# CORAL SEA MARINE BIODIVERSITY

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REEF LIFE SURVEY

# Summary
Through a unique collaboration with the Reef Life Survey (RLS) program, which engages recreational SCUBA divers trained to undertake scientific surveys, this project involved the first comprehensive survey of marine biodiversity of important Coral Sea reef systems. Through project activities, as well as follow up surveys currently underway at additional Coral Sea reef systems, detailed surveys of fauna and flora on the majority of shallow coral reef systems located in the offshore Coral Sea region will provide an enormous and valuable body of new knowledge of this remote, relatively unexplored part of the Australian Exclusive Economic Zone. This provides a baseline data set that will become increasingly important in future years for tracking changes to biodiversity in the new Coral Sea Marine Commonwealth Marine Reserve, and understanding the distribution and impacts of threats to Coral Sea marine plants and animals. Important findings included the discovery of in excess of 100 fish species not previously recorded in the Coral Sea, and high relative abundances of large black cod and Galapagos sharks at Elizabeth and Middleton Reefs.

# Introduction

Australia's Coral Sea lies to the east of the Great Barrier Reef (GBR), and is bounded by Vanuatu and New Caledonia in the east (to the edge of Australia's exclusive economic zone). In the north, it reaches the south coast of eastern New Guinea, including the Gulf of Papua, and merges with the Tasman Sea in the south, with the Solomon Sea in the north and the Pacific Ocean in the east. In the northwest, it connects with the Arafura Sea through the Torres Strait. The Coral Sea encompasses a number of shallow coral reef systems, which are regarded as among the coral reefs least impacted by humans in the world. These reefs harbour a rich diversity or marine life and a number of endemic species (Ceccarelli 2011).

When this project was developed, the only spatial conservation protection afforded to the Coral Sea reefs occurred within the Coral Sea Conservation Zone, which included the Coringa-Herald National Nature Reserve and the Lihou Reef National Nature Reserve. The marine biodiversity on the vast majority of reef systems in the Coral Sea remained largely unexplored, and their biodiversity value largely unknown.

On November 17th 2012, the Australian Government declared the newly combined multi-zoned reserve system; the Coral Sea Commonwealth Marine Reserve – of almost one million square km (Table 1). Although approximately half of the reserve is green zone (no-take); the majority of this area is offshore, with its nearest point approximately 60 kilometres from the coast and extending out to ca. 1100 kilometres from the mainland. No systematic biodiversity survey had been undertaken across the many reef systems now included within the reserve, or those that remain unprotected (Ceccarelli 2012).

This project was developed due to a lack of: (1) sufficient data identifying the areas with the greatest conservation value and that are most in need of protection, and (2) baseline data that, for any newly protected area, can be used as a reference through the long-term for assessing whether protection from fishing is working and identifying any future impacts of bleaching, crown-of-thorns seastar infestations and climate change.

The primary aim of this project was thus to provide a baseline of the marine biodiversity of major Coral Sea reef systems using globally-standardised RLS methods, complimenting and extending knowledge gained from the few previous surveys in the region (Oxley et al. 2004, Ceccarelli et al. 2007). Implementation of this thorough and repeatable survey method will allow future surveys to determine whether the condition of the Coral Sea reefs changes in time, with or without protection from fishing. The collaboration with Reef Life Survey (RLS; www.reeflifesurvey.com) also allowed this project to be undertaken for a fraction of the cost of what would usually be an extremely expensive exercise. RLS was responsible for collecting data from these remote reefs which are logistically difficult and expensive to reach, cutting down on personnel costs through the engagement of skilled recreational divers who provide their time and expertise free of charge.

In return for the assistance of skilled divers through RLS, and in an effort to build capacity in this project and for similar future work, an additional aim of the project was to provide further training for RLS volunteers in diverse coral reef surveys, to boost the number of RLS divers with the necessary skills for such challenging surveys (coral reefs with very high fish species richness require a detailed knowledge of tropical Indo-Pacific reef fishes).

As part of the project, an immediate goal of data analysis was to provide a better understanding of the characteristics of reef systems which receive little fishing pressure, since it is likely that the majority of MPAs in Australia have not been established long enough to have returned to pre-European settlement conditions (Edgar et al. 2009). Involvement of RLS and the use of standard RLS methods provided a unique opportunity to put the Coral Sea reefs into the context of the broader region, taking advantage of the extensive reach of the RLS global dataset. A longer-term goal is to allow future surveys to assess whether reefs that have lower direct anthropogenic disturbance are less vulnerable to climate change impacts than those that are subject to the full range of threats; contributing valuable empirical evidence to the widely-posed question of whether MPAs confer resilience to human-impacts (Hughes et al. 2003, Mumby et al. 2007).

**Table 1. Coral Sea Commonwealth Marine reserve (CSCMR) as declared November 2012.** Taken from http://www.environment.gov.au/marinereserves/coralsea/publications/pubs/fs-coralsea-reserve.pdf. Note that the CSCMR will not come into effect until July 2014 (see here for more information: http://www.environment.gov.au/marinereserves/coralsea/index.html).

| | |
|---|---|
| Reserve Area | 989 842km$^2$ |
| Depth Range | <15 – 5000 m |
| Key conservation values | • Habitat and important areas for a range of species have been identified in the region, including for humpback whales during their annual migration along the east coast of Australia; nesting and inter-nesting sites for green turtles; breeding and foraging areas for multiple seabird species including noddies, terns, boobies, frigatebirds, and tropic birds; white shark distribution and whale shark aggregation.<br>• Transient populations of highly migratory pelagic species, including small fish schools, billfish, tuna and sharks.<br>• The East Australian Current forms in the region and is considered a major pathway for mobile predators such as billfish and tunas. Black marlin undergo seasonal movements into the Queensland Plateau area.<br>• Includes three Key Ecological Features: the reefs, cays and herbivorous fish of the Queensland Plateau and the Marion Plateau and the northern extent of the Tasmantid seamount chain.<br>• Heritage values include many historic shipwrecks including three World War II shipwrecks from the Battle of the Coral Sea.<br>• The reserve represents the full range of seafloor features found in the region, including numerous reefs ranging from Ashmore and Boot Reefs in the north of the region to Cato Island and surrounding reefs in the south. The reserve includes canyons, troughs and plateaux, including Bligh Canyon approximately 200 kilometres off the coast from Lockhart River and theTownsville Trough, which separates the Queensland and Marion Plateaux. The reserve extends into the deeper waters of the Coral Sea Basin in the north, and provides protection for the pinnacles of the northern extent of the Tasmantid seamount chain.<br>• Six provincial bioregions, 94 depth ranges, and 16 seafloor types are represented in the reserve |
| Zone types and area size | • Marine National Park Zone (IUCN Category II) – 502 654 km$^2$<br>• Habitat Protection Zone (Coral Sea) (IUCN Category IV) – 182 578 km$^2$<br>• Habitat Protection Zone (Seamounts) (IUCN Category IV) – 85 507 km$^2$<br>• Conservation Park Zone (IUCN Category IV) – 20 570 km$^2$<br>• Multiple Use Zone (IUCN Category VI) – 194 233 km$^2$<br>• General Use Zone (IUCN Category VI) – 4300 km$^2$ |

# Methods

## Biodiversity survey methods

All fieldwork involved the use of standardised RLS underwater visual census protocols (manual downloadable at http://reeflifesurvey.com/information). These methods are based around 50m transects, and include three components:

*Method 1: Fish surveys*

Divers record the species, estimated number and size-category of all fishes sighted within 5 m blocks either side of the transect line. Size-classes of total fish length (from snout to tip of tail) used are 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 400, 500, 625 mm, and above. Lengths of fish larger than 500 mm are estimated to the nearest 12.5 cm and individually recorded.

*Method 2: Macroinvertebrate and cryptic fish surveys*

Large macro-invertebrates (molluscs, echinoderms and crustaceans > 2.5 cm) and cryptic fishes (i.e. inconspicuous fish species from particular families which are closely associated with the seabed that were likely to be overlooked during general fish surveys) are censused along the same transect lines set for fish surveys. Divers swim along the bottom, recording all mobile macroinvertebrates and cryptic fishes on exposed surfaces of the reef within 1 m of the line. Giant clams in the genus *Tridacna*, although not mobile, are also counted within the 1 m wide bands for this component of the survey.

*Method 3: Photoquadrats of benthic cover*

Information on the percentage cover of sessile fauna and flora are collected in digital photo-quadrats, taken vertically-downward each 2.5 m along each 50 m transect, each encompassing an area of ca. 0.3 m x 0.3 m. Processing of images to obtain percentage cover estimates for each species or category are ideally obtained using Coral Point Count with Excel extensions (CPCe) software (Kohler and Gill 2006), with 56 points scored per image to the highest possible taxonomic resolution. Processing of photos for this study was done using a more rapid method, however, scoring 100 points per transect (5 points per image) using functional group categories.

