REEF LIFE SURVEY

Biodiversity Survey of the Temperate East Coast Commonwealth Marine Reserve Network: Elizabeth & Middleton Reefs, Lord Howe Island & Norfolk Island

Graham J Edgar, Daniela Ceccarelli, Rick D Stuart-Smith, Antonia T Cooper

Report to Parks Australia, Department of the Environment

2017

Citation

Edgar GJ, Ceccarelli D, Stuart-Smith RD, Cooper AT (2017) Biodiversity Survey of the Temperate East Coast Commonwealth Marine Reserve Network: Elizabeth & Middleton Reefs, Lord Howe Island & Norfolk Island. Reef Life Survey Foundation Incorporated.

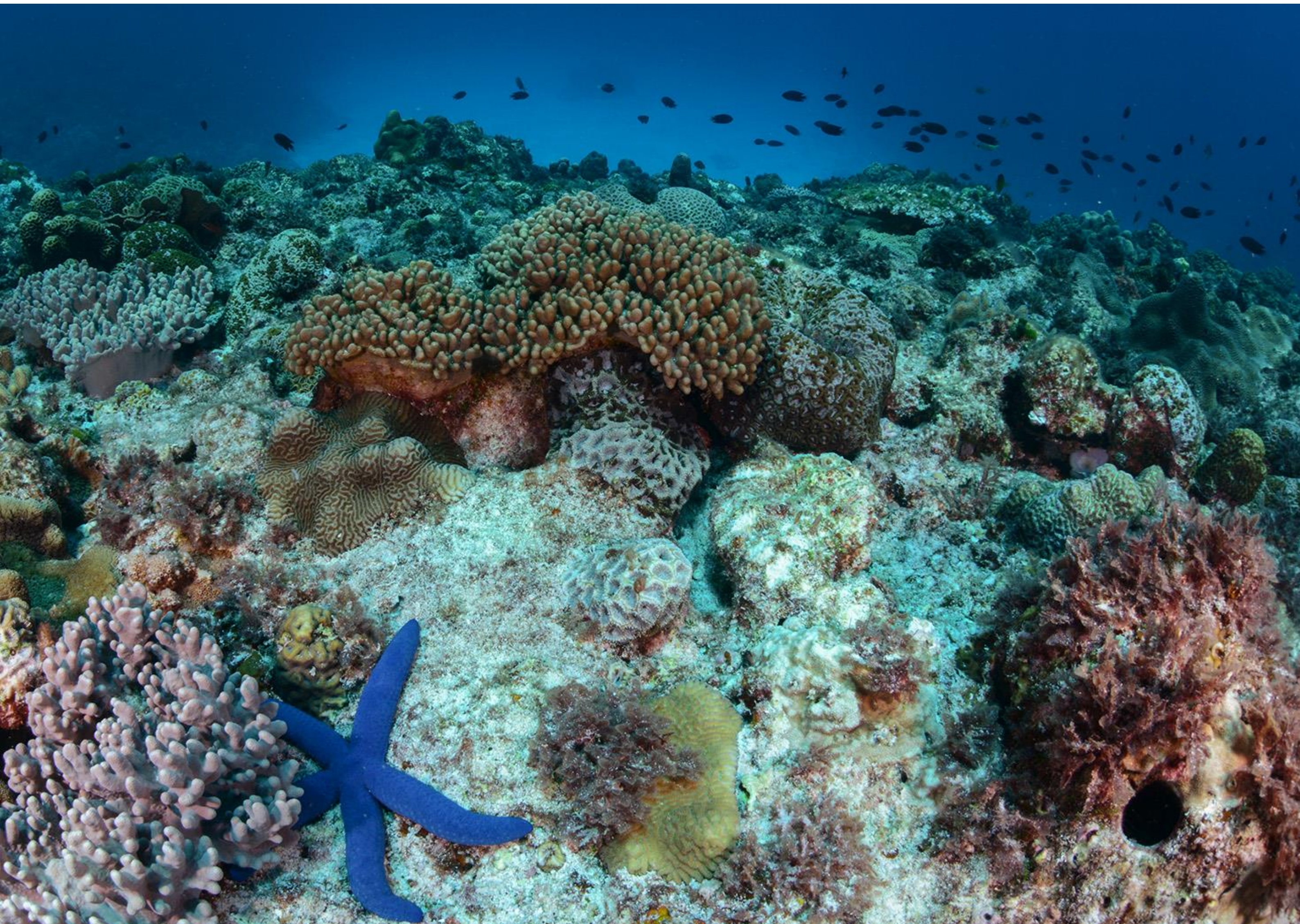
Copyright and disclaimer

Important disclaimer

Images

Graham Edgar and Rick Stuart-Smith

Contents

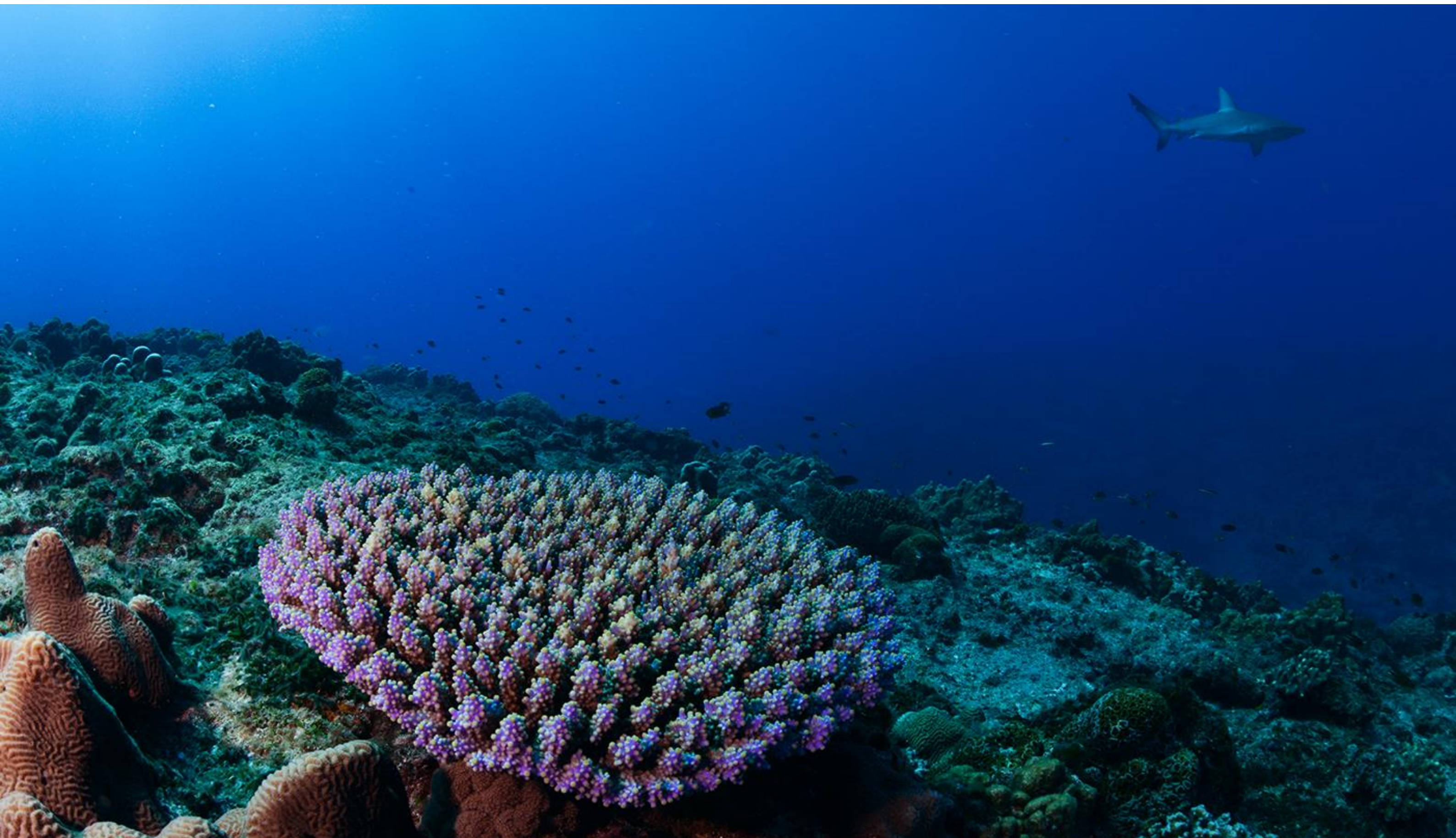


Figures

Tables

List of acronyms

ACRONYM	EXPANDED
AMP/CMR	Australian Marine Park/ Commonwealth Marine Reserve
RLSF	The Reef Life Survey Foundation
MPA	Marine Protected Area
IUCN	International Union for Conservation of Nature
RLS	Reef Life Survey
EEZ	Exclusive Economic Zone
CTI	Community Temperature Index



Executive summary

The Temperate East Commonwealth Marine Reserve (CMR) Network includes Commonwealth waters between the southern limit of the Great Barrier Reef to the southern coast of New South Wales, eastward to Lord Howe Island, and includes the Commonwealth waters surrounding Norfolk Island further east. Eight CMRs have been established in this CMR Network, four of which are known to support prominent reef systems: the Cod Grounds and Solitary Islands CMRs, the Lord Howe CMR and the Norfolk CMR. This report focuses on the latter two.

