	Wreck Reef NE	Southern	5	

APPENDIX 2

Reef Life Survey benthic functional groups.

Broad group	**RLS Functional group**
Coral	Ahermatypic corals
Coral	Bleached coral
Coral	Branching *Acropora*
Coral	Encrusting corals
Coral	Hydrocoral
Coral	Large-polyp stony corals
Coral	Massive corals (Live)
Coral	Other branching/erect corals (Live)
Coral	*Pocillopora*

Broad group	RLS Functional group
Coral	Soft corals and gorgonians
Coral	Tabular Coral (Live)
Other	Ascidians (stalked)
Other	Ascidians (unstalked)
Other	Bare Rock
Other	Barnacles
Other	Bryozoan (hard)
Other	Bryozoan (soft)
Other	Colonial Anemones, Zoanthids and Corallimorphs
Other	Dead Coral
Other	Hydroids
Other	Pebbles/unconsolidated rocky bottom/coral rubble
Other	Polychaete
Other	Sand
Other	Seagrass (*Halophila*)
Other	Seagrass (other)
Other	Sessile bivalves
Other	Sessile gastropods
Other	Solitary Anemones
Other	Sponges (encrusting)
Other	Sponges (erect)
Other	Sponges (hollow)
Other	Sponges (massive)
Algae	algal mat/slime
Algae	*Caulerpa*
Algae	Crustose coralline algae
Algae	cyanobacterial mat/slime
Algae	*Desmarestia* and *Himantothallus*
Algae	*Durvillaea*
Algae	Encrusting leathery algae
Algae	Filamentous epiphytic algae
Algae	Filamentous rock-attached algae
Algae	Foliose red algae
Algae	Geniculate coralline algae
Algae	Green calcified algae
Algae	Large brown laminarian kelps

Broad group	RLS Functional group
Algae	Other foliose green algae
Algae	Other fucoids
Algae	*Phyllospora*
Algae	Small to medium foliose brown algae
Algae	Turfing algae (<2 cm high algal/sediment mat on rock)

APPENDIX 3

Fish species list and functional groups

Method 1	Method 2	Species	Functional group	Functional group (broad)
Y		*Aetobatus narinari*	Benthic carnivore	Benthic carnivore
Y		*Amblyeleotris fasciata*	Benthic carnivore	Benthic carnivore
Y		*Amblyeleotris steinitzi*	Benthic carnivore	Benthic carnivore
Y		*Amblyeleotris wheeleri*	Benthic carnivore	Benthic carnivore
Y	Y	*Amblygobius nocturnus*	Benthic carnivore	Benthic carnivore
Y		*Anampses caeruleopunctatus*	Benthic carnivore	Benthic carnivore
Y		*Anampses femininus*	Benthic carnivore	Benthic carnivore
Y		*Anampses geographicus*	Benthic carnivore	Benthic carnivore
Y		*Anampses meleagrides*	Benthic carnivore	Benthic carnivore
Y		*Anampses neoguinaicus*	Benthic carnivore	Benthic carnivore
Y		*Anampses twistii*	Benthic carnivore	Benthic carnivore
Y		*Apogon angustatus*	Benthic carnivore	Benthic carnivore
Y		*Apogon apogonides*	Benthic carnivore	Benthic carnivore
	Y	*Apogon exostigma*	Benthic carnivore	Benthic carnivore
Y		*Apogon kallopterus*	Benthic carnivore	Benthic carnivore
Y		*Apogon limenus*	Benthic carnivore	Benthic carnivore
Y	Y	*Apogon nigrofasciatus*	Benthic carnivore	Benthic carnivore
Y		*Archamia fucata*	Benthic carnivore	Benthic carnivore
Y		*Arothron caeruleopunctatus*	Benthic carnivore	Benthic carnivore
Y		*Arothron stellatus*	Benthic carnivore	Benthic carnivore
Y		*Assessor macneilli*	Benthic carnivore	Benthic carnivore
Y		*Aulostomus chinensis*	Benthic carnivore	Benthic carnivore
Y		*Balistoides conspicillum*	Benthic carnivore	Benthic carnivore
Y		*Bodianus axillaris*	Benthic carnivore	Benthic carnivore
Y		*Bodianus loxozonus*	Benthic carnivore	Benthic carnivore
Y		*Bodianus mesothorax*	Benthic carnivore	Benthic carnivore
Y		*Bodianus perditio*	Benthic carnivore	Benthic carnivore
Y		*Calloplesiops altivelis*	Benthic carnivore	Benthic carnivore
Y		*Cantherhines fronticinctus*	Benthic carnivore	Benthic carnivore
Y		*Cantherhines pardalis*	Benthic carnivore	Benthic carnivore
	Y	*Caracanthus maculatus*	Benthic carnivore	Benthic carnivore
Y		*Carangoides ferdau*	Benthic carnivore	Benthic carnivore
Y		*Carangoides fulvoguttatus*	Benthic carnivore	Benthic carnivore
Y		*Carangoides orthogrammus*	Benthic carnivore	Benthic carnivore
Y		*Chaetodon lunulatus*	Benthic carnivore	Benthic carnivore
Y		*Chaetodon melannotus*	Benthic carnivore	Benthic carnivore
Y		*Chaetodon mertensii*	Benthic carnivore	Benthic carnivore
Y		*Chaetodon ulietensis*	Benthic carnivore	Benthic carnivore
Y		*Chaetodon unimaculatus*	Benthic carnivore	Benthic carnivore
Y		*Cheilinus chlorourus*	Benthic carnivore	Benthic carnivore

Y		*Cheilinus fasciatus*	Benthic carnivore	Benthic carnivore
Y		*Cheilinus oxycephalus*	Benthic carnivore	Benthic carnivore
Y		*Cheilinus trilobatus*	Benthic carnivore	Benthic carnivore
Y		*Cheilinus undulatus*	Benthic carnivore	Benthic carnivore
Y		*Cheilodipterus parazonatus*	Benthic carnivore	Benthic carnivore
Y	Y	*Cheilodipterus quinquelineatus*	Benthic carnivore	Benthic carnivore
Y		*Choerodon fasciatus*	Benthic carnivore	Benthic carnivore
Y		*Choerodon graphicus*	Benthic carnivore	Benthic carnivore
Y	Y	*Cirrhitichthys falco*	Benthic carnivore	Benthic carnivore
	Y	*Cirrhitichthys oxycephalus*	Benthic carnivore	Benthic carnivore
Y		*Cirrhitus pinnulatus*	Benthic carnivore	Benthic carnivore
Y	Y	*Cirripectes stigmaticus*	Benthic carnivore	Benthic carnivore
Y		*Coris aygula*	Benthic carnivore	Benthic carnivore
Y		*Coris batuensis*	Benthic carnivore	Benthic carnivore
Y		*Coris bulbifrons*	Benthic carnivore	Benthic carnivore
Y		*Coris dorsomacula*	Benthic carnivore	Benthic carnivore
Y		*Coris gaimard*	Benthic carnivore	Benthic carnivore
Y		*Cryptocentrus fasciatus*	Benthic carnivore	Benthic carnivore
Y		*Ctenogobiops crocineus*	Benthic carnivore	Benthic carnivore
	Y	*Cymbacephalus beauforti*	Benthic carnivore	Benthic carnivore
	Y	*Cypho purpurascens*	Benthic carnivore	Benthic carnivore
Y		*Dendrochirus zebra*	Benthic carnivore	Benthic carnivore
Y		*Diodon holocanthus*	Benthic carnivore	Benthic carnivore
Y		*Diodon hystrix*	Benthic carnivore	Benthic carnivore
	Y	*Enneapterygius pallidoserialis*	Benthic carnivore	Benthic carnivore
Y		*Epibulus insidiator*	Benthic carnivore	Benthic carnivore
Y		*Forcipiger flavissimus*	Benthic carnivore	Benthic carnivore
Y		*Forcipiger longirostris*	Benthic carnivore	Benthic carnivore
Y		*Gnathodentex aureolineatus*	Benthic carnivore	Benthic carnivore
	Y	*Gobiodon quinquestrigatus*	Benthic carnivore	Benthic carnivore
Y		*Gomphosus varius*	Benthic carnivore	Benthic carnivore
Y		*Gymnocranius euanus*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres biocellatus*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres chloropterus*	Benthic carnivore	Benthic carnivore
Y	Y	*Halichoeres hortulanus*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres margaritaceus*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres marginatus*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres nebulosus*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres ornatissimus*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres prosopeion*	Benthic carnivore	Benthic carnivore
Y		*Halichoeres trimaculatus*	Benthic carnivore	Benthic carnivore
Y		*Hemigymnus fasciatus*	Benthic carnivore	Benthic carnivore
Y		*Hemigymnus melapterus*	Benthic carnivore	Benthic carnivore
Y		*Heniochus chrysostomus*	Benthic carnivore	Benthic carnivore

Y		*Heniochus monoceros*	Benthic carnivore	Benthic carnivore
Y		*Heniochus singularius*	Benthic carnivore	Benthic carnivore
Y		*Heniochus varius*	Benthic carnivore	Benthic carnivore
Y		*Himantura fai*	Benthic carnivore	Benthic carnivore
Y		*Hologymnosus annulatus*	Benthic carnivore	Benthic carnivore
Y		*Hologymnosus doliatus*	Benthic carnivore	Benthic carnivore
Y		*Iniistius pavo*	Benthic carnivore	Benthic carnivore
Y		*Istigobius decoratus*	Benthic carnivore	Benthic carnivore
Y	Y	*Istigobius rigilius*	Benthic carnivore	Benthic carnivore
Y		*Lethrinus erythracanthus*	Benthic carnivore	Benthic carnivore
Y		*Lethrinus nebulosus*	Benthic carnivore	Benthic carnivore
Y		*Lethrinus rubrioperculatus*	Benthic carnivore	Benthic carnivore
Y		*Lethrinus xanthochilus*	Benthic carnivore	Benthic carnivore
Y		*Macropharyngodon kuiteri*	Benthic carnivore	Benthic carnivore
Y		*Macropharyngodon meleagris*	Benthic carnivore	Benthic carnivore
Y		*Macropharyngodon negrosensis*	Benthic carnivore	Benthic carnivore
Y		*Macropharyngodon ornatus*	Benthic carnivore	Benthic carnivore
Y		*Malacanthus brevirostris*	Benthic carnivore	Benthic carnivore
Y		*Monotaxis grandoculis*	Benthic carnivore	Benthic carnivore
Y		*Mulloidichthys flavolineatus*	Benthic carnivore	Benthic carnivore
Y		*Mulloidichthys vanicolensis*	Benthic carnivore	Benthic carnivore
Y		*Myrichthys maculosus*	Benthic carnivore	Benthic carnivore
Y	Y	*Myripristis amaena*	Benthic carnivore	Benthic carnivore
Y	Y	*Neocirrhites armatus*	Benthic carnivore	Benthic carnivore
	Y	*Neoniphon argenteus*	Benthic carnivore	Benthic carnivore
Y		*Neoniphon opercularis*	Benthic carnivore	Benthic carnivore
Y	Y	*Novaculichthys taeniourus*	Benthic carnivore	Benthic carnivore
Y		*Ogilbyina queenslandiae*	Benthic carnivore	Benthic carnivore
Y		*Oxycercichthys veliferus*	Benthic carnivore	Benthic carnivore
Y		*Oxycheilinus digrammus*	Benthic carnivore	Benthic carnivore
Y		*Oxycheilinus orientalis*	Benthic carnivore	Benthic carnivore
Y		*Oxycheilinus rhodochrous*	Benthic carnivore	Benthic carnivore
Y		*Oxycheilinus unifasciatus*	Benthic carnivore	Benthic carnivore
Y	Y	*Paracirrhites arcatus*	Benthic carnivore	Benthic carnivore
Y	Y	*Paracirrhites forsteri*	Benthic carnivore	Benthic carnivore
Y		*Paracirrhites hemistictus*	Benthic carnivore	Benthic carnivore
Y	Y	*Parapercis australis*	Benthic carnivore	Benthic carnivore
Y	Y	*Parapercis clathrata*	Benthic carnivore	Benthic carnivore
	Y	*Parapercis lineopunctata*	Benthic carnivore	Benthic carnivore
Y		*Parapercis millepunctata*	Benthic carnivore	Benthic carnivore
Y	Y	*Parapercis multiplicata*	Benthic carnivore	Benthic carnivore
Y	Y	*Parapercis pacifica*	Benthic carnivore	Benthic carnivore
Y		*Parapercis schauinslandii*	Benthic carnivore	Benthic carnivore
Y		*Parupeneus barberinoides*	Benthic carnivore	Benthic carnivore