*Training*

A training expedition was held at Ningaloo Reef, from 22/7/12 – 3/8/12, in which six RLS divers experienced in surveys in temperate and sub-tropical regions undertook intensive training in coral reef surveys. Ningaloo Reef was chosen for the training expedition because logistics were considerably easier and the cost lower than undertaking the same training program out in the Coral Sea, while a high proportion and richness of widespread Indo-Pacific reef fishes meant that skills learned by divers are widely useful throughout the broader region. Details of the Ningaloo training expedition, including survey sites and results, can be found on the RLS website (http://reeflifesurvey.com/2012/08/13/ningaloo-tropical-training-and-survey-expedition-22nd-july-%E2%80%93-2nd-august-2012/).

## Coral Sea survey expeditions

Four separate survey expeditions were undertaken during the course of this project. The first involved surveys of the central Great Barrier Reef (GBR) offshore from Townsville from 2/4/12 – 10/4/12, following an unsuccessful attempt to reach Lihou Reef (due to weather conditions). Surveys of the GBR in this region still formed a valuable contribution to the project, however, providing contextual data from a part of the GBR previously unsurveyed by RLS and close to some of the Coral Sea reefs surveyed in subsequent expeditions. The second expedition targeted the previously unsurveyed Marion Reef (MR) and ran from 9/9/12 - 12/9/12. The third was to the Herald Cays and Coringa Islets in the Coringa-Herald National Nature Reserve (CHNNR), from 23/10/12 – 28/10/12, while the fourth was to Elizabeth and Middleton Reefs (EMR) from 15/1/13 – 18/1/13 (all dates represent survey dates, not inclusive of travel to and from reef systems by yacht). Thus, the project covered a large area from the central to very southern boundary of the Coral Sea (Fig. 1). Details of survey effort are provided in Table 1, and site maps are in Figure 1. Considerable further survey effort has been possible since the completion of the project (and is still underway), covering a large number of additional Coral Sea reefs. The results of these surveys are not presented here, but will form part of a larger report of the Coral Sea reef biodiversity at a later date.

**Table 2. Details of sites surveyed during the Coral Sea project**

| Location | SiteCode | Site | Latitude | Longitude |
|---|---|---|---|---|
| **Marion Reef** | | | | |
| | CS1 | Long Reef West | -19.297 | 152.2352 |
| | CS2 | Brodie Cay NW | -19.2844 | 152.212 |
| | CS3 | Brodie Cay SE | -19.2848 | 152.2208 |
| | CS4 | Paget Cay Bommie | -19.2303 | 152.3259 |
| | CS5 | Paget Cay South East | -19.2532 | 152.3482 |
| | CS6 | Paget Cay South | -19.258 | 152.3418 |
| | CS7 | Weather Station Inner Reef | -19.1254 | 152.3881 |
| | CS8 | Carola Cay | -19.0953 | 152.3871 |
| **Coringa-Herald National Nature Reserve** | | | | |
| | CS9 | NE Herald Cay NE | -16.9219 | 149.200 |
| | CS10 | NE Herald Cay SW | -16.9478 | 149.1826 |
| | CS11 | NE Herald Cay Central | -16.9365 | 149.197 |
| | CS12 | NE Herald Bommie | -16.9301 | 149.1933 |
| | CS13 | NE Herald Back Reef | -16.9282 | 149.2023 |
| | CS14 | Chilcott South | -16.9357 | 149.9941 |
| | CS15 | Chilcott Bommie | -16.9225 | 150.0065 |
| | CS16 | Chilcott NE | -16.9225 | 150.0114 |
| | CS17 | SW South West Islet | -16.9716 | 149.9048 |
| | CS18 | South West Islet Bommie | -16.9613 | 149.9055 |
| **Central GBR** | | | | |
| | QLD58 | Davies Reef | -18.832 | 147.633 |
| | QLD59 | Lynch's Reef | -18.7314 | 147.7247 |
| | QLD60 | Chicken Reef | -18.6608 | 147.7028 |
| | QLD61 | Chicken Reef East | -18.6617 | 147.7231 |
| | QLD62 | Chicken Reef NW | -18.6515 | 147.7099 |
| | QLD63 | Bowl Reef S | -18.536 | 147.5325 |
| | QLD64 | Inner Dip | -18.4057 | 147.4456 |
| | QLD65 | Dip Reef NE | -18.404 | 147.4485 |
| | QLD66 | Myrmidon Reef | -18.2688 | 147.3787 |
| | QLD67 | Myrmidon Lagoon | -18.2671 | 147.3838 |
| | QLD68 | Myrmidon Wall | -18.2626 | 147.3776 |
| | QLD69 | Grub Reef SW | -18.6507 | 147.4013 |
| | QLD70 | Grub Reef | -18.6503 | 147.4046 |

**Table 2 cont. Details of sites surveyed during the Coral Sea project**

| Location | SiteCode | Site | Latitude | Longitude |
|---|---|---|---|---|
| **Elizabeth & Middleton Reefs** | | | | |
| | EMR1 | Lagoon Inner Wreck Middleton Reef | -29.451 | 159.0623 |
| | EMR2 | Lagoon 2 Middleton Reef | -29.4568 | 159.0622 |
| | EMR3 | SW Lagoon Middleton Reef | -29.4645 | 159.0687 |
| | EMR4 | Wreck 1 | -29.4475 | 159.0539 |
| | EMR5 | Wreck 2 | -29.4427 | 159.0609 |
| | EMR6 | North West Horn | -29.4437 | 159.068 |
| | EMR7 | Back reef bommie Middleton Reef | -29.44 | 159.0932 |
| | EMR8 | Back Reef 1 | -29.4456 | 159.0937 |
| | EMR9 | Blue Holes W | -29.4428 | 159.1123 |
| | EMR10 | Blue Holes N | -29.4425 | 159.1184 |
| | EMR11 | Blue Holes 3 | -29.448 | 159.115 |
| | EMR12 | NW outer reef1 Middleton Reef | -29.4223 | 159.1107 |
| | EMR13 | NW outer reef2 Middleton Reef | -29.4266 | 159.1261 |
| | EMR14 | NW outer reef3 Middleton Reef | -29.4335 | 159.1354 |
| | EMR15 | NW inner bommie Middleton Reef | -29.4341 | 159.0948 |
| | EMR16 | Wreck 3 | -29.4541 | 159.0486 |
| | EMR17 | Wreck outer reef4 Middleton Reef | -29.4522 | 159.0499 |
| | EMR18 | North Cay Elizabeth Reef | -29.9255 | 159.0511 |
| | EMR19 | Lagoon blue hole Elizabeth Reef | -29.9333 | 159.0561 |
| | EMR20 | Cay Bommie Elizabeth Reef | -29.9319 | 159.0616 |
| | EMR21 | Elizabeth SW | -29.9579 | 159.0281 |
| | EMR22 | Elizabeth SW2 | -29.9612 | 159.0366 |
| | EMR23 | Wreck Flank | -29.9282 | 159.0275 |
| | EMR24 | North Point Elizabeth Reef | -29.911 | 159.0691 |
| | EMR25 | Northern Tip | -29.9118 | 159.0813 |
| | EMR26 | Elizabeth Anchorage South | -29.9268 | 159.0442 |
| | EMR27 | Elizabeth Anchorage East | -29.9173 | 159.0603 |
| | EMR28 | Elizabeth Hole | -29.9305 | 159.0621 |
| | EMR29 | NW anchorage Elizabeth Reef | -29.9166 | 159.0568 |
| | EMR30 | NE Wreck Elizabeth Reef | -29.923 | 159.0929 |
| | EMR31 | NE Inlet Elizabeth Reef | -29.9337 | 159.0971 |
| | EMR32 | East Elizabeth North | -29.9561 | 159.1273 |
| | EMR33 | South Elizabeth Reef | -29.958 | 159.1276 |