Field surveys in the Temperate East were conducted between 2009 and 2013 by a team of skilled divers from the Reef Life Survey program (www.reeflifesurvey.com) and the University of Tasmania. Ecological surveys were conducted at varying depths along 173 transects at 53 sites across the East CMR Network.

The reefs of the Temperate East CMR Network have developed on the latitudinal boundary of coral reef formation, between tropical, subtropical and temperate influences. Reef communities are further structured according to their isolation and the dominant habitat. Elizabeth and Middleton Reefs had broadly similar reef communities that differed from those at Lord Howe Island and Norfolk Island; the two islands often also differed from each other. Elizabeth and Middleton Reefs had more tropical species commonly found on the Great Barrier Reef, Lord Howe Island hosted a mix of tropical, subtropical and temperate species and Norfolk Island was dominated by subtropical and temperate species. The isolation of these reefs from each other and from the surrounding reef bioregions has also contributed to the presence of endemic fauna, and the high abundance of populations that may be rare or unusual elsewhere.

Despite the abundance of some tropical reef fishes, some key factors distinguish Elizabeth and Middleton low latitude reefs: a lack of high-intensity pulse disturbances typical in the tropics (e.g. cyclones and bleaching events); a high abundance of scraping and excavating fishes at Elizabeth and Middleton Reefs, whose effects on coral are both beneficial (by removing algal biomass) and detrimental (by removing live coral and coral recruits); and a historically low cover of live hard corals. Functionally-important fishes were recorded in high densities, including excavating and scraping parrotfishes and large browsing herbivorous fishes. Middleton Reef in particular had very high fish biomass, likely driven by a high abundance of top-order piscivores such as the Galapagos shark and black cod. Grazers contributed to high biomass in all areas except Norfolk Island. To some degree this is reflected in the benthic communities, as macroalgal cover was highest at Norfolk Island, which had the lowest biomass of grazers.

Biogeographically, Elizabeth and Middleton Reefs appear to have some connectivity to Lord Howe Island, but less than would be expected given their geographic proximity. The Lord Howe Island reef fauna probably has relatively low genetic diversity; populations of corals, for example, are genetically isolated and likely derived from few colonists. Norfolk Island is the most isolated of the locations studied, with expected high levels of self-replenishment and peripheral populations that are highly vulnerable to extinction.