Y		*Parupeneus barberinus*	Benthic carnivore	Benthic carnivore
Y		*Parupeneus ciliatus*	Benthic carnivore	Benthic carnivore
Y		*Parupeneus crassilabris*	Benthic carnivore	Benthic carnivore
Y		*Parupeneus cyclostomus*	Benthic carnivore	Benthic carnivore
Y		*Parupeneus multifasciatus*	Benthic carnivore	Benthic carnivore
Y		*Parupeneus pleurostigma*	Benthic carnivore	Benthic carnivore
Y		*Parupeneus spilurus*	Benthic carnivore	Benthic carnivore
Y		*Pervagor alternans*	Benthic carnivore	Benthic carnivore
Y		*Pervagor janthinosoma*	Benthic carnivore	Benthic carnivore
Y		*Pictichromis paccagnellae*	Benthic carnivore	Benthic carnivore
Y		*Plectorhinchus chaetodonoides*	Benthic carnivore	Benthic carnivore
Y		*Plectorhinchus lessonii*	Benthic carnivore	Benthic carnivore
Y		*Plectorhinchus picus*	Benthic carnivore	Benthic carnivore
Y		*Plotosus lineatus*	Benthic carnivore	Benthic carnivore
Y		*Priacanthus blochii*	Benthic carnivore	Benthic carnivore
Y	Y	*Priacanthus hamrur*	Benthic carnivore	Benthic carnivore
Y		*Pseudobalistes flavimarginatus*	Benthic carnivore	Benthic carnivore
Y		*Pseudobalistes fuscus*	Benthic carnivore	Benthic carnivore
Y		*Pseudocheilinus evanidus*	Benthic carnivore	Benthic carnivore
Y		*Pseudocheilinus hexataenia*	Benthic carnivore	Benthic carnivore
Y		*Pseudocheilinus octotaenia*	Benthic carnivore	Benthic carnivore
Y		*Pseudocoris yamashiroi*	Benthic carnivore	Benthic carnivore
Y		*Pseudodax moluccanus*	Benthic carnivore	Benthic carnivore
Y		*Pseudojuloides cerasinus*	Benthic carnivore	Benthic carnivore
Y		*Pseudolabrus guentheri*	Benthic carnivore	Benthic carnivore
Y		*Pteragogus cryptus*	Benthic carnivore	Benthic carnivore
Y		*Pteragogus enneacanthus*	Benthic carnivore	Benthic carnivore
Y	Y	*Pterois antennata*	Benthic carnivore	Benthic carnivore
Y		*Pterois volitans*	Benthic carnivore	Benthic carnivore
Y	Y	*Sargocentron caudimaculatum*	Benthic carnivore	Benthic carnivore
Y	Y	*Sargocentron diadema*	Benthic carnivore	Benthic carnivore
Y		*Sargocentron ittodai*	Benthic carnivore	Benthic carnivore
Y	Y	*Sargocentron melanospilos*	Benthic carnivore	Benthic carnivore
Y	Y	*Sargocentron spiniferum*	Benthic carnivore	Benthic carnivore
Y		*Sargocentron spp.*	Benthic carnivore	Benthic carnivore
Y		*Sargocentron tiereoides*	Benthic carnivore	Benthic carnivore
Y		*Scolopsis bilineata*	Benthic carnivore	Benthic carnivore
Y		*Scolopsis monogramma*	Benthic carnivore	Benthic carnivore
Y		*Serranocirrhitus latus*	Benthic carnivore	Benthic carnivore
Y		*Stethojulis bandanensis*	Benthic carnivore	Benthic carnivore
Y		*Stethojulis interrupta*	Benthic carnivore	Benthic carnivore
Y		*Taeniura lymma*	Benthic carnivore	Benthic carnivore
Y		*Taeniura meyeni*	Benthic carnivore	Benthic carnivore
Y		*Thalassoma amblycephalum*	Benthic carnivore	Benthic carnivore

Y		*Thalassoma hardwicke*	Benthic carnivore	Benthic carnivore
Y		*Thalassoma jansenii*	Benthic carnivore	Benthic carnivore
Y		*Thalassoma lunare*	Benthic carnivore	Benthic carnivore
Y		*Thalassoma lutescens*	Benthic carnivore	Benthic carnivore
Y		*Thalassoma nigrofasciatum*	Benthic carnivore	Benthic carnivore
Y		*Thalassoma quinquevittatum*	Benthic carnivore	Benthic carnivore
Y		*Thalassoma trilobatum*	Benthic carnivore	Benthic carnivore
Y	Y	*Valenciennea strigata*	Benthic carnivore	Benthic carnivore
Y		*Zanclus cornutus*	Benthic carnivore	Benthic carnivore
Y		*Acanthurus albipectoralis*	Planktivore	Planktivore
Y		*Acanthurus mata*	Planktivore	Planktivore
Y		*Acanthurus thompsoni*	Planktivore	Planktivore
Y		*Amblyglyphidodon aureus*	Planktivore	Planktivore
Y		*Apogon cyanosoma*	Planktivore	Planktivore
	Y	*Assessor flavissimus*	Planktivore	Planktivore
Y	Y	*Bryaninops yongei*	Planktivore	Planktivore
Y		*Caesio caerulaurea*	Planktivore	Planktivore
Y		*Caesio lunaris*	Planktivore	Planktivore
Y		*Caesio teres*	Planktivore	Planktivore
Y		*Chromis acares*	Planktivore	Planktivore
Y		*Chromis agilis*	Planktivore	Planktivore
Y		*Chromis alpha*	Planktivore	Planktivore
Y		*Chromis amboinensis*	Planktivore	Planktivore
Y		*Chromis analis*	Planktivore	Planktivore
Y		*Chromis atripectoralis*	Planktivore	Planktivore
Y		*Chromis atripes*	Planktivore	Planktivore
Y		*Chromis chrysura*	Planktivore	Planktivore
Y		*Chromis flavomaculata*	Planktivore	Planktivore
Y		*Chromis fumea*	Planktivore	Planktivore
Y		*Chromis iomelas*	Planktivore	Planktivore
Y		*Chromis lepidolepis*	Planktivore	Planktivore
Y		*Chromis margaritifer*	Planktivore	Planktivore
Y		*Chromis nitida*	Planktivore	Planktivore
Y		*Chromis retrofasciata*	Planktivore	Planktivore
Y		*Chromis ternatensis*	Planktivore	Planktivore
Y		*Chromis vanderbilti*	Planktivore	Planktivore
Y		*Chromis viridis*	Planktivore	Planktivore
Y		*Chromis weberi*	Planktivore	Planktivore
Y		*Chromis xanthochira*	Planktivore	Planktivore
Y		*Chromis xanthura*	Planktivore	Planktivore
Y		*Chrysiptera flavipinnis*	Planktivore	Planktivore
Y		*Chrysiptera rollandi*	Planktivore	Planktivore
Y		*Chrysiptera starcki*	Planktivore	Planktivore
Y		*Chrysiptera taupou*	Planktivore	Planktivore

Y		*Cirrhilabrus scottorum*	Planktivore	Planktivore
Y		*Cirrhilabrus exquisitus*	Planktivore	Planktivore
Y		*Cirrhilabrus laboutei*	Planktivore	Planktivore
Y		*Cirrhilabrus lineatus*	Planktivore	Planktivore
Y		*Cirrhilabrus punctatus*	Planktivore	Planktivore
Y		*Cirrhilabrus scottorum*	Planktivore	Planktivore
Y		*Ctenogobiops feroculus*	Planktivore	Planktivore
	Y	*Ctenogobiops maculosus*	Planktivore	Planktivore
	Y	*Ctenogobiops pomastictus*	Planktivore	Planktivore
	Y	*Cyprinocirrhites polyactis*	Planktivore	Planktivore
Y		*Dascyllus aruanus*	Planktivore	Planktivore
Y		*Dascyllus reticulatus*	Planktivore	Planktivore
Y		*Dascyllus trimaculatus*	Planktivore	Planktivore
Y	Y	*Eviota guttata*	Planktivore	Planktivore
Y	Y	*Eviota prasites*	Planktivore	Planktivore
	Y	*Eviota sebreei*	Planktivore	Planktivore
Y	Y	*Fusigobius duospilus*	Planktivore	Planktivore
	Y	*Gorgasia galzini*	Planktivore	Planktivore
	Y	*Helcogramma striatum*	Planktivore	Planktivore
Y		*Hemitaurichthys polylepis*	Planktivore	Planktivore
Y		*Hoplolatilus starcki*	Planktivore	Planktivore
Y		*Macolor macularis*	Planktivore	Planktivore
Y	Y	*Meiacanthus atrodorsalis*	Planktivore	Planktivore
Y		*Meiacanthus ditrema*	Planktivore	Planktivore
Y	Y	*Meiacanthus phaeus*	Planktivore	Planktivore
Y		*Myripristis adusta*	Planktivore	Planktivore
Y	Y	*Myripristis berndti*	Planktivore	Planktivore
Y		*Myripristis hexagona*	Planktivore	Planktivore
Y	Y	*Myripristis kuntee*	Planktivore	Planktivore
Y	Y	*Myripristis murdjan*	Planktivore	Planktivore
Y		*Myripristis pralinia*	Planktivore	Planktivore
Y	Y	*Myripristis violacea*	Planktivore	Planktivore
Y	Y	*Myripristis vittata*	Planktivore	Planktivore
Y		*Naso brevirostris*	Planktivore	Planktivore
Y		*Naso caeruleacauda*	Planktivore	Planktivore
Y		*Naso caesius*	Planktivore	Planktivore
Y		*Naso hexacanthus*	Planktivore	Planktivore
Y		*Naso vlamingii*	Planktivore	Planktivore
Y	Y	*Nemateleotris magnifica*	Planktivore	Planktivore
Y		*Neopomacentrus spp.*	Planktivore	Planktivore
Y		*Odonus niger*	Planktivore	Planktivore
Y		*Paracanthurus hepatus*	Planktivore	Planktivore
Y	Y	*Pempheris oualensis*	Planktivore	Planktivore
	Y	*Pempheris schwenkii*	Planktivore	Planktivore