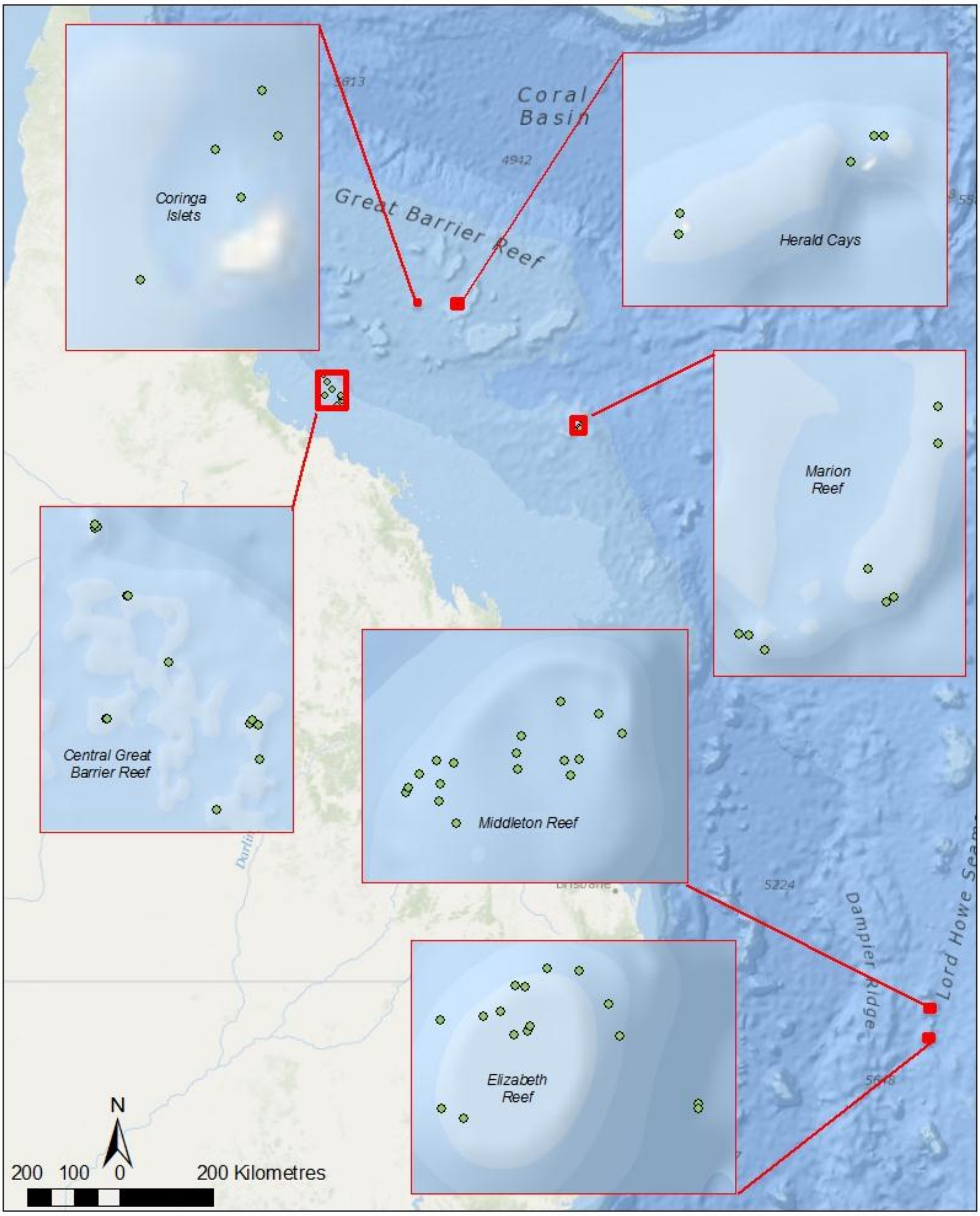


**Figure 1. Locations of sites surveyed during the Coral Sea project**

## Results

### Reef fishes

Reef fish community structure of the Coral Sea reefs was reasonably different to that of the parts of the GBR surveyed by RLS, tending to be more similar to other SW Pacific coral reef locations (Fig. 2). In the multidimensional scaling (MDS) plot shown in Fig. 2, locations depicted close to each other have very similar fish communities in terms of the species composition and biomass, while those at distance have few fish in common. Fish community structure at CHNNR was highly similar to Marion Reef, with both quite similar to reef fish communities at Tonga and the remote Minerva Reefs. The EMR reef community differed from these, closer to that at Lord Howe Island, sharing sub-tropical and even temperate faunal components.

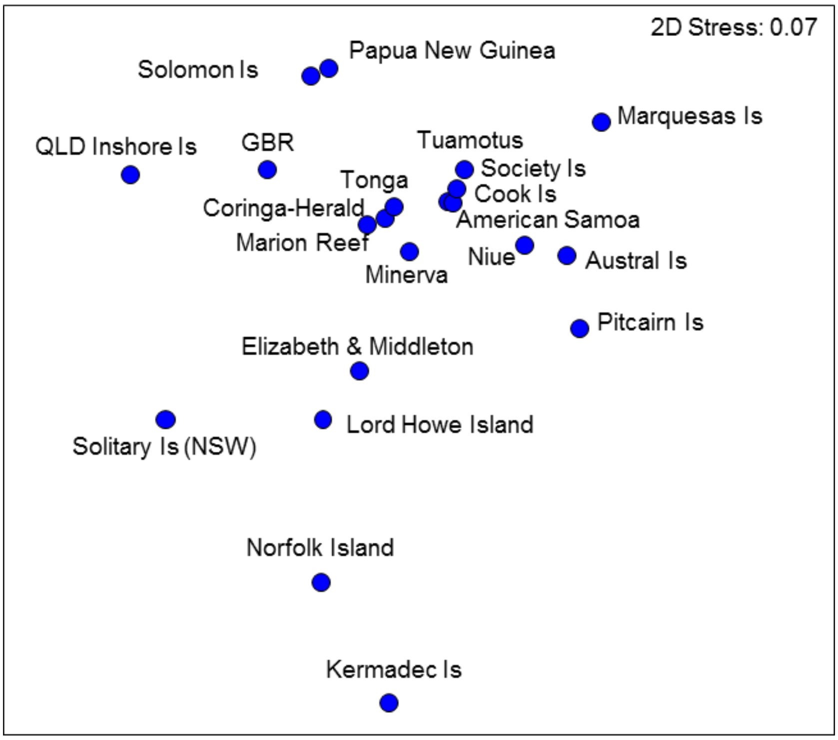


**Figure 2. MDS plot based on mean fish community dissimilarity (using log-transformed biomass data) for reefs surveyed by RLS in the SW Pacific region.** The GBR includes northern (Lizard Is, Cairns) and central (Townsville) regions, while QLD inshore Is includes sites at Great Keppel Island, and in the Whitsunday, Frankland and Family groups.

Fish species richness at CHNNR and Marion Reef was in general quite similar to that found at most locations in the SW Pacific (Fig. 3), averaging 61 and 54 species per transect (500 $m^2$), respectively. Fish species richness was higher along the GBR (averaging 67 species), making it one of the most species-rich regions surveyed in the SW Pacific by RLS. The richness of fishes at EMR was lower than the majority of SW Pacific locations.

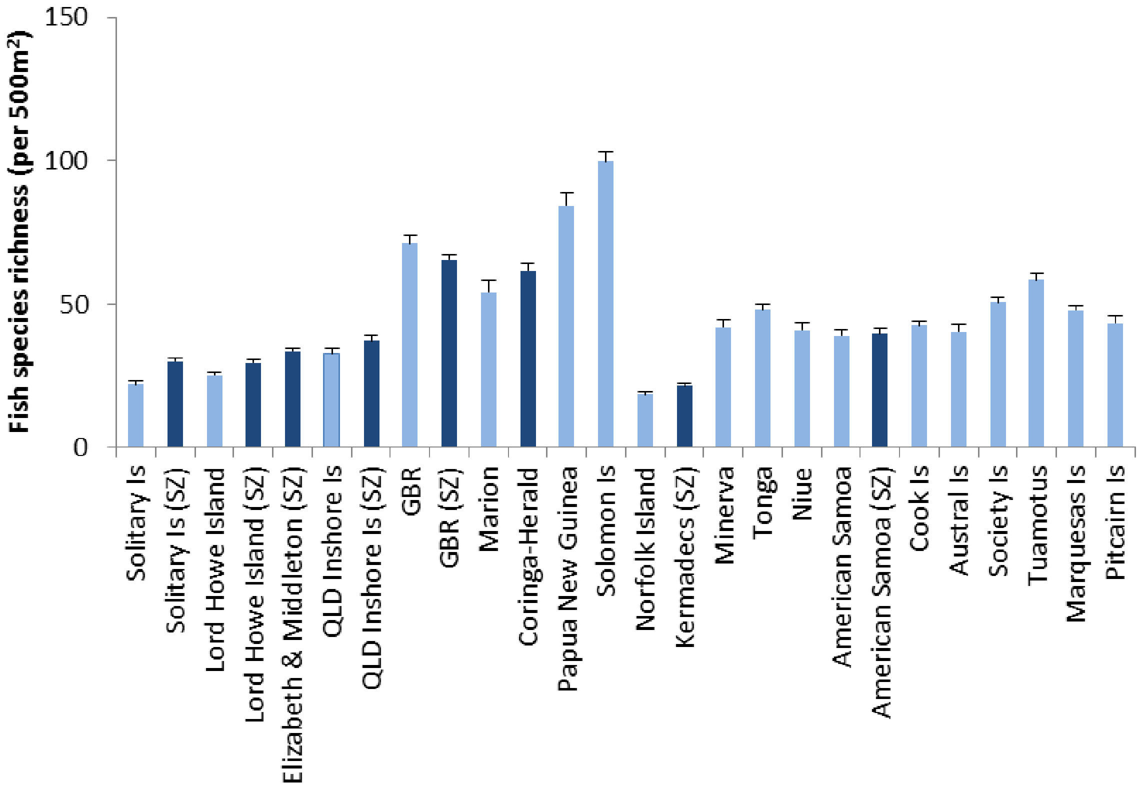


**Figure 3. Mean fish species richness (+SE) on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

As suggested by the broad similarity of Coral Sea reefs and even EMR and GBR to other SW Pacific locations, a large number of fish species (76; 17%) were shared between all four locations surveyed in this project (CHNNR, Marion Reef, EMR and the central GBR). The shared fauna included numerous species of *Acanthurus*, *Chaetodon*, *Scarus* and *Thalassoma*, while *Labroides dimidiatus*, the common cleaner wrasse, was recorded on more than 65% of transects in all locations (and as many as 100% at particular locations). Table 3 lists the species most frequently recorded on transects at each location, with their mean relative abundance and biomass when recorded.