Differences in fish community structure may also have been driven by underlying reef geomorphology and exposure to prevailing wind and swell. This was certainly reflected in the benthic community composition, with low-lying turfs and encrusting corals dominating the oceanic platform reefs, and a wider variety of sessile biota recorded on the fringing reefs of Lord Howe and Norfolk Islands. Erect and tabular corals, and calcified algae (e.g. *Halimeda* spp.) rather than crustose coralline algae, are often typical of sheltered habitats, as is a high cover of fleshy macroalgae. Elizabeth and Middleton appear to have the typical low-relief structure of highly exposed reef fronts, with more delicate sessile biota restricted to the lagoons.

RECOMMENDATIONS

- Undertake regular monitoring of physical characteristics – seasonal or more frequent reporting using loggers of water quality, nutrients, turbidity, light and other physical parameters that support ecological processes;
- Undertake ongoing ecological monitoring at intervals of 1-3 years to build up a temporal dataset to assess changes relative to data provided by this survey, with results reported using a comprehensive suite of sensitive environmental indicators;
- Include timed swims for more accurate assessment of Galapagos sharks and black cod populations;
- Support involvement of Lord Howe rangers in the monitoring of Elizabeth and Middleton, as they have the opportunity to coincide with suitable weather conditions in which to undertake surveys,
- Examine levels of gene flow between Elizabeth and Middleton and protected areas off the NSW coast, Norfolk Island, New Zealand and Lord Howe Island, to establish possible pathways of stock replenishment,
- Investigate seasonal changes in diversity, abundance and functional groups or productivity of fish and invertebrate communities, to further understand the dynamics of these highly dynamic systems and processes associated with recruitment and stock fluctuations,
- Investigate food webs, including addressing the question of whether large biomasses of sharks were usual elsewhere in previous decades, and how a large biomass of sharks influences the reef community.

1 Introduction

The Temperate East Commonwealth Marine Reserve (CMR) Network includes Commonwealth waters from the southern limit of the Great Barrier Reef to the southern coast of New South Wales, eastward to encompass Lord Howe Island, and including Commonwealth waters surrounding Norfolk Island in the far east. This CMR spans subtropical and temperate waters, and contains extensive seamount chains (Keene et al. 2008).

The Region's oceanography and marine ecology are dominated and driven by the East Australian Current, which flows southwards from the Coral Sea to waters east of Tasmania. Its strength varies seasonally, and productivity is affected by its large eddies and associated upwellings. It flows to 500 m depth and 100 km width, conveying up to 30 million cubic meters per second, with associated southward transport of tropical and subtropical species to temperate waters. The East Australian Current meets the Tasman Front at approximately 30 degrees latitude, and this delineates the tropical-temperate transition. This convergence zone is highly productive and geographically dynamic, in that it moves seasonally north or south (Ceccarelli 2010).

The East Australian Current, Tasman Front and offshore seamount chains (the Tasmantid, Lord Howe and Norfolk Ridge seamount chains) are recognised as some of the key ecological features of this CMR Network. Seamounts, in particular, have attracted scientific research for their volcanic, geological, biological, ecological and biogeographic attributes (McDougall and Green 1988). Emergent reefs and shallow shoals have formed at the tops of these seamounts, and they sustain a rich biodiversity and aggregate pelagic fauna. Eight CMRs have been established in this CMR Network, four of which are known to support prominent reef systems: the Cod Grounds and Solitary Islands CMRs (see Cod Grounds CMR Report), the Lord Howe CMR and the Norfolk CMR. This report focuses on the latter two.

The Lord Howe CMR contains Lord Howe Island, Balls Pyramid, and, to the north, Elizabeth and Middleton Reefs. Elizabeth and Middleton Reefs – the peaks of volcanic seamounts – are the two southern-most platform reefs in the world. Lord Howe is considered the southern-most locality in the world with a well-developed fringing coral reef that includes a lagoonal system (Zann 2000). Elizabeth, Middleton and the Lord Howe Island reefs host a unique and highly diverse assemblage of tropical and temperate organisms, and are notable as global strongholds for the Galapagos shark, *Carcharhinus galapagensis*, and the black cod, *Epinephelus daemelii*. Middleton Reef is protected within a Marine National Park Zone (IUCN II), while limited fishing is allowed in Elizabeth Reef's Recreational Use Zone (IUCN IV). CMR zoning around Lord Howe Island is more complex; outside of the NSW-managed Lord Howe Island Marine Park, the island is surrounded by a Habitat Protection (Lord Howe) (IUCN IV) zone, with a small no-take (IUCN II) zone to the east of the island, and another around the southern half of Ball's Pyramid. No strong protection exists for Norfolk Island, as the area surrounding the island (and containing all shallow reef habitat) is a Multiple Use (IUCN VI) Zone.