Y		*Pomacentrus coelestis*	Planktivore	Planktivore
Y		*Pomacentrus lepidogenys*	Planktivore	Planktivore
Y		*Pomacentrus philippinus*	Planktivore	Planktivore
Y		*Pomachromis richardsoni*	Planktivore	Planktivore
Y		*Pseudanthias ?cooperi*	Planktivore	Planktivore
Y		*Pseudanthias huchtii*	Planktivore	Planktivore
Y		*Pseudanthias olivaceus*	Planktivore	Planktivore
Y		*Pseudanthias pascalus*	Planktivore	Planktivore
Y		*Pseudanthias pictilis*	Planktivore	Planktivore
Y		*Pseudanthias spp.*	Planktivore	Planktivore
Y		*Pseudanthias squamipinnis*	Planktivore	Planktivore
Y		*Pseudanthias tuka*	Planktivore	Planktivore
Y		*Ptereleotris evides*	Planktivore	Planktivore
Y		*Ptereleotris zebra*	Planktivore	Planktivore
Y		*Pterocaesio digramma*	Planktivore	Planktivore
Y		*Pterocaesio marri*	Planktivore	Planktivore
Y		*Pterocaesio tile*	Planktivore	Planktivore
Y		*Pterocaesio trilineata*	Planktivore	Planktivore
Y		*Selar crumenophthalmus*	Planktivore	Planktivore
Y		*Selaroides leptolepis*	Planktivore	Planktivore
Y		*Trimma benjamini*	Planktivore	Planktivore
Y		*Trimma caesiura*	Planktivore	Planktivore
Y		*Trimma lantana*	Planktivore	Planktivore
Y		*Aethaloperca rogaa*	Piscivore	Piscivore
Y		*Anyperodon leucogrammicus*	Piscivore	Piscivore
Y		*Aphareus furca*	Piscivore	Piscivore
Y		*Aphareus rutilans*	Piscivore	Piscivore
Y		*Aprion virescens*	Piscivore	Piscivore
Y		*Belonoperca chabanaudi*	Piscivore	Piscivore
Y		*Carangoides plagiotaenia*	Piscivore	Piscivore
Y		*Caranx ignobilis*	Piscivore	Piscivore
Y		*Caranx lugubris*	Piscivore	Piscivore
Y		*Caranx melampygus*	Piscivore	Piscivore
Y		*Caranx sexfasciatus*	Piscivore	Piscivore
Y		*Carcharhinus albimarginatus*	Piscivore	Piscivore
Y		*Carcharhinus amblyrhynchos*	Piscivore	Piscivore
Y	Y	*Cephalopholis argus*	Piscivore	Piscivore
Y		*Cephalopholis leopardus*	Piscivore	Piscivore
Y		*Cephalopholis spiloparaea*	Piscivore	Piscivore
Y	Y	*Cephalopholis urodeta*	Piscivore	Piscivore
Y	Y	*Cheilodipterus macrodon*	Piscivore	Piscivore
Y		*Chromileptes altivelis*	Piscivore	Piscivore
Y		*Elagatis bipinnulata*	Piscivore	Piscivore
Y	Y	*Epinephelus fasciatus*	Piscivore	Piscivore

Y		*Epinephelus lanceolatus*	Piscivore	Piscivore
Y		*Epinephelus maculatus*	Piscivore	Piscivore
Y	Y	*Epinephelus merra*	Piscivore	Piscivore
Y	Y	*Epinephelus polyphekadion*	Piscivore	Piscivore
Y		*Epinephelus spp.*	Piscivore	Piscivore
Y	Y	*Epinephelus tauvina*	Piscivore	Piscivore
Y		*Fistularia commersonii*	Piscivore	Piscivore
Y		*Grammistes sexlineatus*	Piscivore	Piscivore
Y		*Gymnosarda unicolor*	Piscivore	Piscivore
Y	Y	*Gymnothorax javanicus*	Piscivore	Piscivore
Y	Y	*Gymnothorax meleagris*	Piscivore	Piscivore
Y		*Gymnothorax thrysoideus*	Piscivore	Piscivore
Y		*Gymnothorax undulatus*	Piscivore	Piscivore
Y		*Lethrinus olivaceus*	Piscivore	Piscivore
Y		*Lutjanus bohar*	Piscivore	Piscivore
Y		*Lutjanus fulvus*	Piscivore	Piscivore
Y		*Lutjanus gibbus*	Piscivore	Piscivore
Y		*Lutjanus kasmira*	Piscivore	Piscivore
Y		*Lutjanus monostigma*	Piscivore	Piscivore
Y		*Lutjanus quinquelineatus*	Piscivore	Piscivore
Y		*Macolor niger*	Piscivore	Piscivore
Y	Y	*Neoniphon sammara*	Piscivore	Piscivore
Y		*Plectropomus laevis*	Piscivore	Piscivore
Y		*Plectropomus leopardus*	Piscivore	Piscivore
Y		*Plectropomus spp.*	Piscivore	Piscivore
Y	Y	*Pseudochromis fuscus*	Piscivore	Piscivore
Y		*Pseudochromis spp.*	Piscivore	Piscivore
	Y	*Saurida gracilis*	Piscivore	Piscivore
Y		*Saurida nebulosa*	Piscivore	Piscivore
Y		*Scomberoides lysan*	Piscivore	Piscivore
Y		*Scomberoides tol*	Piscivore	Piscivore
Y		*Scomberomorus queenslandicus*	Piscivore	Piscivore
	Y	*Scorpaena cardinalis*	Piscivore	Piscivore
Y		*Scorpaenodes parvipinnis*	Piscivore	Piscivore
Y	Y	*Scorpaenopsis venosa*	Piscivore	Piscivore
Y		*Sphyraena barracuda*	Piscivore	Piscivore
Y		*Synodus binotatus*	Piscivore	Piscivore
Y	Y	*Synodus dermatogenys*	Piscivore	Piscivore
Y	Y	*Synodus variegatus*	Piscivore	Piscivore
Y		*Triaenodon obesus*	Piscivore	Piscivore
Y		*Variola louti*	Piscivore	Piscivore
Y		*Acanthurus achilles*	Cropper	Grazer
Y		*Acanthurus guttatus*	Cropper	Grazer
Y		*Acanthurus lineatus*	Cropper	Grazer

Y		*Acanthurus nigricans*	Cropper	Grazer
Y		*Acanthurus nigrofuscus*	Cropper	Grazer
Y		*Acanthurus pyroferus*	Cropper	Grazer
Y		*Acanthurus triostegus*	Cropper	Grazer
Y		*Canthigaster bennetti*	Cropper	Grazer
Y		*Centropyge flavissimus*	Cropper	Grazer
Y		*Centropyge heraldi*	Cropper	Grazer
Y		*Centropyge loricula*	Cropper	Grazer
Y		*Centropyge tibicen*	Cropper	Grazer
Y		*Centropyge vroliki*	Cropper	Grazer
Y		*Cirripectes alboapicalis*	Cropper	Grazer
Y		*Cirripectes castaneus*	Cropper	Grazer
Y		*Cirripectes filamentosus*	Cropper	Grazer
Y		*Cirripectes polyzona*	Cropper	Grazer
Y		*Cirripectes variolosus*	Cropper	Grazer
Y		*Crossosalarias macrospilus*	Cropper	Grazer
	Y	*Ecsenius aequalis*	Cropper	Grazer
	Y	*Ecsenius fourmanoiri*	Cropper	Grazer
	Y	*Ecsenius tigris*	Cropper	Grazer
Y		*Naso annulatus*	Cropper	Grazer
Y		*Naso lituratus*	Cropper	Grazer
Y		*Naso tonganus*	Cropper	Grazer
Y		*Naso unicornis*	Cropper	Grazer
Y		*Kyphosus bigibbus*	Browser	Grazer
Y		*Kyphosus cinerascens*	Browser	Grazer
Y		*Kyphosus sectatrix*	Browser	Grazer
Y		*Kyphosus spp.*	Browser	Grazer
Y		*Siganus argenteus*	Browser	Grazer
Y		*Siganus corallinus*	Browser	Grazer
Y		*Siganus fuscescens*	Browser	Grazer
Y		*Siganus punctatissimus*	Browser	Grazer
Y		*Siganus punctatus*	Browser	Grazer
Y		*Siganus stellatus*	Browser	Grazer
Y		*Zebrasoma scopas*	Browser	Grazer
Y		*Zebrasoma veliferum*	Browser	Grazer
Y		*Acanthurus auranticavus*	Detritivore	Grazer
Y		*Acanthurus blochii*	Detritivore	Grazer
Y		*Acanthurus dussumieri*	Detritivore	Grazer
Y		*Acanthurus grammoptilus*	Detritivore	Grazer
Y		*Acanthurus leucocheilus*	Detritivore	Grazer
Y		*Acanthurus nigricauda*	Detritivore	Grazer
Y		*Acanthurus nigroris*	Detritivore	Grazer
Y		*Acanthurus olivaceus*	Detritivore	Grazer
Y		*Acanthurus xanthopterus*	Detritivore	Grazer

Y	*Ctenochaetus binotatus*	Detritivore	Grazer
Y	*Ctenochaetus cyanocheilus*	Detritivore	Grazer
Y	*Ctenochaetus spp.*	Detritivore	Grazer
Y	*Ctenochaetus striatus*	Detritivore	Grazer
Y	*Bolbometopon muricatum*	Excavator	Grazer
Y	*Cetoscarus bicolor*	Excavator	Grazer
Y	*Chlorurus bleekeri*	Excavator	Grazer
Y	*Chlorurus microrhinos*	Excavator	Grazer
Y	*Chlorurus sordidus*	Excavator	Grazer
Y	*Calotomus carolinus*	Scraper	Grazer
Y	*Hipposcarus longiceps*	Scraper	Grazer
Y	*Scarid spp.*	Scraper	Grazer
Y	*Scarus altipinnis*	Scraper	Grazer
Y	*Scarus chameleon*	Scraper	Grazer
Y	*Scarus dimidiatus*	Scraper	Grazer
Y	*Scarus festivus*	Scraper	Grazer
Y	*Scarus flavipectoralis*	Scraper	Grazer
Y	*Scarus forsteni*	Scraper	Grazer
Y	*Scarus frenatus*	Scraper	Grazer
Y	*Scarus ghobban*	Scraper	Grazer
Y	*Scarus globiceps*	Scraper	Grazer
Y	*Scarus longipinnis*	Scraper	Grazer
Y	*Scarus niger*	Scraper	Grazer
Y	*Scarus oviceps*	Scraper	Grazer
Y	*Scarus psittacus*	Scraper	Grazer
Y	*Scarus rivulatus*	Scraper	Grazer
Y	*Scarus rubroviolaceus*	Scraper	Grazer
Y	*Scarus schlegeli*	Scraper	Grazer
Y	*Scarus spinus*	Scraper	Grazer
Y	*Chrysiptera biocellata*	Indeterminate farmer	Farmer
Y	*Chrysiptera brownriggii*	Indeterminate farmer	Farmer
Y	*Plectroglyphidodon imparipennis*	Indeterminate farmer	Farmer
Y	*Plectroglyphidodon johnstonianus*	Indeterminate farmer	Farmer
Y	*Pomacentrus bankanensis*	Indeterminate farmer	Farmer
Y	*Pomacentrus chrysurus*	Indeterminate farmer	Farmer
Y	*Pomacentrus tripunctatus*	Indeterminate farmer	Farmer
Y	*Pomacentrus vaiuli*	Indeterminate farmer	Farmer
Y	*Plectroglyphidodon lacrymatus*	Extensive farmer	Farmer
Y	*Plectroglyphidodon phoenixensis*	Extensive farmer	Farmer
Y	*Stegastes fasciolatus*	Extensive farmer	Farmer
Y	*Dischistodus melanotus*	Intensive farmer	Farmer
Y	*Dischistodus pseudochrysopoecilus*	Intensive farmer	Farmer
Y	*Plectroglyphidodon dickii*	Intensive farmer	Farmer
Y	*Stegastes albifasciatus*	Intensive farmer	Farmer