Few localised endemics were recorded, with the majority of species recorded only at one location still generally widespread Indo-Pacific species. Despite this, a number of records were new for the Coral Sea. New records for the entire region made up 18% of fish species recorded, clearly showing that even the species inventory, the most basic element of biodiversity knowledge for the area, is far from exhaustive. Broken down by regions, all species recorded at Marion Reef represent new records (as this reef system has not previously been surveyed), while ca. 19% and ca. 43% of species (ca. 50 and 100 species) represent new records for CHNNR and EMR, respectively. Many new records were small or cryptic species in the families Blenniidae, Gobiidae and Muraenidae, which may have been easily overlooked by previous survey efforts, but others such as members of Labridae and Ephippidae were quite easily detected, and are clear indications of the relatively low survey effort undertaken in the region.

**Table 3. Most common fish species recorded at Coral Sea and central GBR sites during the project.** *F*(%) is the frequency of occurrence measured as a percentage of transects surveyed, *N* is the mean relative abundance (number per 500 $m^2$ when recorded), and *B*(g) the mean biomass in grams when recorded.

| Species | *F* (%) | *N* | *B* (g) |
|---|---|---|---|
| **Coringa-Herald National Nature Reserve** | | | |
| *Ctenochaetus striatus* | 100 | 42 | 2,530 |
| *Labroides dimidiatus* | 100 | 5 | 16 |
| *Acanthurus nigrofuscus* | 95 | 36 | 1,999 |
| *Pomacentrus vaiuli* | 95 | 66 | 175 |
| *Halichoeres hortulanus* | 90 | 7 | 366 |
| *Chaetodon citrinellus* | 85 | 3 | 98 |
| *Gomphosus varius* | 85 | 6 | 66 |
| *Thalassoma lutescens* | 85 | 8 | 203 |
| *Chromis margaritifer* | 80 | 33 | 77 |
| *Halichoeres biocellatus* | 80 | 14 | 208 |
| **Marion Reef** | | | |
| *Thalassoma lutescens* | 100 | 10 | 148 |
| *Pomacentrus philippinus* | 94 | 8 | 216 |
| *Acanthurus nigrofuscus* | 88 | 96 | 3,832 |
| *Ctenochaetus striatus* | 81 | 26 | 1,236 |
| *Gomphosus varius* | 81 | 6 | 65 |
| *Labroides dimidiatus* | 75 | 3 | 251 |
| *Halichoeres hortulanus* | 75 | 5 | 243 |
| *Thalassoma hardwicke* | 75 | 11 | 127 |
| *Monotaxis grandoculis* | 75 | 4 | 755 |
| *Naso lituratus* | 75 | 4 | 888 |
| **Central GBR** | | | |
| *Pomacentrus lepidogenys* | 96 | 76 | 427 |
| *Plectroglyphidodon lacrymatus* | 92 | 15 | 216 |
| *Thalassoma lunare* | 88 | 9 | 248 |
| *Pomacentrus moluccensis* | 88 | 37 | 249 |
| *Labroides dimidiatus* | 85 | 5 | 34 |
| *Thalassoma hardwicke* | 85 | 10 | 204 |
| *Amblyglyphidodon curacao* | 85 | 21 | 254 |
| *Ctenochaetus striatus* | 81 | 12 | 1,460 |
| *Pomacentrus philippinus* | 77 | 11 | 69 |
| *Anampses neoguinaicus* | 77 | 3 | 118 |
| **Elizabeth & Middleton Reefs** | | | |
| *Pseudolabrus luculentus* | 97 | 77 | 1,180 |
| *Thalassoma lutescens* | 92 | 49 | 954 |
| *Stegastes gascoynei* | 91 | 111 | 2,499 |
| *Chrysiptera notialis* | 76 | 224 | 1,245 |
| *Labroides dimidiatus* | 65 | 4 | 18 |
| *Stethojulis bandanensis* | 65 | 5 | 41 |
| *Coris bulbifrons* | 65 | 6 | 954 |
| *Chlorurus sordidus* | 64 | 54 | 3,044 |
| *Chromis hypsilepis* | 62 | 560 | 4,219 |
| *Kyphosus pacificus* | 62 | 34 | 22,130 |

**Plate 1. Examples of species not previously recorded at the Coral Sea reefs.** *Canthigaster coronata* (EMR), *Gnatholepis cauerensis* (CHNNR, EMR), *Sargocentron melanospilos* (CHNNR), *Ecsenius tigris* (CHNNR), *Pervagor janthinosoma* (CHNNR, EMR), *Synodus dermatogenys* (CHNNR, MR, EMR).

In order to better understand characteristics reef systems that experience low fishing pressure, fish relative abundance and biomass data from the CS reefs were compared with those from areas across the broader SW Pacific, including sites in no-take MPAs and other remote reef systems (e.g. Minerva Reefs). Despite their isolation, the CS reefs possessed near average values of total fish biomass and biomass of higher carnivores in the context of the broader region (Figs. 4 & 5). Elizabeth and Middleton Reefs had greatest values of biomass of the CS reefs surveyed in this project, largely due to the presence of numerous large individuals of higher carnivores, such as black cod (*Epinephelus daemelii*) and sharks (*Carcharhinus galapagensis*).