Oceanographically, Lord Howe Island is generally influenced by the colder Tasman Sea water, but Elizabeth and Middleton Reefs generally receive warmer water from eastward-flowing eddies of the East Australian Current (Brewer et al. 2007). These eddies transport larvae from the Great Barrier Reef and Coral Sea. Additionally, the NSW coastal ecosystems to the west, which support subtropical reef ecosystems, are a potential source of propagules of temperate and subtropical species. The prevailing winds are from east to southwest, resulting in very exposed reef front habitats on the southern face of the reefs. Waves wrapping around the western and north-eastern aspects of the reef ensure that these sides are also exposed to heavy seas (Kennedy and Woodroffe 2004).

Middleton and Elizabeth Reefs are atoll-like structures or platform reefs associated with a seamount chain that extends northward from Lord Howe Island (Woodroffe et al. 2004). Both reefs consist of an extensive lagoon surrounded by a well-defined reef crest with characteristic spur and groove formations, broken only by channels on the northern edges (Choat et al. 2006). Lord Howe Island has evolved from a volcanic island (guyot), believed to have been active 6 or 7 million years ago (Exon et al. 2004). Together with Balls Pyramid further to the south, Lord Howe Island forms the southernmost and youngest in the same chain of seamounts that includes Elizabeth and Middleton Reefs. Norfolk Island, lying 900 km to the east, is part of a different and younger geological formation, but subject to similar environmental conditions and biogeographic drivers as Lord Howe Island.

The Commonwealth waters of the Lord Howe CMR contain parts of the structure of the seamount proper, a large proportion of the shelf area, the topographic discontinuity known as the drop-off zone where the shelf falls steeply into depths greater than 2000 m, and the deep-sea pelagic environment (Dickson 2006). Due to its position at the latitudinal limit for reef growth, Lord Howe Island provides an opportunity to examine possible changes in reef growth during periods of climate change (Kennedy et al. 2007).

Early research by Australian Museum staff indicated that live coral cover has historically been higher at Elizabeth Reef than at Middleton Reef (Australian Museum 1992). Original research in the 1980s identified a total of 121 coral species, of which 111 were also recorded in 2003 (Oxley et al. 2004). Coral communities differ between Elizabeth and Middleton Reef and Lord Howe Island. Additionally, differences between the reef communities of Elizabeth and Middleton Reefs hint that small-scale stochasticity in larval input and post-settlement survival are important, and extinction risk is potentially high (Noreen et al. 2009).

Over 320 species of algae, 86 species of scleractinian coral, 110 species of echinoderms, 433 species of fish and over 1,500 species of mollusc have been identified for the Lord Howe Island Region (Allen et al. 1977; Veron and Done 1979; Millar and Kraft 1993; Edgar et al. 2010). An Australian Museum review of samples taken from waters more than 40 m deep shows a species-rich fauna with 13.1% endemism; it is expected that shallow water fauna would show lower levels of endemism. Deep waters of the CMR support a unique deep-sea environment characterised by strong currents and high species diversity, and provide habitat for endemic, rare and endangered species of plants and animals (Richer de Forges et al. 2000; Clark et al. 2010). Samples taken from four seamounts on the Lord Howe Island Rise revealed 108 species of fishes and macroinvertebrates, of which 31% were new to science and potential seamount endemics (Richer de Forges et al. 2000).