Y		*Stegastes gascoynei*	Intensive farmer	Farmer
Y		*Stegastes nigricans*	Intensive farmer	Farmer
Y		*Stegastes punctatus*	Intensive farmer	Farmer
Y		*Abudefduf vaigiensis*	Omnivore	Omnivore
Y		*Acanthochromis polyacanthus*	Omnivore	Omnivore
Y		*Acanthopagrus australis*	Omnivore	Omnivore
Y		*Amanses scopas*	Omnivore	Omnivore
Y		*Amblyglyphidodon curacao*	Omnivore	Omnivore
Y		*Amblyglyphidodon leucogaster*	Omnivore	Omnivore
Y		*Amblygobius phalaena*	Omnivore	Omnivore
Y		*Amphiprion akindynos*	Omnivore	Omnivore
Y		*Amphiprion chrysopterus*	Omnivore	Omnivore
Y		*Amphiprion clarkii*	Omnivore	Omnivore
Y		*Amphiprion melanopus*	Omnivore	Omnivore
Y		*Amphiprion perideraion*	Omnivore	Omnivore
Y		*Balistapus undulatus*	Omnivore	Omnivore
Y		*Blenniella chrysospilos*	Omnivore	Omnivore
Y		*Canthigaster amboinensis*	Omnivore	Omnivore
Y		*Canthigaster coronata*	Omnivore	Omnivore
Y		*Canthigaster epilampra*	Omnivore	Omnivore
Y		*Canthigaster janthinoptera*	Omnivore	Omnivore
Y		*Canthigaster papua*	Omnivore	Omnivore
Y		*Canthigaster valentini*	Omnivore	Omnivore
Y		*Centropyge bicolor*	Omnivore	Omnivore
Y		*Centropyge bispinosa*	Omnivore	Omnivore
Y		*Ecsenius bicolor*	Omnivore	Omnivore
Y		*Ecsenius fourmanoiri*	Omnivore	Omnivore
Y		*Gnatholepis anjerensis*	Omnivore	Omnivore
Y		*Gnatholepis cauerensis*	Omnivore	Omnivore
	Y	*Meiacanthus lineatus*	Omnivore	Omnivore
Y		*Melichthys vidua*	Omnivore	Omnivore
Y		*Neoglyphidodon melas*	Omnivore	Omnivore
Y		*Ostracion cubicus*	Omnivore	Omnivore
Y		*Ostracion meleagris*	Omnivore	Omnivore
Y		*Ostracion solorensis*	Omnivore	Omnivore
Y		*Paraluteres prionurus*	Omnivore	Omnivore
Y	Y	*Pervagor aspricaudus*	Omnivore	Omnivore
	Y	*Pictichromis paccagnellae*	Omnivore	Omnivore
Y		*Platax boersii*	Omnivore	Omnivore
Y		*Platax orbicularis*	Omnivore	Omnivore
Y		*Platax pinnatus*	Omnivore	Omnivore
Y		*Platax teira*	Omnivore	Omnivore
Y		*Pomacentrus ?australis*	Omnivore	Omnivore
Y		*Pomacentrus amboinensis*	Omnivore	Omnivore

Y		*Pomacentrus auriventris*	Omnivore	Omnivore
Y		*Pomacentrus imitator*	Omnivore	Omnivore
Y		*Pomacentrus moluccensis*	Omnivore	Omnivore
Y		*Rhinecanthus aculeatus*	Omnivore	Omnivore
Y		*Rhinecanthus rectangulus*	Omnivore	Omnivore
Y		*Rhinecanthus verrucosus*	Omnivore	Omnivore
Y		*Salarias alboguttatus*	Omnivore	Omnivore
Y		*Sufflamen bursa*	Omnivore	Omnivore
Y		*Sufflamen chrysopterum*	Omnivore	Omnivore
Y		*Apolemichthys trimaculatus*	Spongivore	Other
Y		*Arothron mappa*	Spongivore	Other
Y		*Echeneis naucrates*	Cleaner	Other
Y		*Labrichthys unilineatus*	Cleaner	Other
Y		*Labroides bicolor*	Cleaner	Other
Y		*Labroides dimidiatus*	Cleaner	Other
Y		*Labroides pectoralis*	Cleaner	Other
Y		*Labropsis australis*	Cleaner	Other
Y		*Labropsis xanthonota*	Cleaner	Other
Y	Y	*Plagiotremus laudandus*	Parasite	Other
Y	Y	*Plagiotremus rhinorhynchos*	Parasite	Other
Y		*Plagiotremus tapeinosoma*	Parasite	Other
Y		*Pomacanthus imperator*	Parasite	Other
Y		*Pomacanthus semicirculatus*	Spongivore	Other
Y		*Pygoplites diacanthus*	Spongivore	Other
Y		*Arothron meleagris*	Facultative corallivore	Corallivore
Y		*Arothron nigropunctatus*	Facultative corallivore	Corallivore
Y		*Balistoides viridescens*	Facultative corallivore	Corallivore
Y		*Cantherhines dumerilii*	Facultative corallivore	Corallivore
Y		*Chaetodon auriga*	Facultative corallivore	Corallivore
Y		*Chaetodon citrinellus*	Facultative corallivore	Corallivore
Y		*Chaetodon ephippium*	Facultative corallivore	Corallivore
Y		*Chaetodon flavirostris*	Facultative corallivore	Corallivore
Y		*Chaetodon guentheri*	Facultative corallivore	Corallivore
Y		*Chaetodon kleinii*	Facultative corallivore	Corallivore
Y		*Chaetodon lineolatus*	Facultative corallivore	Corallivore
Y		*Chaetodon lunula*	Facultative corallivore	Corallivore
Y		*Chaetodon meyeri*	Facultative corallivore	Corallivore
Y		*Chaetodon rafflesii*	Facultative corallivore	Corallivore
Y		*Chaetodon speculum*	Facultative corallivore	Corallivore
Y		*Chaetodon vagabundus*	Facultative corallivore	Corallivore
Y		*Chelmon marginalis*	Facultative corallivore	Corallivore
Y	Y	*Ecsenius stictus*	Facultative corallivore	Corallivore
Y	Y	*Exallias brevis*	Facultative corallivore	Corallivore
Y		*Chaetodon aureofasciatus*	Obligate corallivore	Corallivore

Y	*Chaetodon bennetti*	Obligate corallivore	Corallivore
Y	*Chaetodon ornatissimus*	Obligate corallivore	Corallivore
Y	*Chaetodon pelewensis*	Obligate corallivore	Corallivore
Y	*Chaetodon plebeius*	Obligate corallivore	Corallivore
Y	*Chaetodon rainfordi*	Obligate corallivore	Corallivore
Y	*Chaetodon reticulatus*	Obligate corallivore	Corallivore
Y	*Chaetodon trifascialis*	Obligate corallivore	Corallivore
Y	*Chaetodon trifasciatus*	Obligate corallivore	Corallivore
Y	*Oxymonacanthus longirostris*	Obligate corallivore	Corallivore

Appendix 4

ANOSIM table fish functional groups R values (grey=significant)

	Osprey Reef	Holmes Reef	Willis Islets	Magdelaine Cays	Herald Cays	Coringa Islets	Lihou Reef	Abington Reef	Diamond Islets	Flinders Reef	Mellish Reef	Marion Reef	Frederick Reef	Kenn Reef	Saumarez Reef	Wreck Reefs	Cato Reef
Osprey Reef		0.759	0.664	0.468	0.419	0.515	0.043	0.64	0.382	0.372	0.13	0.098	0.201	0.126	0.214	0.126	0.254
Holmes Reef	0.759		0.799	0.292	0.847	0.478	-0.066	0.582	0.086	0.403	-0.048	0.364	0.157	0.419	0.562	0.24	0.444
Willis Islets	0.664	0.799		0.005	0.456	0.051	-0.092	0.531	-0.112	0.024	0.111	0.112	0.186	0.303	0.294	0.279	0.222
Magdelaine Cays	0.468	0.292	0.005		0.018	0.045	-0.018	0.063	0.231	0.192	0.125	0.321	0.25	0.405	0.377	0.366	0.325
Herald Cays	0.419	0.847	0.456	0.018		0.052	-0.064	0.35	0.034	0.161	0.141	0.216	0.171	0.121	0.371	0.169	0.169
Coringa Islets	0.515	0.478	0.051	0.045	0.052		0.15	0.448	0.139	0.144	0.311	0.453	0.406	0.51	0.568	0.435	0.38
Lihou Reef	0.043	-0.066	-0.092	-0.018	-0.064	0.15		-0.098	0.081	0.149	0.029	0.08	0.046	0.13	0.109	0.149	0.064
Abington Reef	0.64	0.582	0.531	0.063	0.35	0.448	-0.098		0.235	0.407	0.108	0.241	0.142	0.179	0.361	0.165	0.246
Diamond Islets	0.382	0.086	-0.112	0.231	0.034	0.139	0.081	0.235		0.185	0.207	0.361	0.258	0.356	0.511	0.326	0.224
Flinders Reef	0.372	0.403	0.024	0.192	0.161	0.144	0.149	0.407	0.185		0.271	0.304	0.259	0.269	0.431	0.391	0.163
Mellish Reef	0.13	-0.048	0.111	0.125	0.141	0.311	0.029	0.108	0.207	0.271		0.059	0.073	0.255	0.094	0.292	0.186
Marion Reef	0.098	0.364	0.112	0.321	0.216	0.453	0.08	0.241	0.361	0.304	0.059		0.058	0.151	-0.079	0.144	0.127
Frederick Reef	0.201	0.157	0.186	0.25	0.171	0.406	0.046	0.142	0.258	0.259	0.073	0.058		0.031	0.127	0.156	0.045
Kenn Reef	0.126	0.419	0.303	0.405	0.121	0.51	0.13	0.179	0.356	0.269	0.255	0.151	0.031		0.276	0.12	0.086
Saumarez Reef	0.214	0.562	0.294	0.377	0.371	0.568	0.109	0.361	0.511	0.431	0.094	-0.079	0.127	0.276		0.248	0.176
Wreck Reefs	0.126	0.24	0.279	0.366	0.169	0.435	0.149	0.165	0.326	0.391	0.292	0.144	0.156	0.12	0.248		0.065
Cato Reef	0.254	0.444	0.222	0.325	0.169	0.38	0.064	0.246	0.224	0.163	0.186	0.127	0.045	0.086	0.176	0.065	

Appendix 4 continued:
SIMPER results, fish functional groups (only 10% + contributors)

Groups Marion Reef & Herald Cays Average dissimilarity = 18.78						
	Group Marion Reef	Group Herald Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.52	4.29	2.83	2.27	15.06	15.06
AllFarmers	2.61	4.09	2.43	1.94	12.96	28.02
Planktivores	4.58	5.74	2.31	1.15	12.3	40.32
Groups Marion Reef & Lihou Reef Average dissimilarity = 19.91						
	Group Marion Reef	Group Lihou Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.58	5.54	2.42	1.25	12.17	12.17
Omnivores	2.52	1.84	2.38	1.46	11.96	24.12
Groups Herald Cays & Lihou Reef Average dissimilarity = 17.41						
	Group Herald Cays	Group Lihou Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	1.84	3.85	1.65	22.1	22.1
Planktivores	5.74	5.54	1.89	1.34	10.84	32.94
Groups Marion Reef & Diamond Islets Average dissimilarity = 18.73						
	Group Marion Reef	Group Diamond Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	4.13	2.58	1.8	13.77	13.77
Detritivores	3.04	4.28	2.18	1.56	11.64	25.41
Planktivores	4.58	5.81	2.18	1.13	11.62	37.03
Omnivores	2.52	2.75	2.01	1.61	10.73	47.76
Groups Herald Cays & Diamond Islets Average dissimilarity = 14.48						
	Group Herald Cays	Group Diamond Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	2.75	2.32	1.18	16.04	16.04
Detritivores	3.41	4.28	1.69	1.71	11.67	27.71
Groups Lihou Reef & Diamond Islets Average dissimilarity = 17.50						
	Group Lihou Reef	Group Diamond Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	2.75	2.66	1.44	15.19	15.19
AllFarmers	3.37	4.13	1.64	1.21	9.37	24.55
Groups Marion Reef & Abington Reef Average dissimilarity = 20.58						
	Group Marion Reef	Group Abington Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.58	6.81	3.38	1.52	16.44	16.44
AllFarmers	2.61	4.56	2.98	2.09	14.5	30.95
Croppers	4.12	2.95	2.18	1.33	10.58	41.53
Groups Herald Cays & Abington Reef Average dissimilarity = 14.31						
	Group Herald Cays	Group Abington Reef				

Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	2.36	3.29	1.76	23	23
Planktivores	5.74	6.81	1.93	1.64	13.5	36.5
Browsers	0.89	1.37	1.44	1.63	10.03	46.53
Groups Lihou Reef & Abington Reef Average dissimilarity = 17.88						
	Group Lihou Reef	Group Abington Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	2.36	2.5	1.35	13.98	13.98
Planktivores	5.54	6.81	2.15	1.15	12	25.98
AllFarmers	3.37	4.56	1.8	1.38	10.09	36.06
Groups Diamond Islets & Abington Reef Average dissimilarity = 15.98						
	Group Diamond Islets	Group Abington Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.75	2.36	2.48	1.61	15.52	15.52
Croppers	3.92	2.95	1.67	1.48	10.44	25.96
Planktivores	5.81	6.81	1.6	1.49	9.99	35.95
Groups Marion Reef & Flinders Reef Average dissimilarity = 19.03						
	Group Marion Reef	Group Flinders Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	4.65	3.24	1.81	17.03	17.03
Planktivores	4.58	5.58	2.14	1.18	11.26	28.3
Browsers	1.59	2.08	1.81	1.42	9.52	37.81
Groups Herald Cays & Flinders Reef Average dissimilarity = 15.46						
	Group Herald Cays	Group Flinders Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	0.89	2.08	1.91	1.51	12.38	12.38
Omnivores	4.29	3.15	1.74	1.32	11.29	23.66
Planktivores	5.74	5.58	1.57	1.33	10.18	33.84
Groups Lihou Reef & Flinders Reef Average dissimilarity = 19.22						
	Group Lihou Reef	Group Flinders Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	3.15	2.71	1.47	14.1	14.1
Browsers	0.89	2.08	2.21	1.46	11.5	25.6
AllFarmers	3.37	4.65	2.11	1.26	11	36.6
Groups Diamond Islets & Flinders Reef Average dissimilarity = 16.06						
	Group Diamond Islets	Group Flinders Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritivores	4.28	3.03	2.06	1.65	12.81	12.81
Browsers	1.33	2.08	1.81	1.45	11.29	24.1
Omnivores	2.75	3.15	1.78	1.2	11.09	35.2
Groups Abington Reef & Flinders Reef Average dissimilarity = 17.81						
	Group Abington Reef	Group Flinders Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.36	3.15	2.4	1.66	13.48	13.48

Planktivores	6.81	5.58	1.95	1.34	10.94	24.42
Croppers	2.95	4.25	1.87	1.42	10.49	34.9
Browsers	1.37	2.08	1.82	1.36	10.24	45.14
Groups Marion Reef & Coringa Islets Average dissimilarity = 19.96						
	Group Marion Reef	Group Coringa Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	4.51	3.02	1.9	15.15	15.15
Planktivores	4.58	5.61	2.81	1.21	14.1	29.25
Omnivores	2.52	3.63	2.45	1.57	12.3	41.55
Groups Herald Cays & Coringa Islets Average dissimilarity = 13.92						
	Group Herald Cays	Group Coringa Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.74	5.61	2.12	1.04	15.19	15.19
Omnivores	4.29	3.63	1.79	1.23	12.84	28.03
Croppers	3.36	4.3	1.38	1.4	9.9	37.94
Groups Lihou Reef & Coringa Islets Average dissimilarity = 18.55						
	Group Lihou Reef	Group Coringa Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	3.63	3.36	1.44	18.12	18.12
Planktivores	5.54	5.61	2.22	0.97	11.98	30.09
AllFarmers	3.37	4.51	1.82	1.18	9.82	39.91
Groups Diamond Islets & Coringa Islets Average dissimilarity = 15.45						
	Group Diamond Islets	Group Coringa Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.75	3.63	2.36	1.29	15.26	15.26
Planktivores	5.81	5.61	1.78	0.85	11.49	26.75
Obligate corallivores	1.7	0.77	1.68	1.57	10.86	37.61
Groups Abington Reef & Coringa Islets Average dissimilarity = 17.32						
	Group Abington Reef	Group Coringa Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.36	3.63	2.96	1.55	17.11	17.11
Planktivores	6.81	5.61	2.12	0.85	12.24	29.35
Croppers	2.95	4.3	1.95	1.66	11.27	40.62
Groups Flinders Reef & Coringa Islets Average dissimilarity = 15.53						
	Group Flinders Reef	Group Coringa Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	2.08	0.53	2.32	1.69	14.92	14.92
Planktivores	5.58	5.61	1.96	0.93	12.62	27.53
Omnivores	3.15	3.63	1.92	1.36	12.35	39.88
Groups Marion Reef & Magdelaine Cays Average dissimilarity = 20.54						
	Group Marion Reef	Group Magdelaine Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	4.82	3.31	2.02	16.1	16.1
Planktivores	4.58	5.84	2.73	1.38	13.28	29.38

Omnivores	2.52	3.04	2.02	1.65	9.84	39.22
Groups Herald Cays & Magdelaine Cays Average dissimilarity = 14.66						
	Group Herald Cays	Group Magdelaine Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.74	5.84	2.02	1.41	13.75	13.75
Omnivores	4.29	3.04	2	1.06	13.64	27.39
Croppers	3.36	4.3	1.64	1.55	11.22	38.61
Groups Lihou Reef & Magdelaine Cays Average dissimilarity = 18.46						
	Group Lihou Reef	Group Magdelaine Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	3.04	2.75	1.45	14.88	14.88
AllFarmers	3.37	4.82	2.15	1.37	11.65	26.53
Planktivores	5.54	5.84	2.15	1.23	11.63	38.16
Groups Diamond Islets & Magdelaine Cays Average dissimilarity = 16.39						
	Group Diamond Islets	Group Magdelaine Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.75	3.04	2.03	1.24	12.36	12.36
Planktivores	5.81	5.84	1.78	1.32	10.85	23.21
Browsers	1.33	0.71	1.65	1.39	10.07	33.28
Groups Abington Reef & Magdelaine Cays Average dissimilarity = 16.15						
	Group Abington Reef	Group Magdelaine Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.36	3.04	2.51	1.59	15.54	15.54
Croppers	2.95	4.3	2.07	1.56	12.83	28.37
Planktivores	6.81	5.84	1.96	1.06	12.15	40.52
Browsers	1.37	0.71	1.7	1.46	10.53	51.05
Groups Flinders Reef & Magdelaine Cays Average dissimilarity = 16.82						
	Group Flinders Reef	Group Magdelaine Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	2.08	0.71	2.3	1.59	13.64	13.64
Planktivores	5.58	5.84	1.96	1.36	11.63	25.27
Omnivores	3.15	3.04	1.71	1.25	10.15	35.42
Groups Coringa Islets & Magdelaine Cays Average dissimilarity = 15.10						
	Group Coringa Islets	Group Magdelaine Cays				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.61	5.84	2.34	1.04	15.49	15.49
Omnivores	3.63	3.04	2.18	1.25	14.45	29.94
Excavators	0.92	1.65	1.51	1.43	10.02	39.96
Groups Marion Reef & Willis Islets Average dissimilarity = 18.40						
	Group Marion Reef	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	4.92	3.48	2.11	18.89	18.89
Omnivores	2.52	3.64	2.04	1.77	11.11	30
Excavators	1.52	1	1.8	1.65	9.77	39.77

Groups Herald Cays & Willis Islets Average dissimilarity = 13.30						
	Group Herald Cays	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	1.25	1	1.66	2.01	12.49	12.49
Croppers	3.36	4.53	1.66	1.82	12.47	24.96
AllFarmers	4.09	4.92	1.34	1.48	10.09	35.04
Groups Lihou Reef & Willis Islets Average dissimilarity = 17.45						
	Group Lihou Reef	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	3.64	3.05	1.48	17.5	17.5
AllFarmers	3.37	4.92	2.33	1.49	13.33	30.83
Excavators	1.5	1	1.91	1.46	10.93	41.76
Groups Diamond Islets & Willis Islets Average dissimilarity = 13.60						
	Group Diamond Islets	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.75	3.64	1.89	1.18	13.88	13.88
Excavators	1.12	1	1.55	1.49	11.39	25.27
AllFarmers	4.13	4.92	1.55	1.16	11.38	36.65
Groups Abington Reef & Willis Islets Average dissimilarity = 15.58						
	Group Abington Reef	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.36	3.64	2.71	1.81	17.41	17.41
Croppers	2.95	4.53	2.22	2.01	14.24	31.65
Excavators	1.7	1	1.81	2.31	11.6	43.25
Planktivores	6.81	5.53	1.75	2.05	11.2	54.46
Groups Flinders Reef & Willis Islets Average dissimilarity = 14.79						
	Group Flinders Reef	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	2.08	0.92	1.87	1.43	12.64	12.64
Detritivores	3.03	3.97	1.55	1.74	10.5	23.14
Facultative corallivores	2.4	1.38	1.45	1.52	9.83	32.97
Groups Coringa Islets & Willis Islets Average dissimilarity = 13.58						
	Group Coringa Islets	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Obligate corallivores	0.77	1.96	1.75	1.72	12.92	12.92
Omnivores	3.63	3.64	1.69	1.3	12.43	25.35
Planktivores	5.61	5.53	1.56	0.8	11.52	36.87
Excavators	0.92	1	1.47	1.23	10.83	47.7
Groups Magdelaine Cays & Willis Islets Average dissimilarity = 14.83						
	Group Magdelaine Cays	Group Willis Islets				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	1.65	1	1.78	1.64	11.98	11.98
Planktivores	5.84	5.53	1.7	1.6	11.49	23.48
Omnivores	3.04	3.64	1.67	1.1	11.23	34.71

Groups Marion Reef & Holmes Reef Average dissimilarity = 18.01						
	Group Marion Reef	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	4.68	3.04	2.11	16.85	16.85
Planktivores	4.58	6.36	2.66	1.29	14.75	31.6
Piscivores	1.88	3.46	2.27	2.3	12.6	44.2
Groups Herald Cays & Holmes Reef Average dissimilarity = 14.05						
	Group Herald Cays	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	2.01	3.1	4.09	22.08	22.08
Planktivores	5.74	6.36	1.56	1.71	11.11	33.19
Scrapers	1.61	2.51	1.25	1.99	8.86	42.05
Groups Lihou Reef & Holmes Reef Average dissimilarity = 16.01						
	Group Lihou Reef	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	3.37	4.68	1.93	1.45	12.03	12.03
Omnivores	1.84	2.01	1.81	1.65	11.32	23.35
Piscivores	2.47	3.46	1.72	1.4	10.77	34.12
Planktivores	5.54	6.36	1.65	1.02	10.32	44.43
Groups Diamond Islets & Holmes Reef Average dissimilarity = 13.96						
	Group Diamond Islets	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	2.75	2.01	1.83	1.95	13.14	13.14
Piscivores	2.37	3.46	1.71	1.7	12.26	25.4
Excavators	1.12	2.08	1.41	1.34	10.13	35.53
Groups Abington Reef & Holmes Reef Average dissimilarity = 12.21						
	Group Abington Reef	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Croppers	2.95	4.24	1.75	1.55	14.37	14.37
Omnivores	2.36	2.01	1.6	1.17	13.11	27.47
Browsers	1.37	1.04	1.31	1.51	10.72	38.2
Groups Flinders Reef & Holmes Reef Average dissimilarity = 15.95						
	Group Flinders Reef	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	0.73	2.08	1.93	1.93	12.1	12.1
Scrapers	1.34	2.51	1.72	1.37	10.8	22.9
Browsers	2.08	1.04	1.69	1.48	10.59	33.49
Omnivores	3.15	2.01	1.65	1.57	10.34	43.83
Piscivores	2.35	3.46	1.63	1.58	10.24	54.07
Groups Coringa Islets & Holmes Reef Average dissimilarity = 15.34						
	Group Coringa Islets	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.63	2.01	2.45	1.7	16	16
Excavators	0.92	2.08	1.78	2.02	11.58	27.58