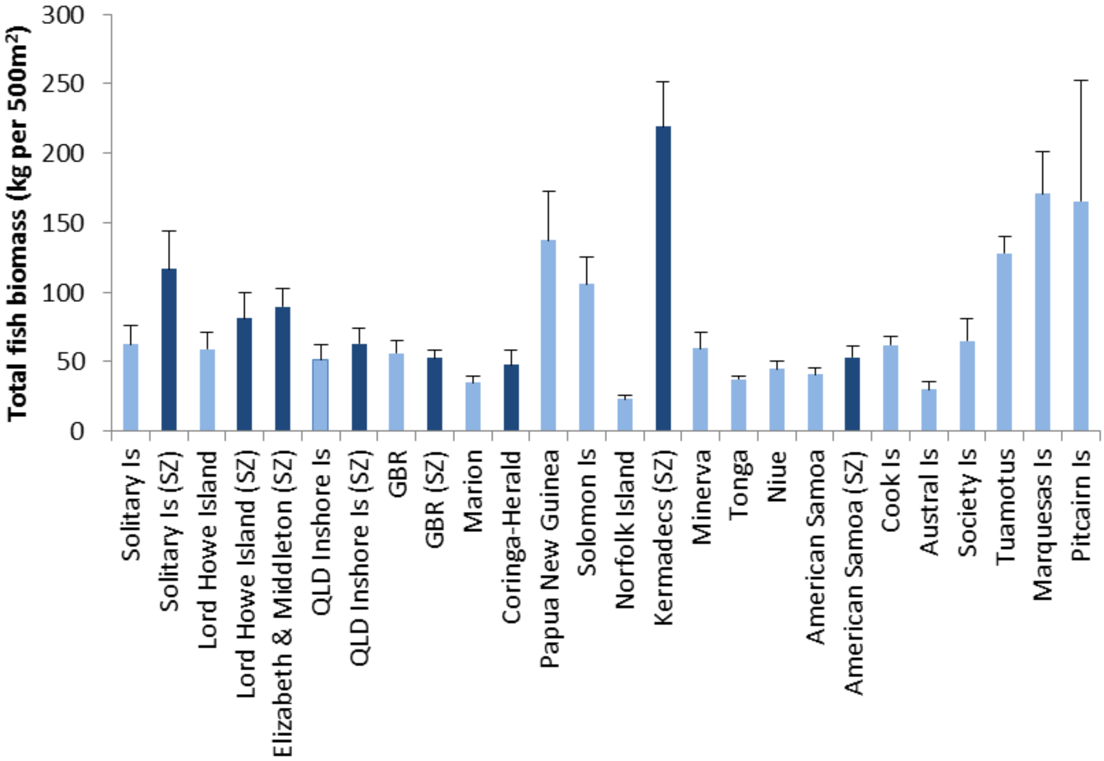


**Figure 4. Mean total fish biomass (+SE) on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

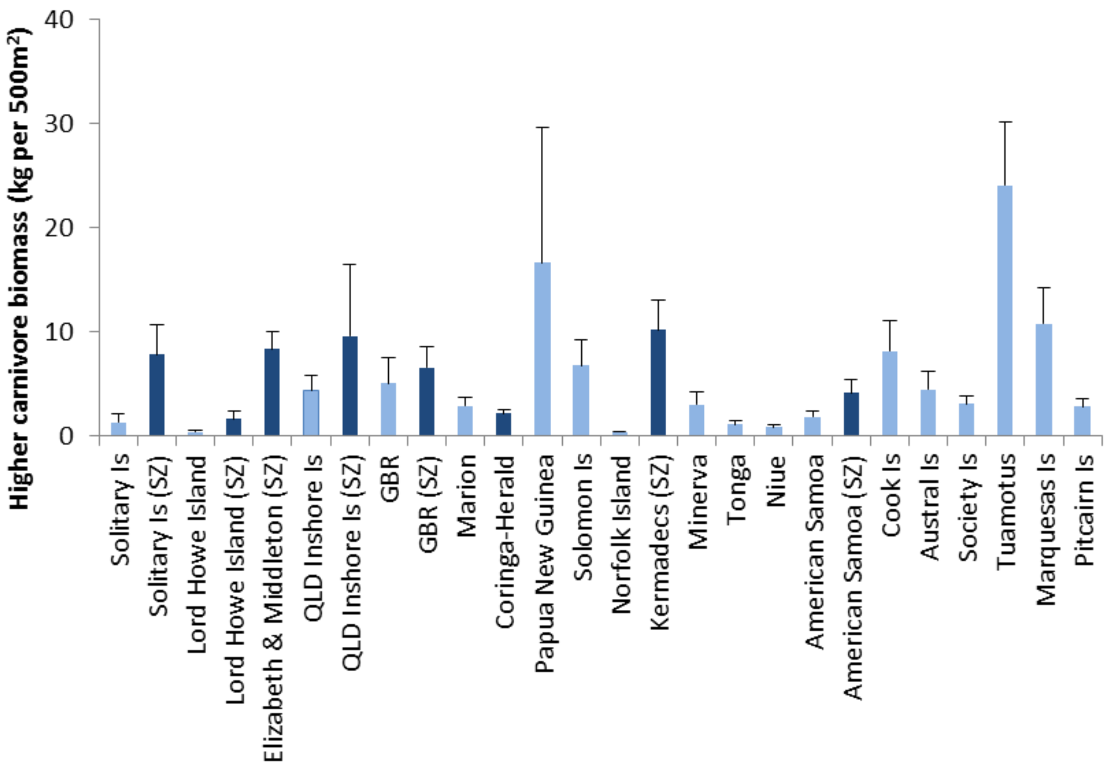


**Figure 5. Mean biomass of higher carnivores (+SE) on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

The relative abundance of sharks at Elizabeth and Middleton Reefs was the third highest of any locations surveyed by RLS in the SW Pacific, only exceeded on reefs at the Kermadec Islands (NZ) and Pitcairn Islands (British Overseas Territory) (Fig. 6). While shark abundances (*Carcharhinus galapagensis*) were consistently high at the Kermadec Islands, the massive numbers at the Pitcairns was the result of a massive aggregation of *Carcharhinus galapagensis* at a single site. Sharks were present at sites in the CHNNR and Marion Reefs (*Carcharhinus amblyrhynchos* and *Triaenodon obesus*), but only in moderate numbers.

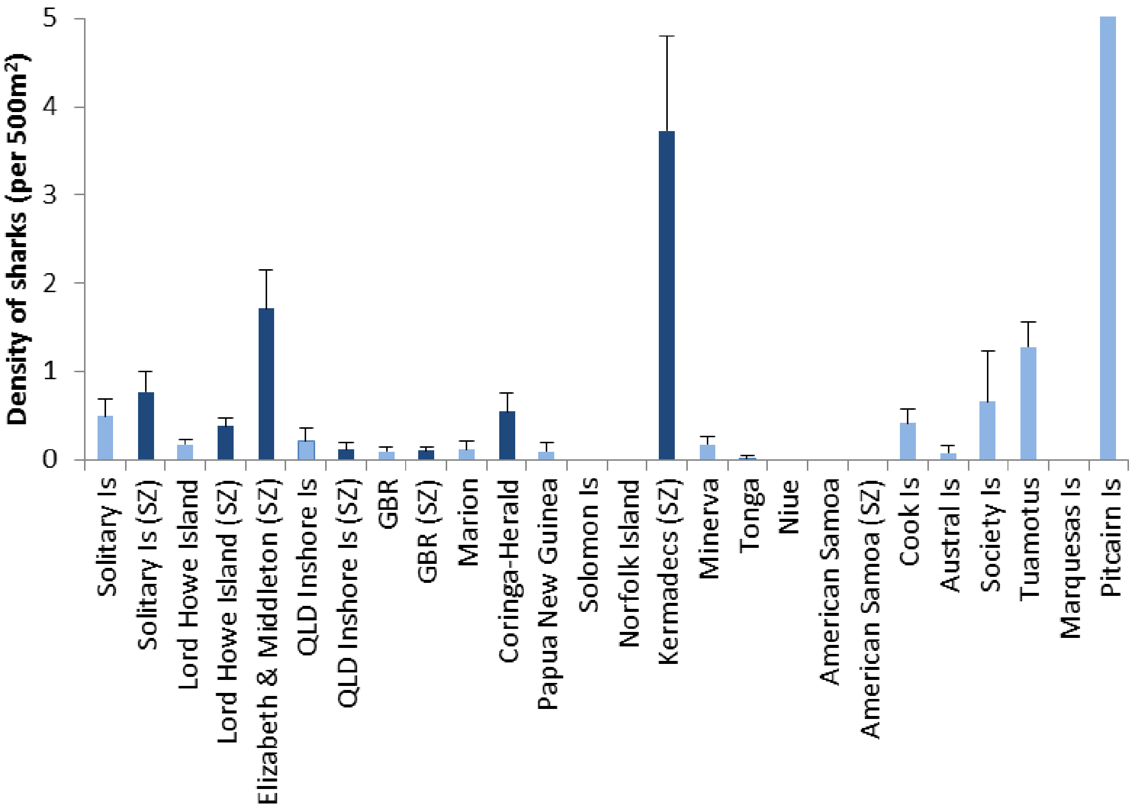


**Figure 6. Mean relative abundance of sharks (+SE) on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue. Note that the value for Pitcairn Islands is off the y-axis scale, with a mean of 32.9 sharks per 500 m2 (±31.7 SE).

## Mobile invertebrates

The mobile invertebrate fauna surveyed included at least 33 echinoderm, 33 gastropod and 10 crustacean species. Included in this were at least 14 Holothurians (sea cucumbers), many of which are commercially exploited in the Coral Sea and which were in relatively high numbers. Holothurian relative abundance was greatest of any SW Pacific location surveyed by RLS at EMR, with over three individuals per 100 $m^2$ (Fig. 7). The CHNNR and Marion Reef also had relatively high holothurian relative abundance by standards observed elsewhere.

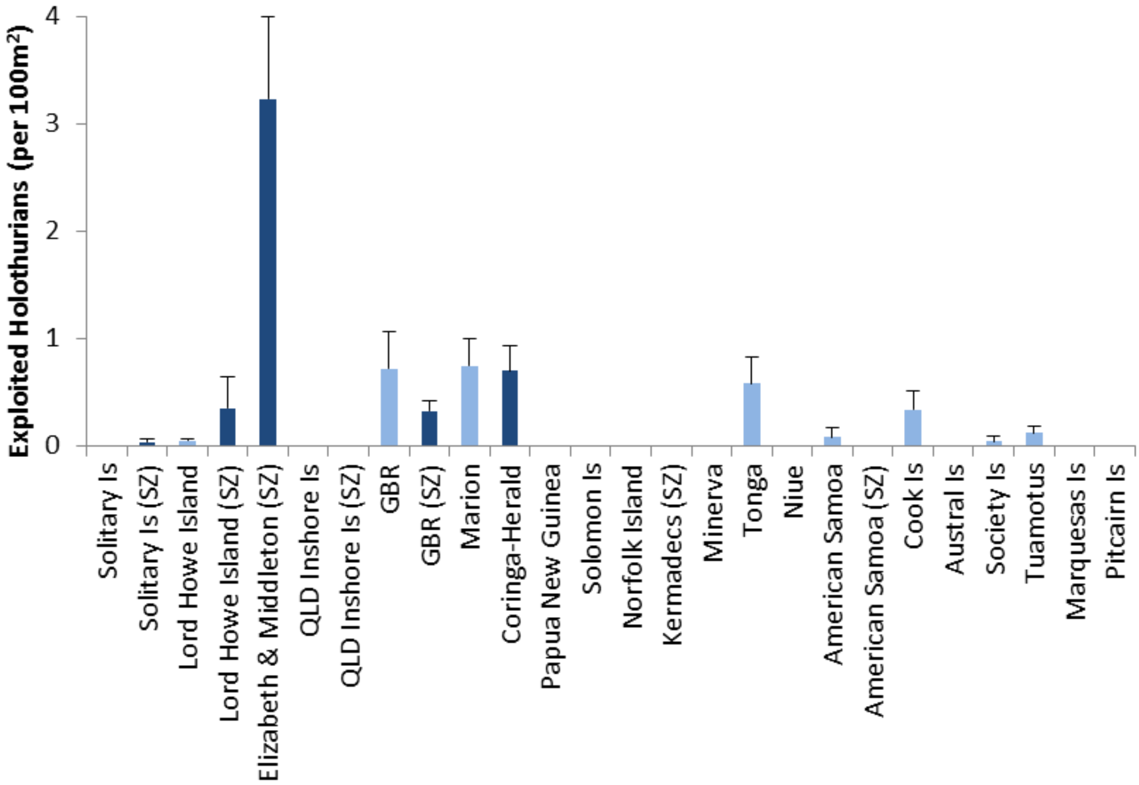


**Figure 7. Mean relative abundance (+SE) of sea cucumber species which are harvested in the Coral Sea fishery on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

**Plate 2. A sea cucumber** (*Bohadschia argus*) in lagoonal habitat at NE Herald Cay.

The most common sea urchins recorded were abundant, widespread tropical species (*Echinometra mathaei*, *Echinostrephus* spp. and *Diadema savignyi*), with the relative abundance of *Echinostrephus* spp. particularly high at EMR (Fig. 8). Few *Acanthaster planci* (crown-of-thorns sea stars) were recorded at any of the reefs surveyed in this project, with abundances lower than observed at other SW Pacific coral reefs (Fig. 9). Likewise, the relative abundance of giant clams in the genus *Tridacna* was relatively low at the CHNNR, Marion Reef and EMR (Fig. 10).