Genetically, Elizabeth and Middleton Reefs appear to be similar to each other and reefs further north, but distinct from Lord Howe Island (van Herwerden et al. 2009). Of special interest has been the association between tropical species at the southern range of their geographic distribution, and subtropical species not found on the GBR. The coral communities tend to be dominated by a few abundant species, including *Acropora palifera*, *A. glauca*, *Porites* spp. and *Pocillopora damicornis*. Lord Howe Island corals have relatively low genetic diversity and populations are genetically isolated and most probably derived from few colonists, especially for brooding corals (Ayre and Hughes 2004).

In 2004, the Australian Institute of Marine Science undertook surveys of benthic habitats and fish faunas in the deeper Commonwealth waters of the Lord Howe and Balls Pyramid rises (30 – 200 m) (Speare et al. 2004). The survey used towed underwater cameras and BRUVS. A fossil coral reef was located extending to a depth of 45m, providing habitat for sparse stands of brown and green algae (Kennedy et al. 2007). The steep shelf slopes were composed of finer silty sediments flowing down between bedrock outcroppings, providing a topographically complex habitat, inhabited by sessile benthos and fish. Deep-water solitary corals and algal communities were recorded on the shelf of Balls Pyramid.

Commercially important invertebrates, such as holothurians, were abundant in 2003, with very high densities of the high-value *Holothuria whitmaei* (133.3 individuals per hectare) recorded during reef surveys (Oxley et al. 2004). Elizabeth and Middleton Reefs also support populations of endemic molluscs (Lee Long 2009).

Previous surveys have reported 322 species of reef fishes at Elizabeth and Middleton Reefs, with a high proportion of excavating and scraping parrotfishes and large herbivorous browsing fishes (Choat et al. 2006). Black cod and Galapagos shark populations were last recorded as abundant and stable, with the observation that the Elizabeth Reef lagoon may serve as a nursery habitat for Galapagos sharks (Oxley et al. 2004; Choat et al. 2006). Currently, 447 species and 107 families have been recorded around Lord Howe Island. In waters > 200m deep off Lord Howe Island, high densities of fish have been recorded, including large kingfish (*Seriola lalandi*), redfish (*Centroberyx* sp.), rosy jobfish (*Pristipomoides multidens*), and large unidentified groupers (Epinephelinae)(Speare et al. 2004). Additionally, three new fish records were made for the island in the baited video surveys: the smooth hammerhead shark (*Sphyrna zygaena*), the lancer (*Lethrinus genivittatus*), and the gilded triggerfish (*Xanthichthys auromarginatus*). Reef Life Surveys in the shallow waters of the NSW managed LHI MPA biennially since 2008 have resulted in numerous new records, mostly tropical fishes from the GBR that have recruited to the shallow coral reef habitat at LHI (Stuart-Smith et al. 2015).

This report outlines the results of the latest reef surveys at Elizabeth and Middleton Reefs, Lord Howe Island and Norfolk Island.

2 Methods

Field surveys in the Temperate East were conducted between 2009 and 2013 by a team of skilled divers from the Reef Life Survey program (www.reeflifesurvey.com) and the University of Tasmania. Geographical coordinates of sites (in WGS84) were recorded using handheld Garmin GPS units (APPENDIX 1). Ecological surveys were conducted at varying depths along 173 transects at 53 sites across the East CMR Network, with 34 transects at 17 sites in the strictly protected (IUCN II) Marine National Park Zone of Middleton Reef, 32 transects at 16 sites in the Recreational Use Zone (IUCN IV) at Elizabeth Reefs, 65 transects at 7 sites open to limited fishing in Lord Howe Island lagoon, and 42 transects at 13 sites in the Multiple Use Zone (IUCN VI) of Norfolk Island (Figure 1). Sites surveyed by RLS divers at Lord Howe Island outside the lagoon were not considered appropriate as reference sites for Elizabeth and Middleton Reef because of considerable habitat differences.

Data collected from each site consisted of abundance and size of fishes, abundance of mobile macroinvertebrates and cryptic fishes, and percentage cover of sessile biota. These are described separately below. Sites were selected to encompass the range of reef types and depth both inside and outside the CMR, but with the depth range limited by dive safety considerations and bottom time restrictions.