Planktivores	5.61	6.36	1.71	0.77	11.17	38.75
Piscivores	2.38	3.46	1.62	1.83	10.57	49.32
Obligate corallivores	0.77	1.89	1.61	1.65	10.49	59.81
Scrapers	1.37	2.51	1.59	2.3	10.33	70.15
Groups Magdelaine Cays & Holmes Reef Average dissimilarity = 13.99						
	Group Magdelaine Cays	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.04	2.01	1.94	2.06	13.87	13.87
Planktivores	5.84	6.36	1.68	1.1	12.01	25.88
Scrapers	1.29	2.51	1.66	1.69	11.89	37.77
Groups Willis Islets & Holmes Reef Average dissimilarity = 12.56						
	Group Willis Islets	Group Holmes Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.64	2.01	2.17	2.11	17.29	17.29
Excavators	1	2.08	2.01	2.57	16	33.29
Piscivores	2.33	3.46	1.67	1.79	13.26	46.55
Groups Marion Reef & Osprey Reef Average dissimilarity = 16.46						
	Group Marion Reef	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	3.47	1.98	1.58	12.05	12.05
Croppers	4.12	3.36	1.73	1.39	10.53	22.59
Planktivores	4.58	5.07	1.66	1.04	10.1	32.69
Excavators	1.52	2.43	1.66	1.45	10.09	42.78
Browsers	1.59	1.12	1.66	1.27	10.07	52.85
Groups Herald Cays & Osprey Reef Average dissimilarity = 13.85						
	Group Herald Cays	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	3.11	1.8	1.49	12.99	12.99
Excavators	1.25	2.43	1.7	1.45	12.29	25.28
Detritivores	3.41	2.33	1.58	1.27	11.44	36.72
Planktivores	5.74	5.07	1.45	1.24	10.48	47.2
Groups Lihou Reef & Osprey Reef Average dissimilarity = 17.89						
	Group Lihou Reef	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	3.11	2.74	1.47	15.32	15.32
Detritivores	3.63	2.33	2.04	1.49	11.42	26.73
Excavators	1.5	2.43	1.94	1.27	10.85	37.58
Groups Diamond Islets & Osprey Reef Average dissimilarity = 16.66						
	Group Diamond Islets	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritivores	4.28	2.33	2.88	2.38	17.3	17.3
Excavators	1.12	2.43	2	1.47	12.02	29.32
Omnivores	2.75	3.11	1.83	1.3	10.97	40.29
Groups Abington Reef & Osprey Reef Average dissimilarity = 16.66						

	Group Abington Reef	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.81	5.07	2.51	2.42	15.09	15.09
Omnivores	2.36	3.11	2.43	1.71	14.61	29.71
Detritivores	3.64	2.33	1.92	2.31	11.51	41.22
Groups Flinders Reef & Osprey Reef Average dissimilarity = 16.80						
	Group Flinders Reef	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	0.73	2.43	2.58	2	15.35	15.35
AllFarmers	4.65	3.47	2.02	1.33	12.04	27.39
Browsers	2.08	1.12	1.9	1.49	11.29	38.68
Groups Coringa Islets & Osprey Reef Average dissimilarity = 17.58						
	Group Coringa Islets	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	0.92	2.43	2.39	1.98	13.57	13.57
Planktivores	5.61	5.07	2.08	1.13	11.86	25.43
Detritivores	3.6	2.33	2	1.68	11.38	36.81
Omnivores	3.63	3.11	1.92	1.39	10.94	47.75
Groups Magdelaine Cays & Osprey Reef Average dissimilarity = 17.61						
	Group Magdelaine Cays	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.84	5.07	2.08	1.84	11.81	11.81
AllFarmers	4.82	3.47	2.02	1.37	11.45	23.26
Detritivores	3.56	2.33	1.8	2.09	10.2	33.45
Groups Willis Islets & Osprey Reef Average dissimilarity = 15.62						
	Group Willis Islets	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	1	2.43	2.5	2.04	15.97	15.97
Detritivores	3.97	2.33	2.37	3.05	15.2	31.17
AllFarmers	4.92	3.47	2.21	1.55	14.12	45.29
Croppers	4.53	3.36	1.7	4.79	10.87	56.16
Groups Holmes Reef & Osprey Reef Average dissimilarity = 15.05						
	Group Holmes Reef	Group Osprey Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritivores	3.72	2.33	1.96	2.32	13.03	13.03
Piscivores	3.46	2.13	1.89	1.84	12.56	25.59
Planktivores	6.36	5.07	1.82	1.81	12.1	37.69
AllFarmers	4.68	3.47	1.8	1.47	11.94	49.63
Omnivores	2.01	3.11	1.59	1.48	10.54	60.17
Groups Marion Reef & Cato Reef Average dissimilarity = 18.49						
	Group Marion Reef	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	2.61	3.87	2.38	1.56	12.87	12.87
Croppers	4.12	3.38	1.96	1.39	10.6	23.47

Detritivores	3.04	2.99	1.92	1.31	10.37	33.84
Groups Herald Cays & Cato Reef Average dissimilarity = 16.37						
	Group Herald Cays	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	2.24	3.07	2.05	18.73	18.73
Browsers	0.89	1.8	1.82	1.54	11.13	29.86
Detritivores	3.41	2.99	1.8	1.27	11.01	40.88
Groups Lihou Reef & Cato Reef Average dissimilarity = 18.49						
	Group Lihou Reef	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	2.24	2.23	1.52	12.04	12.04
Browsers	0.89	1.8	2.09	1.38	11.29	23.33
Detritivores	3.63	2.99	1.98	1.16	10.72	34.05
Groups Diamond Islets & Cato Reef Average dissimilarity = 16.56						
	Group Diamond Islets	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritivores	4.28	2.99	2.31	1.22	13.98	13.98
Omnivores	2.75	2.24	2.01	1.51	12.14	26.12
Browsers	1.33	1.8	1.79	1.47	10.8	36.93
Groups Abington Reef & Cato Reef Average dissimilarity = 17.26						
	Group Abington Reef	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.81	5.4	2.08	2.03	12.04	12.04
Omnivores	2.36	2.24	2.06	1.42	11.96	24
Browsers	1.37	1.8	1.82	1.42	10.54	34.54
Groups Flinders Reef & Cato Reef Average dissimilarity = 16.69						
	Group Flinders Reef	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.15	2.24	1.78	1.32	10.66	10.66
Detritivores	3.03	2.99	1.77	1.34	10.61	21.27
AllFarmers	4.65	3.87	1.77	1.46	10.59	31.85
Browsers	2.08	1.8	1.67	1.39	10.01	41.87
Groups Coringa Islets & Cato Reef Average dissimilarity = 17.88						
	Group Coringa Islets	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.63	2.24	2.56	1.43	14.29	14.29
Browsers	0.53	1.8	2.16	1.6	12.06	26.35
Planktivores	5.61	5.4	1.89	0.96	10.56	36.91
Detritivores	3.6	2.99	1.88	1.15	10.51	47.42
Groups Magdelaine Cays & Cato Reef Average dissimilarity = 18.57						
	Group Magdelaine Cays	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	0.71	1.8	2.13	1.43	11.48	11.48
Omnivores	3.04	2.24	2.06	1.52	11.09	22.57

Planktivores	5.84	5.4	1.92	1.62	10.32	32.89
Groups Willis Islets & Cato Reef Average dissimilarity = 16.46						
	Group Willis Islets	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.64	2.24	2.15	1.43	13.06	13.06
AllFarmers	4.92	3.87	1.82	1.54	11.03	24.09
Browsers	0.92	1.8	1.8	1.5	10.97	35.05
Detritivores	3.97	2.99	1.78	1.04	10.79	45.84
Croppers	4.53	3.38	1.69	1.53	10.29	56.13
Groups Holmes Reef & Cato Reef Average dissimilarity = 16.46						
	Group Holmes Reef	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Piscivores	3.46	1.73	2.46	2.01	14.96	14.96
Excavators	2.08	0.86	1.8	1.91	10.94	25.9
Browsers	1.04	1.8	1.64	1.57	9.94	35.84
Groups Osprey Reef & Cato Reef Average dissimilarity = 16.32						
	Group Osprey Reef	Group Cato Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	2.43	0.86	2.45	1.98	15.03	15.03
Detritivores	2.33	2.99	1.94	1.63	11.89	26.92
Browsers	1.12	1.8	1.81	1.42	11.1	38.02
Omnivores	3.11	2.24	1.71	1.22	10.45	48.46
Groups Marion Reef & Wreck Reefs Average dissimilarity = 19.72						
	Group Marion Reef	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.58	4.82	2.72	1.33	13.8	13.8
Croppers	4.12	3.08	2.17	1.32	11.02	24.82
Omnivores	2.52	1.65	1.85	1.23	9.39	34.21
Groups Herald Cays & Wreck Reefs Average dissimilarity = 19.15						
	Group Herald Cays	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	1.65	4.17	2.8	21.76	21.76
Planktivores	5.74	4.82	2.7	1.34	14.09	35.85
AllFarmers	4.09	2.97	1.98	1.54	10.33	46.19
Groups Lihou Reef & Wreck Reefs Average dissimilarity = 19.86						
	Group Lihou Reef	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.54	4.82	2.72	1.26	13.71	13.71
Omnivores	1.84	1.65	2.16	1.43	10.9	24.61
Excavators	1.5	1.04	1.91	1.47	9.6	34.21
Groups Diamond Islets & Wreck Reefs Average dissimilarity = 19.63						
	Group Diamond Islets	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.81	4.82	2.5	1.25	12.74	12.74

Omnivores	2.75	1.65	2.5	1.66	12.71	25.45
AllFarmers	4.13	2.97	2.22	1.55	11.33	36.78
Detritivores	4.28	3.15	1.98	1.75	10.06	46.83
Groups Abington Reef & Wreck Reefs Average dissimilarity = 19.76						
	Group Abington Reef	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.81	4.82	3.39	1.33	17.13	17.13
AllFarmers	4.56	2.97	2.58	1.93	13.07	30.2
Omnivores	2.36	1.65	2.14	1.24	10.84	41.04
Groups Flinders Reef & Wreck Reefs Average dissimilarity = 20.91						
	Group Flinders Reef	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.65	2.97	2.83	1.56	13.52	13.52
Omnivores	3.15	1.65	2.52	1.62	12.06	25.58
Planktivores	5.58	4.82	2.5	1.29	11.95	37.53
Browsers	2.08	1.01	2.11	1.46	10.09	47.62
Groups Coringa Islets & Wreck Reefs Average dissimilarity = 21.15						
	Group Coringa Islets	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.63	1.65	3.36	1.64	15.88	15.88
Planktivores	5.61	4.82	3.11	1.24	14.69	30.56
AllFarmers	4.51	2.97	2.59	1.62	12.26	42.82
Groups Magdelaine Cays & Wreck Reefs Average dissimilarity = 21.24						
	Group Magdelaine Cays	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.84	4.82	2.94	1.33	13.83	13.83
AllFarmers	4.82	2.97	2.91	1.8	13.71	27.54
Omnivores	3.04	1.65	2.65	1.74	12.48	40.02
Groups Willis Islets & Wreck Reefs Average dissimilarity = 20.43						
	Group Willis Islets	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.64	1.65	3.09	1.92	15.13	15.13
AllFarmers	4.92	2.97	3.08	1.87	15.06	30.19
Croppers	4.53	3.08	2.24	2.68	10.98	41.16
Planktivores	5.53	4.82	2.17	1.23	10.61	51.77
Groups Holmes Reef & Wreck Reefs Average dissimilarity = 19.29						
	Group Holmes Reef	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.36	4.82	2.76	1.23	14.32	14.32
AllFarmers	4.68	2.97	2.64	1.87	13.67	27.99
Piscivores	3.46	1.8	2.58	2.17	13.39	41.37
Scrapers	2.51	1.26	1.95	1.58	10.08	51.46
Excavators	2.08	1.04	1.94	2.19	10.04	61.5
Groups Osprey Reef & Wreck Reefs Average dissimilarity = 18.67						