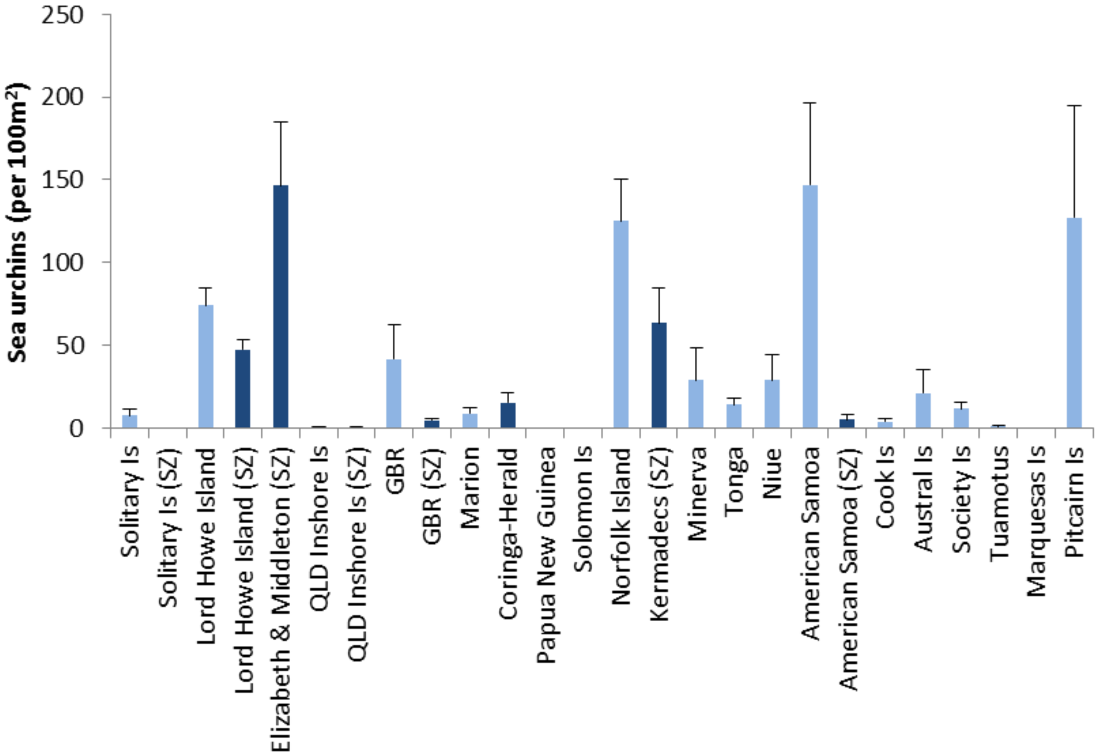


**Figure 8. Mean relative abundance (+SE) of sea urchins on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

**Plate 3. Sea urchins** in the genus *Echinostrephus* were the most abundant sea urchins at many Coral Sea sites

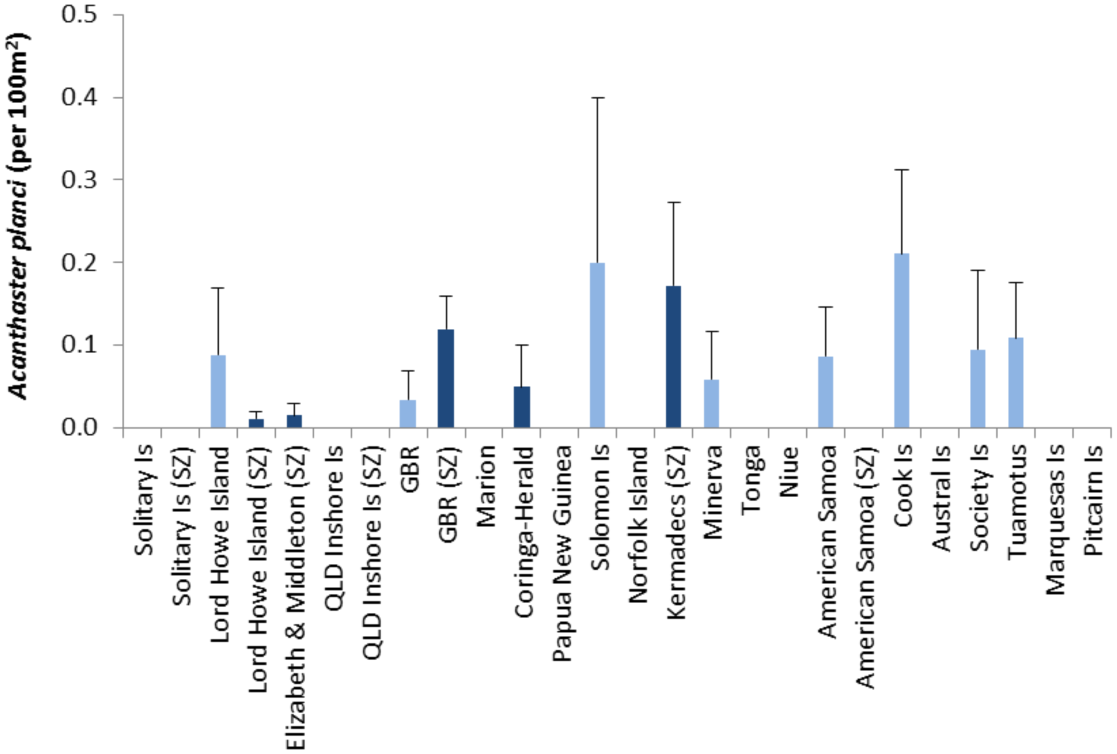


**Figure 9. Mean relative abundance (+SE) of crown of thorns sea stars (*Acanthaster planci*) on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

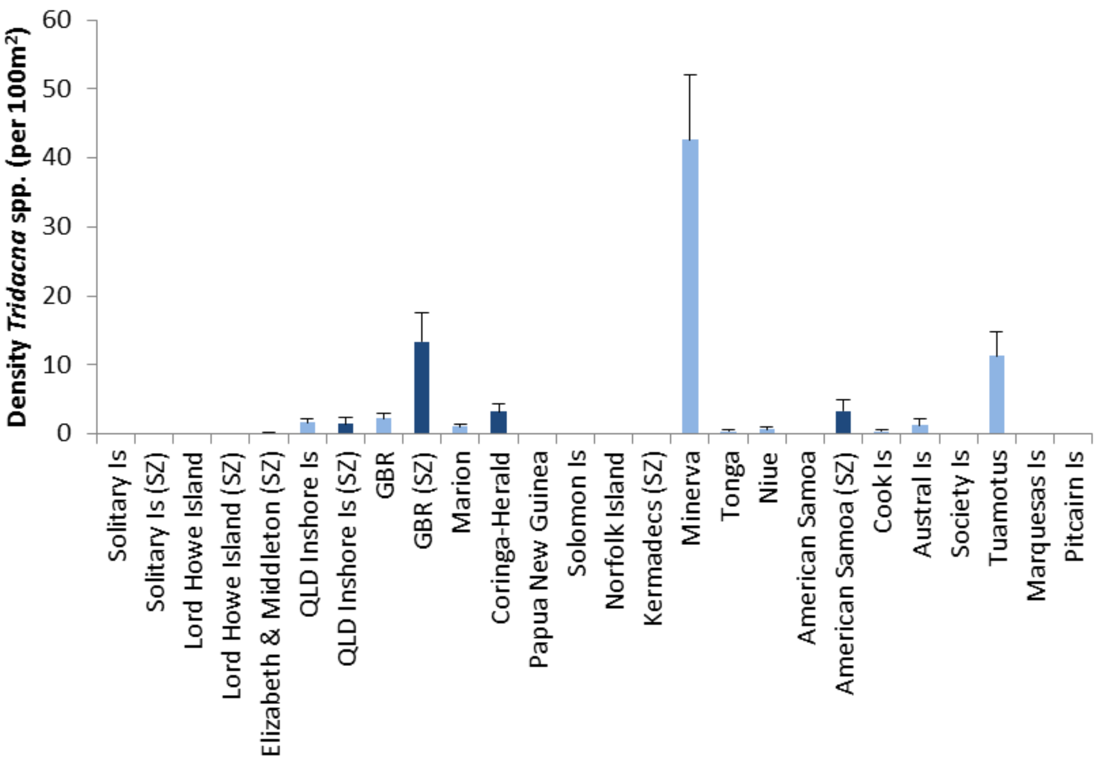


**Figure 10. Mean relative abundance (+SE) of giant clams, *Tridacna* spp. (not including *T. crocea*), on RLS transects across the Pacific.** Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

### Benthic cover

As previously identified for reef areas in the Coringa-Herald National Nature Reserve (CHNNR) and at Lihou (Oxley et al. 2004, Ceccarelli et al. 2007), many Coral Sea reefs generally have a low cover of live coral compared to other coral reefs in Australia (Fig. 11). Sites at Herald Cays, Coringa Islets and Marion Reef, along with the central GBR had the lowest cover of live corals of any coral reef area in Australia for which RLS photo-quadrat data have been processed (note that Lord Howe Island includes extensive areas of rocky reef, and thus coral cover within the lagoonal coral reef area is much higher than shown), averaging only ca. 9% in the CHNNR and 20.8% at Marion Reef. All these areas also had a higher proportion of encrusting and calcified algal cover than elsewhere, with some patches totally dominated by *Halimeda* spp. Plate 4 shows some of the typical benthic communities found at Coral Sea reefs, including the extensive areas of bare rock and rubble. Note that photo-quadrats have not yet been processed for EMR, and while these reefs had many similarities, the coral cover and diversity of benthic communities was noticeably higher at Elizabeth than Middleton Reef (and CHNNR and Marion Reef).