	Group Osprey Reef	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Excavators	2.43	1.04	2.58	2.08	13.83	13.83
Omnivores	3.11	1.65	2.51	1.57	13.46	27.29
Planktivores	5.07	4.82	2.29	1.45	12.28	39.57
Groups Cato Reef & Wreck Reefs Average dissimilarity = 18.32						
	Group Cato Reef	Group Wreck Reefs				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.4	4.82	2.37	1.32	12.95	12.95
Browsers	1.8	1.01	2.02	1.44	11.03	23.98
AllFarmers	3.87	2.97	2	1.32	10.93	34.91
Groups Marion Reef & Saumarez Reef Average dissimilarity = 18.48						
	Group Marion Reef	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.58	4.39	2.11	1.33	11.42	11.42
Excavators	1.52	1.8	1.89	1.52	10.21	21.63
Croppers	4.12	3.73	1.88	1.36	10.2	31.83
Browsers	1.59	1.26	1.85	1.33	10	41.83
Groups Herald Cays & Saumarez Reef Average dissimilarity = 20.13						
	Group Herald Cays	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	2.13	3.3	3.21	16.4	16.4
Planktivores	5.74	4.39	2.41	1.37	11.99	28.39
AllFarmers	4.09	2.67	2.26	1.45	11.21	39.6
Groups Lihou Reef & Saumarez Reef Average dissimilarity = 20.27						
	Group Lihou Reef	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.54	4.39	2.48	1.48	12.25	12.25
Omnivores	1.84	2.13	2.17	1.52	10.72	22.97
Detritivores	3.63	2.74	2.08	1.48	10.25	33.22
Excavators	1.5	1.8	2.08	1.3	10.25	43.47
Groups Diamond Islets & Saumarez Reef Average dissimilarity = 20.17						
	Group Diamond Islets	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritivores	4.28	2.74	2.61	1.67	12.93	12.93
AllFarmers	4.13	2.67	2.47	1.51	12.23	25.15
Planktivores	5.81	4.39	2.35	1.51	11.67	36.82
Omnivores	2.75	2.13	2.04	1.77	10.11	46.93
Groups Abington Reef & Saumarez Reef Average dissimilarity = 21.88						
	Group Abington Reef	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.81	4.39	3.68	2.07	16.82	16.82
AllFarmers	4.56	2.67	2.96	1.95	13.53	30.35
Omnivores	2.36	2.13	1.93	1.27	8.84	39.19

Groups Flinders Reef & Saumarez Reef Average dissimilarity = 19.91						
	Group Flinders Reef	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.65	2.67	3.15	1.57	15.84	15.84
Excavators	0.73	1.8	2.22	1.48	11.16	27
Planktivores	5.58	4.39	2.21	1.43	11.1	38.11
Groups Coringa Islets & Saumarez Reef Average dissimilarity = 21.00						
	Group Coringa Islets	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.61	4.39	3	1.5	14.3	14.3
AllFarmers	4.51	2.67	2.93	1.63	13.97	28.27
Omnivores	3.63	2.13	2.68	1.67	12.77	41.04
Excavators	0.92	1.8	2.14	1.54	10.19	51.24
Groups Magdelaine Cays & Saumarez Reef Average dissimilarity = 21.20						
	Group Magdelaine Cays	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.82	2.67	3.27	1.85	15.44	15.44
Planktivores	5.84	4.39	2.82	1.6	13.31	28.75
Omnivores	3.04	2.13	2.12	1.84	10	38.75
Groups Willis Islets & Saumarez Reef Average dissimilarity = 20.61						
	Group Willis Islets	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.92	2.67	3.44	1.9	16.69	16.69
Omnivores	3.64	2.13	2.31	1.94	11.21	27.9
Excavators	1	1.8	2.22	1.4	10.76	38.65
Groups Holmes Reef & Saumarez Reef Average dissimilarity = 19.35						
	Group Holmes Reef	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.68	2.67	3	1.92	15.49	15.49
Planktivores	6.36	4.39	2.9	1.7	14.98	30.47
Piscivores	3.46	1.66	2.7	1.57	13.94	44.41
Groups Osprey Reef & Saumarez Reef Average dissimilarity = 16.84						
	Group Osprey Reef	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	3.47	2.67	1.88	1.36	11.17	11.17
Excavators	2.43	1.8	1.76	1.22	10.45	21.61
Omnivores	3.11	2.13	1.74	1.48	10.34	31.96
Groups Cato Reef & Saumarez Reef Average dissimilarity = 18.90						
	Group Cato Reef	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	3.87	2.67	2.24	1.3	11.88	11.88
Excavators	0.86	1.8	2.19	1.56	11.6	23.47
Detritivores	2.99	2.74	2.1	1.39	11.12	34.59
Planktivores	5.4	4.39	1.94	1.33	10.24	44.82

Browsers	1.8	1.26	1.91	1.31	10.11	54.93
Groups Wreck Reefs & Saumarez Reef Average dissimilarity = 20.30						
	Group Wreck Reefs	Group Saumarez Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.82	4.39	2.67	1.43	13.17	13.17
Excavators	1.04	1.8	2.34	1.53	11.54	24.71
Browsers	1.01	1.26	1.75	1.55	8.64	33.35
Groups Marion Reef & Kenn Reef Average dissimilarity = 19.39						
	Group Marion Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Croppers	4.12	2.63	2.65	1.34	13.69	13.69
Planktivores	4.58	5.07	2.26	1.24	11.66	25.35
Browsers	1.59	1.86	2.15	1.49	11.08	36.43
Groups Herald Cays & Kenn Reef Average dissimilarity = 16.51						
	Group Herald Cays	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	2.76	2.35	1.75	14.23	14.23
Planktivores	5.74	5.07	2.04	1.33	12.33	26.56
Browsers	0.89	1.86	2	1.38	12.13	38.69
Groups Lihou Reef & Kenn Reef Average dissimilarity = 19.78						
	Group Lihou Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	1.84	2.76	2.51	1.45	12.71	12.71
Browsers	0.89	1.86	2.34	1.44	11.85	24.56
Croppers	3.99	2.63	2.17	1.43	10.95	35.52
Planktivores	5.54	5.07	2.1	1.23	10.64	46.16
Groups Diamond Islets & Kenn Reef Average dissimilarity = 17.95						
	Group Diamond Islets	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritivores	4.28	2.91	2.24	1.64	12.49	12.49
Croppers	3.92	2.63	2.11	1.48	11.75	24.25
Browsers	1.33	1.86	2.07	1.51	11.51	35.76
Omnivores	2.75	2.76	1.86	1.37	10.38	46.14
Planktivores	5.81	5.07	1.8	1.22	10.05	56.19
Groups Abington Reef & Kenn Reef Average dissimilarity = 18.18						
	Group Abington Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.81	5.07	2.69	1.43	14.79	14.79
Omnivores	2.36	2.76	2.25	1.57	12.39	27.18
Browsers	1.37	1.86	2.08	1.43	11.43	38.62
Groups Flinders Reef & Kenn Reef Average dissimilarity = 18.33						
	Group Flinders Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Croppers	4.25	2.63	2.41	1.54	13.17	13.17

AllFarmers	4.65	3.33	2.09	1.37	11.42	24.59
Browsers	2.08	1.86	1.97	1.39	10.74	35.33
Planktivores	5.58	5.07	1.83	1.22	10.01	45.34
Groups Coringa Islets & Kenn Reef Average dissimilarity = 20.01						
	Group Coringa Islets	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Croppers	4.3	2.63	2.53	1.76	12.65	12.65
Obligate corallivores	0.77	2.38	2.49	2.08	12.44	25.09
Planktivores	5.61	5.07	2.47	1.13	12.34	37.43
Browsers	0.53	1.86	2.26	1.36	11.32	48.75
Omnivores	3.63	2.76	2.18	1.43	10.9	59.65
Groups Magdelaine Cays & Kenn Reef Average dissimilarity = 20.00						
	Group Magdelaine Cays	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Croppers	4.3	2.63	2.55	1.55	12.76	12.76
Planktivores	5.84	5.07	2.39	1.4	11.93	24.69
Browsers	0.71	1.86	2.33	1.42	11.65	36.34
AllFarmers	4.82	3.33	2.14	1.53	10.72	47.06
Groups Willis Islets & Kenn Reef Average dissimilarity = 18.39						
	Group Willis Islets	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Croppers	4.53	2.63	2.79	2.08	15.17	15.17
AllFarmers	4.92	3.33	2.31	1.65	12.58	27.75
Browsers	0.92	1.86	2.03	1.45	11.04	38.79
Groups Holmes Reef & Kenn Reef Average dissimilarity = 18.12						
	Group Holmes Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Croppers	4.24	2.63	2.29	1.68	12.63	12.63
Planktivores	6.36	5.07	2.09	1.23	11.51	24.14
AllFarmers	4.68	3.33	1.92	1.68	10.61	34.74
Browsers	1.04	1.86	1.86	1.48	10.29	45.03
Groups Osprey Reef & Kenn Reef Average dissimilarity = 16.32						
	Group Osprey Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	1.12	1.86	2.09	1.45	12.83	12.83
Excavators	2.43	1.1	2.07	1.7	12.68	25.51
Planktivores	5.07	5.07	1.65	1.47	10.12	35.64
Groups Cato Reef & Kenn Reef Average dissimilarity = 17.34						
	Group Cato Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	1.8	1.86	2.08	1.5	12.01	12.01
Detritivores	2.99	2.91	1.88	1.3	10.85	22.86
Croppers	3.38	2.63	1.66	1.27	9.55	32.41
Groups Wreck Reefs & Kenn Reef Average dissimilarity = 19.24						

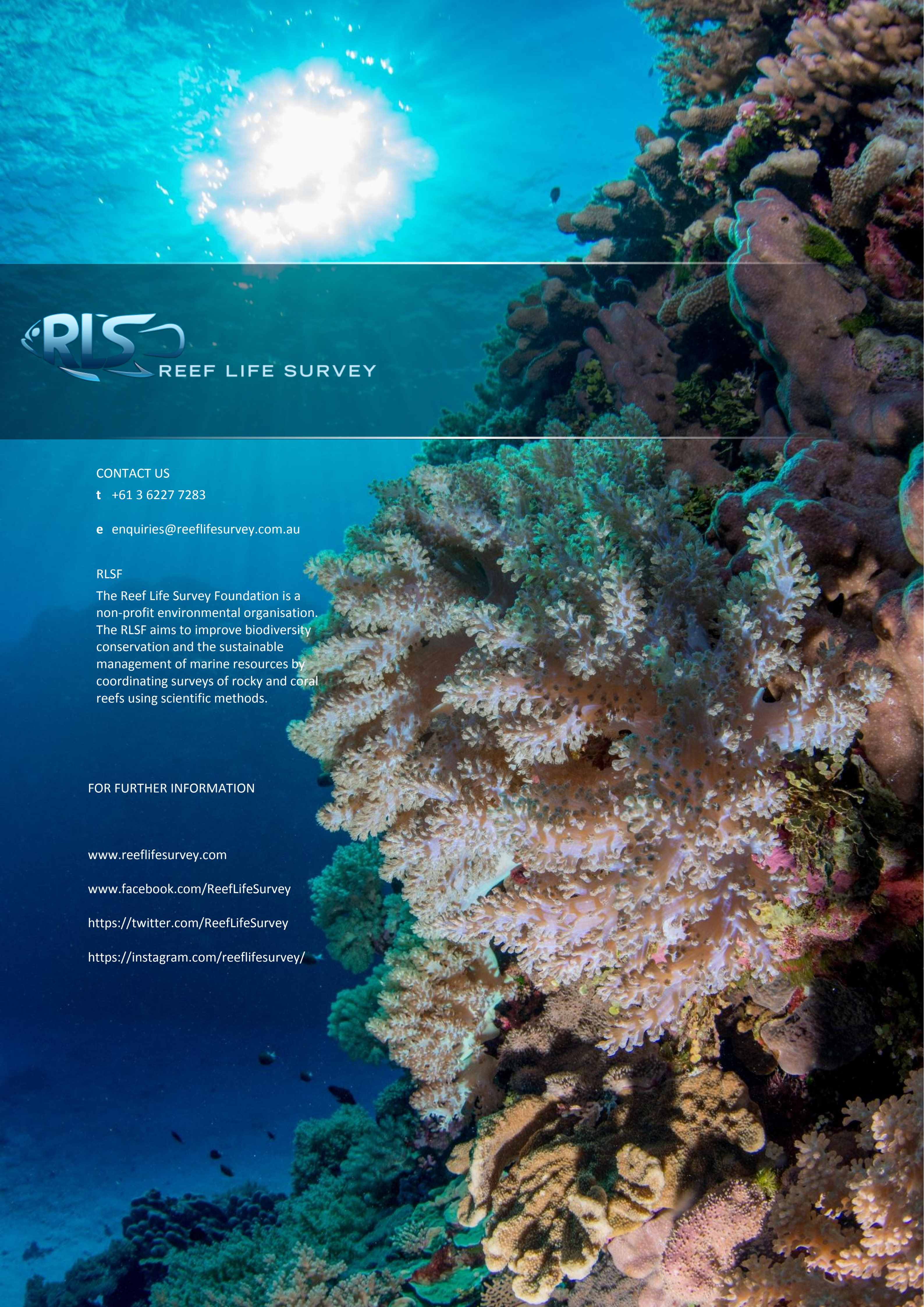
	Group Wreck Reefs	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.82	5.07	2.68	1.32	13.91	13.91
Browsers	1.01	1.86	2.27	1.4	11.79	25.7
Omnivores	1.65	2.76	2.14	1.4	11.1	36.8
Groups Saumarez Reef & Kenn Reef Average dissimilarity = 20.24						
	Group Saumarez Reef	Group Kenn Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	1.26	1.86	2.32	1.6	11.45	11.45
Planktivores	4.39	5.07	2.23	1.38	11.02	22.47
Croppers	3.73	2.63	2.06	1.36	10.17	32.64
Groups Marion Reef & Frederick Reef Average dissimilarity = 19.38						
	Group Marion Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.58	4.96	2.42	1.36	12.49	12.49
Browsers	1.59	2.03	2.18	1.36	11.26	23.75
Croppers	4.12	3.42	2.03	1.31	10.45	34.2
Groups Herald Cays & Frederick Reef Average dissimilarity = 18.95						
	Group Herald Cays	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	2.11	3.29	2.27	17.37	17.37
Planktivores	5.74	4.96	2.34	1.38	12.36	29.72
Browsers	0.89	2.03	2.15	1.42	11.36	41.09
AllFarmers	4.09	2.74	2.11	1.48	11.14	52.23
Groups Lihou Reef & Frederick Reef Average dissimilarity = 19.61						
	Group Lihou Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	0.89	2.03	2.38	1.31	12.16	12.16
Planktivores	5.54	4.96	2.38	1.3	12.15	24.31
Omnivores	1.84	2.11	2.08	1.51	10.59	34.9
Groups Diamond Islets & Frederick Reef Average dissimilarity = 18.72						
	Group Diamond Islets	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.13	2.74	2.33	1.53	12.43	12.43
Planktivores	5.81	4.96	2.18	1.34	11.64	24.07
Browsers	1.33	2.03	2.11	1.37	11.28	35.35
Omnivores	2.75	2.11	2.05	1.6	10.94	46.28
Groups Abington Reef & Frederick Reef Average dissimilarity = 19.54						
	Group Abington Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.81	4.96	3.01	1.4	15.38	15.38
AllFarmers	4.56	2.74	2.7	1.8	13.81	29.2
Browsers	1.37	2.03	2.1	1.28	10.72	39.92
Groups Flinders Reef & Frederick Reef Average dissimilarity = 19.79						

	Group Flinders Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.65	2.74	2.93	1.55	14.8	14.8
Planktivores	5.58	4.96	2.17	1.36	10.99	25.79
Browsers	2.08	2.03	2.02	1.37	10.22	36.01
Groups Coringa Islets & Frederick Reef Average dissimilarity = 20.82						
	Group Coringa Islets	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.61	4.96	2.78	1.27	13.33	13.33
AllFarmers	4.51	2.74	2.7	1.57	12.97	26.3
Omnivores	3.63	2.11	2.63	1.41	12.65	38.95
Browsers	0.53	2.03	2.42	1.41	11.63	50.58
Obligate corallivores	0.77	2.06	2.12	1.83	10.18	60.76
Groups Magdelaine Cays & Frederick Reef Average dissimilarity = 20.38						
	Group Magdelaine Cays	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.82	2.74	3.03	1.78	14.84	14.84
Planktivores	5.84	4.96	2.58	1.34	12.66	27.5
Browsers	0.71	2.03	2.43	1.39	11.94	39.44
Omnivores	3.04	2.11	2.12	1.6	10.41	49.86
Groups Willis Islets & Frederick Reef Average dissimilarity = 19.60						
	Group Willis Islets	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.92	2.74	3.19	1.86	16.28	16.28
Omnivores	3.64	2.11	2.3	1.51	11.72	28
Browsers	0.92	2.03	2.1	1.34	10.7	38.7
Groups Holmes Reef & Frederick Reef Average dissimilarity = 17.66						
	Group Holmes Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
AllFarmers	4.68	2.74	2.77	1.85	15.69	15.69
Planktivores	6.36	4.96	2.43	1.29	13.77	29.46
Browsers	1.04	2.03	1.96	1.4	11.08	40.54
Groups Osprey Reef & Frederick Reef Average dissimilarity = 18.77						
	Group Osprey Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	1.12	2.03	2.18	1.39	11.64	11.64
Detritivores	2.33	3.54	2.09	1.87	11.15	22.79
Planktivores	5.07	4.96	1.95	1.55	10.41	33.2
Excavators	2.43	1.23	1.91	1.38	10.15	43.35
Groups Cato Reef & Frederick Reef Average dissimilarity = 18.26						
	Group Cato Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	1.8	2.03	2.11	1.39	11.58	11.58
AllFarmers	3.87	2.74	2.08	1.27	11.42	23

Planktivores	5.4	4.96	2.04	1.43	11.16	34.16
Detritivores	2.99	3.54	2	1.18	10.94	45.1
Groups Wreck Reefs & Frederick Reef Average dissimilarity = 19.84						
	Group Wreck Reefs	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.82	4.96	2.79	1.34	14.09	14.09
Browsers	1.01	2.03	2.38	1.37	11.98	26.07
Groups Saumarez Reef & Frederick Reef Average dissimilarity = 19.86						
	Group Saumarez Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.39	4.96	2.31	1.36	11.62	11.62
Browsers	1.26	2.03	2.29	1.31	11.52	23.14
Detritivores	2.74	3.54	2.02	1.41	10.19	33.33
Groups Kenn Reef & Frederick Reef Average dissimilarity = 18.51						
	Group Kenn Reef	Group Frederick Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Browsers	1.86	2.03	2.37	1.39	12.78	12.78
Planktivores	5.07	4.96	2.34	1.34	12.62	25.4
Croppers	2.63	3.42	1.94	1.4	10.5	35.9
Groups Marion Reef & Mellish Reef Average dissimilarity = 19.46						
	Group Marion Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.58	4.81	2.62	1.2	13.48	13.48
AllFarmers	2.61	3.58	2.39	1.34	12.26	25.75
Detritivores	3.04	3.91	1.82	1.34	9.36	35.11
Groups Herald Cays & Mellish Reef Average dissimilarity = 19.08						
	Group Herald Cays	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	4.29	1.76	3.72	2.17	19.51	19.51
Planktivores	5.74	4.81	2.56	1.17	13.42	32.93
AllFarmers	4.09	3.58	1.87	1.58	9.8	42.73
Groups Lihou Reef & Mellish Reef Average dissimilarity = 19.40						
	Group Lihou Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.54	4.81	2.71	1.25	14	14
Omnivores	1.84	1.76	2.13	1.44	11	24.99
AllFarmers	3.37	3.58	1.95	1.31	10.07	35.06
Groups Diamond Islets & Mellish Reef Average dissimilarity = 18.43						
	Group Diamond Islets	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.81	4.81	2.47	1.19	13.42	13.42
Omnivores	2.75	1.76	2.3	1.47	12.49	25.91
AllFarmers	4.13	3.58	2.08	1.49	11.31	37.22
Groups Abington Reef & Mellish Reef Average dissimilarity = 19.12						

	Group Abington Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.81	4.81	3.32	1.35	17.37	17.37
AllFarmers	4.56	3.58	2.12	1.65	11.07	28.44
Croppers	2.95	4.19	2.11	1.61	11.03	39.47
Omnivores	2.36	1.76	2.08	1.24	10.88	50.35
Groups Flinders Reef & Mellish Reef Average dissimilarity = 19.66						
	Group Flinders Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.58	4.81	2.46	1.2	12.52	12.52
AllFarmers	4.65	3.58	2.39	1.51	12.14	24.66
Omnivores	3.15	1.76	2.25	1.34	11.44	36.11
Excavators	0.73	2.08	2.17	1.82	11.02	47.13
Groups Coringa Islets & Mellish Reef Average dissimilarity = 19.68						
	Group Coringa Islets	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.63	1.76	3.05	1.49	15.5	15.5
Planktivores	5.61	4.81	3.02	1.22	15.37	30.87
AllFarmers	4.51	3.58	2.21	1.56	11.23	42.11
Excavators	0.92	2.08	2.03	1.9	10.33	52.44
Groups Magdelaine Cays & Mellish Reef Average dissimilarity = 18.88						
	Group Magdelaine Cays	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.84	4.81	2.89	1.31	15.29	15.29
Omnivores	3.04	1.76	2.43	1.53	12.86	28.15
AllFarmers	4.82	3.58	2.38	1.58	12.59	40.74
Groups Willis Islets & Mellish Reef Average dissimilarity = 18.65						
	Group Willis Islets	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Omnivores	3.64	1.76	2.75	1.57	14.74	14.74
AllFarmers	4.92	3.58	2.45	1.58	13.16	27.9
Excavators	1	2.08	2.2	2.02	11.81	39.71
Planktivores	5.53	4.81	2.11	1.08	11.34	51.05
Groups Holmes Reef & Mellish Reef Average dissimilarity = 15.76						
	Group Holmes Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	6.36	4.81	2.77	1.27	17.57	17.57
AllFarmers	4.68	3.58	2.15	1.63	13.66	31.24
Piscivores	3.46	2.42	1.55	1.08	9.81	41.05
Groups Osprey Reef & Mellish Reef Average dissimilarity = 18.39						
	Group Osprey Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritivores	2.33	3.91	2.36	1.75	12.84	12.84
Omnivores	3.11	1.76	2.21	1.26	12.01	24.86

Planktivores	5.07	4.81	2.14	1.09	11.63	36.48
AllFarmers	3.47	3.58	1.96	1.38	10.64	47.12
Groups Cato Reef & Mellish Reef Average dissimilarity = 19.61						
	Group Cato Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.4	4.81	2.27	1.11	11.58	11.58
Detritivores	2.99	3.91	2.09	1.2	10.67	22.25
Excavators	0.86	2.08	2.07	1.85	10.55	32.8
AllFarmers	3.87	3.58	1.99	1.36	10.13	42.93
Groups Wreck Reefs & Mellish Reef Average dissimilarity = 21.63						
	Group Wreck Reefs	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.82	4.81	3.07	1.29	14.19	14.19
Excavators	1.04	2.08	2.23	2.02	10.3	24.5
AllFarmers	2.97	3.58	2.21	1.27	10.21	34.71
Groups Saumarez Reef & Mellish Reef Average dissimilarity = 19.76						
	Group Saumarez Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.39	4.81	2.58	1.24	13.06	13.06
AllFarmers	2.67	3.58	2.34	1.25	11.84	24.91
Detritivores	2.74	3.91	2.26	1.55	11.43	36.34
Groups Kenn Reef & Mellish Reef Average dissimilarity = 21.22						
	Group Kenn Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	5.07	4.81	2.63	1.24	12.42	12.42
Croppers	2.63	4.19	2.59	1.58	12.2	24.62
Browsers	1.86	1.43	2.15	1.53	10.12	34.74
Groups Frederick Reef & Mellish Reef Average dissimilarity = 19.77						
	Group Frederick Reef	Group Mellish Reef				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planktivores	4.96	4.81	2.74	1.27	13.86	13.86
AllFarmers	2.74	3.58	2.2	1.22	11.13	24.99
Browsers	2.03	1.43	2.14	1.32	10.84	35.83



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RLSF

The Reef Life Survey Foundation is a non-profit environmental organisation. The RLSF aims to improve biodiversity conservation and the sustainable management of marine resources by coordinating surveys of rocky and coral reefs using scientific methods.

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