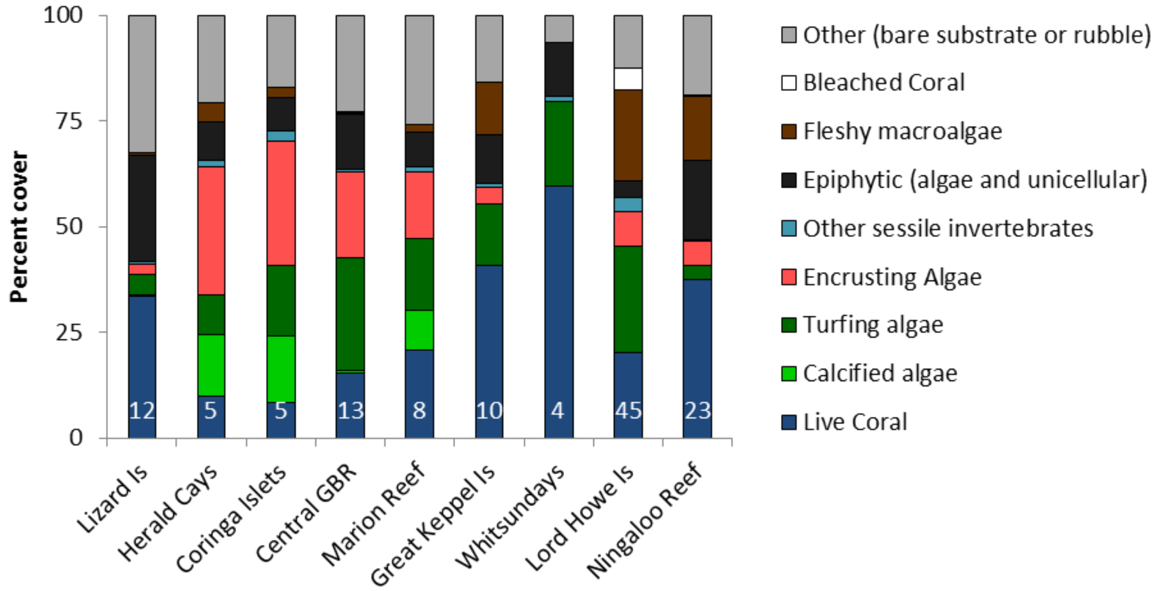


**Figure 11. Percentage cover of major benthic categories at sites in the Coral Sea and other areas of coral reef around Australia.** The number of sites for which photo-quadrats were processed for these cover estimates is provided at the bottom of each bar, and percentage cover estimates represent mean values across multiple transects surveyed at each site.

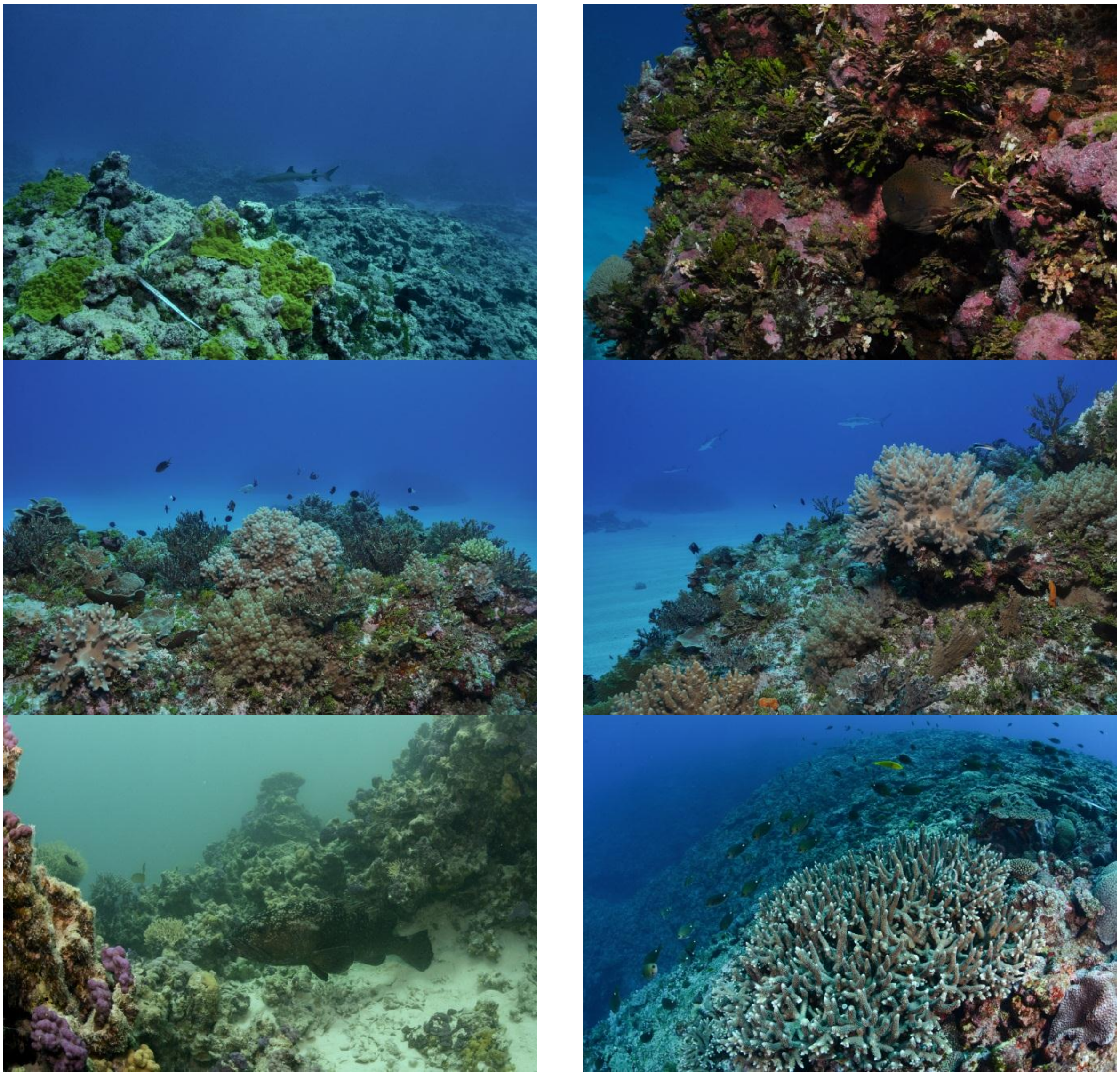

**Plate 4. Benthic communities at the Coral Sea reefs** varied from extensive areas of bare rock and rubble, with only encrusting and calcified algal cover (top row, CHNNR), to small areas densely covered in soft and hard corals, sessile invertebrates and fleshy macroalgae (middle row, CHNNR). Typical lagoon and outer reef benthic communities at Elizabeth and Middleton Reefs are shown in the bottom row.

## Reptiles

A number of species of sea snake (*Emydocephalus annulatus*, *Hydrophis elegans*, *Aipysurus laevis* – the former two still to be confirmed by experts) were common at Marion Reef, with almost two individuals per transect (500 $m^2$), higher than anywhere else surveyed by RLS in the SW Pacific (Fig. 12). Green turtles (*Chelonia mydas*) were recorded at Marion reef and EMR, and were in comparable numbers to most eastern Australian locations (Fig. 13).

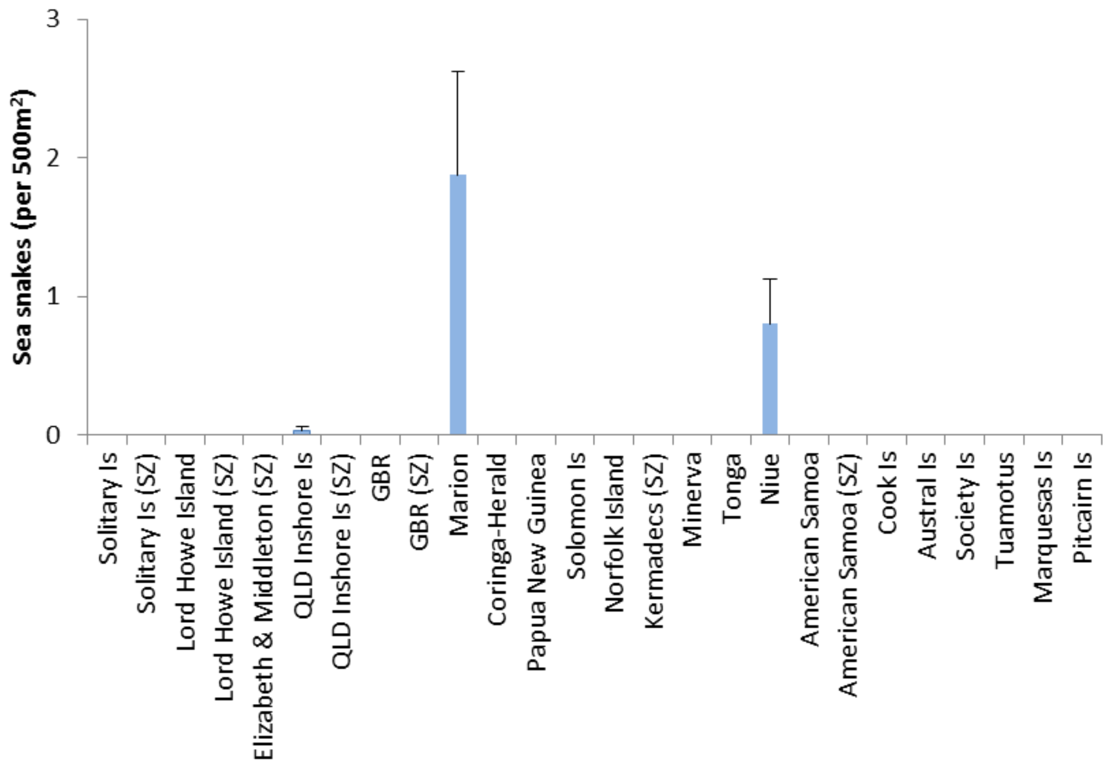


**Figure 12. Mean relative abundance (+SE) of sea snakes** on RLS transects across the Pacific. Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

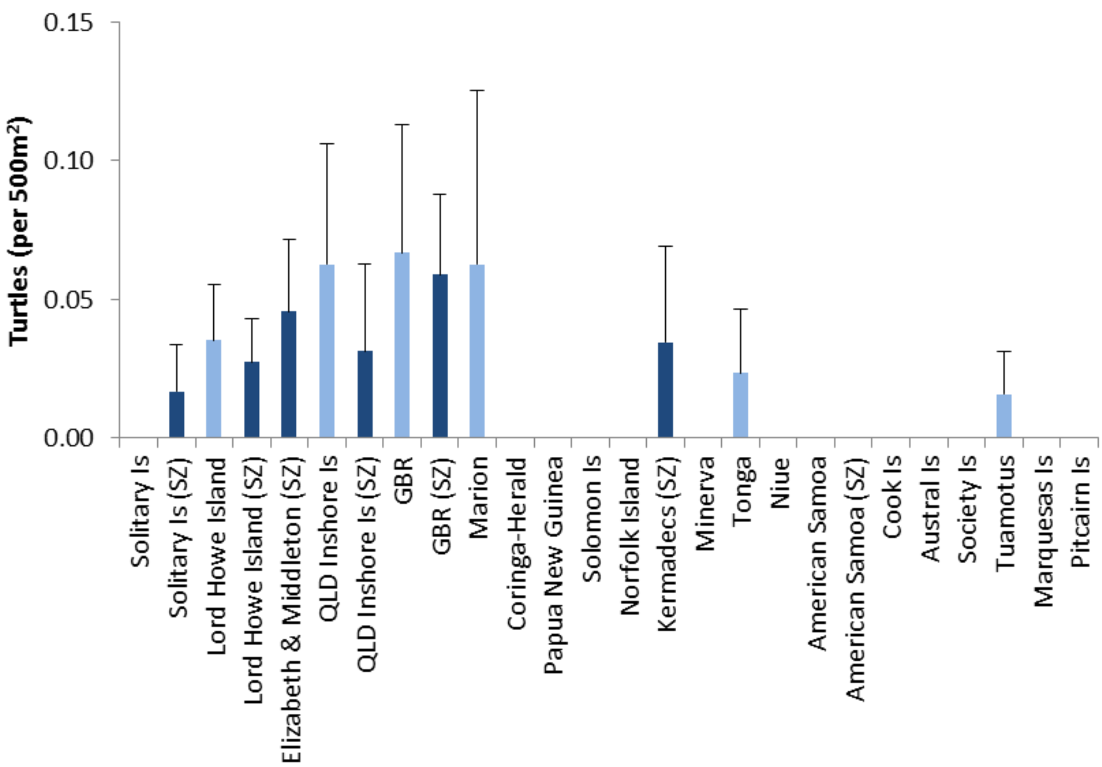


**Figure 13. Mean relative abundance (+SE) sea turtles** (all species) on RLS transects across the Pacific. Sites in no-take zones of Marine Protected Areas are separated within each region and shown in dark blue.

# Discussion

Surveys of Coral Sea reefs in this project have provided new and complementary data to what little has been collected in this offshore and largely unexplored part of Australia's Exclusive Economic Zone. Our results included numerous new records of generally widespread Indo-Pacific reef fish species, making up ca. 18% of fish species recorded in this study. While many of these may be known from Coral Sea reefs from fishing records and unpublished data, such a high proportion of species not previously recorded in the only other thorough surveys of Coral Sea reefs suggests that further surveys are likely to continue to provide new insights. Considering the most basic element of biodiversity knowledge – a species inventory - it is evidently clear that further exploration of biodiversity patterns and values are needed if the full natural heritage value inside and outside the new Commonwealth Marine Reserve sanctuary zones is to be appreciated.

There is of course more to ecological values than species inventories, and surveys reported in this study revealed important trends in reef biodiversity in the context of the broader region, including how reef fish biomass compares with other isolated reefs and sanctuary zones, which species of mobile invertebrate species live on the reefs, in addition to the holothurians and that have previously been surveyed and are commercially exploited, and how current coral cover compares with other coral reefs in Australia.

The patterns in fish community structure among regions surveyed by RLS in the SW Pacific confirm previously reported patterns of general similarity across the western Pacific, which differ from the Great Barrier Reef (Ceccarelli et al. 2007, Ceccarelli 2011) . The similarity of CHNNR and Marion Reef to more distant SW Pacific locations than the nearby GBR also supports the hypothesis that westward flowing currents through the Coral Sea limit eastward dispersal of GBR species, with species observed at Coral Sea reefs typically a subset of broader Indo Pacific species which occur to the east of the Coral Sea (Ceccarelli et al. 2007). The EMR, right at the southern boundary of the Coral Sea, however, clearly receives limited recruitment of tropical species compared with Marion and the CHNNR to the north, sharing more sub-tropical and temperate faunal components with Lord Howe and Norfolk Islands. Thus, the Elizabeth and Middleton reef systems possess a distinctive and unique reef fish fauna, which includes a higher relative abundance of large black cod (*Epinephelus daemelii*) than anywhere else surveyed by RLS (unpublished data), and amongst the highest relative abundances of sharks in the region.

Although it is included in a separate Commonwealth Marine Reserve to the other Coral Sea reefs, recreational fishing is permitted at Elizabeth Reef. The uniquely dense population of (large) black cod here must be considered at risk of over-exploitation, despite the isolation and relatively low visitation rates. This is because this species is long lived and has high site fidelity, and has been overfished on mainland Australia (Harasti and Malcolm 2013).

With respect to the project goal of providing a better understanding of the characteristics of reef systems which are subject to low levels of anthropogenic pressure, particularly low fishing pressure, this project has provided an initial picture that will be built upon with further analysis of the larger Coral Sea dataset that includes data from surveys currently underway at numerous other reefs in the system. Characteristics observed at Coral Sea reefs from this initial analysis which are relatively unique amongst the broader SW Pacific region include high biomass of exploited fishes (such as groupers and sharks), as observed at Elizabeth and Middleton Reefs, and a relatively high relative abundance of exploited holothurians (sea cucumbers). High numbers of sea snakes also appears to be unique, and with further analysis it will be possible to identify those reefs in the CMR which are of greatest importance for sea snakes. Low coral cover suggests that natural stressors such as cyclones, storms and bleaching events are relatively common in the area and have a substantial natural impact. The reefs on the GBR offshore from Townsville that were surveyed during this project also showed clear signs of substantial damage remaining from Cyclone Yasi, which hit the area in 2011. Differentiating human impacts in the context of natural impacts will remain a key challenge for further analyses.

This project made substantial progress towards addressing the lack of sufficient data for identifying regions of greatest biodiversity values in the region, and when data from surveys currently underway in the Coral Sea are added to this database, the resulting dataset will be highly comprehensive and allow a detailed analysis to be undertaken to address this need. The combined dataset will also form a detailed baseline for the newly established Coral Sea Commonwealth Marine Reserve.

The project was also highly successful in its goal to further the capacity and skills within the Reef Life Survey program for undertaking reliable surveys of diverse coral reef faunas. The unique collaboration clearly provided substantial benefits to both the RLS program and this project, run through the Institute for Marine and Antarctic Studies (IMAS) at the University of Tasmania. The ongoing support of IMAS in managing the RLS database, providing direction to survey efforts and analysis and interpretation of data, as in this project, should be recognised as enormously valuable and is critical to maximising scientific, management and community gains.

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