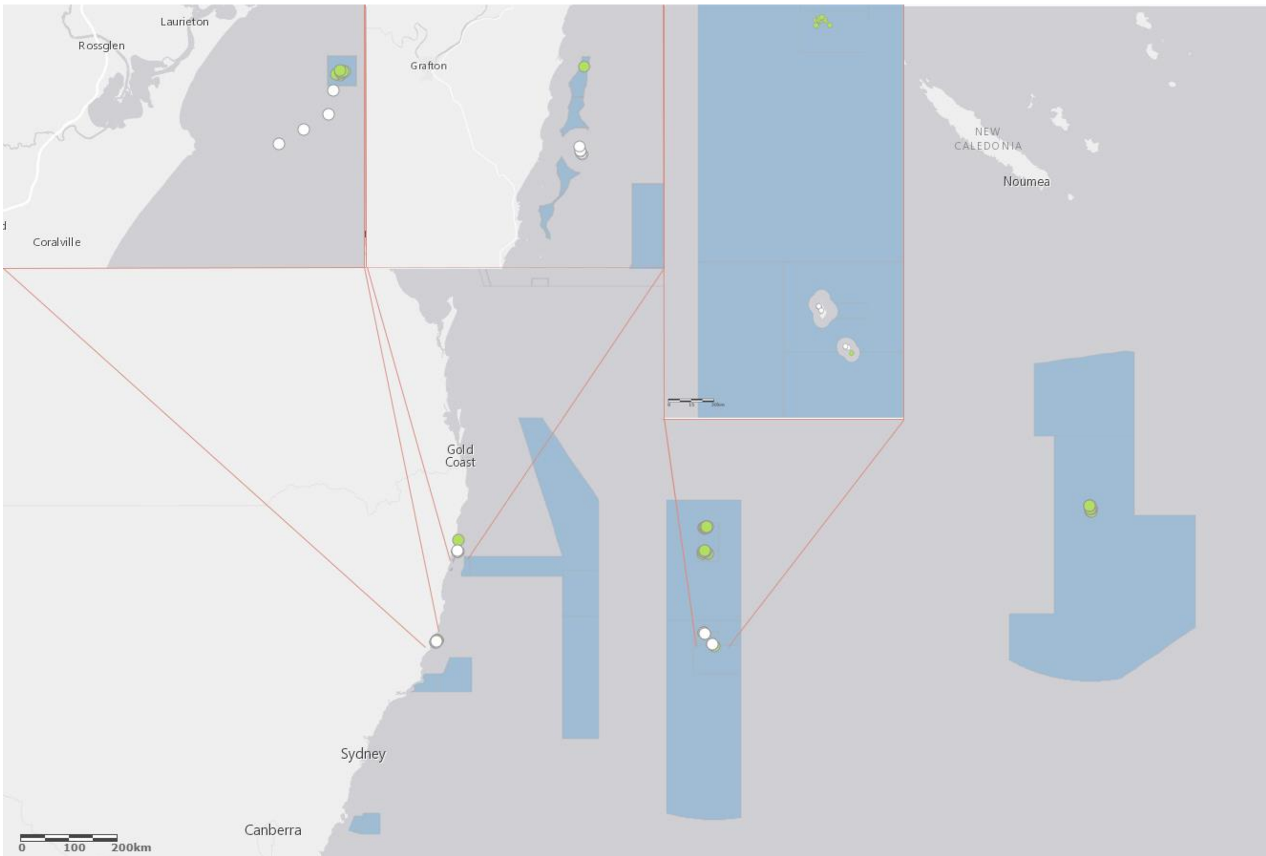


Figure 1. Map of Temperate East sites surveyed from 2009 - 2016.

FISH SURVEYS (METHOD 1)

Fish census protocols involved a diver laying out a 50 m transect line along a depth contour on reef. The number and estimated size-category of all fishes sighted within 5 m blocks either side of the transect line were recorded on waterproof paper as the diver swam slowly along up and down each side. 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 were estimated to the nearest 12.5 cm and individually recorded.

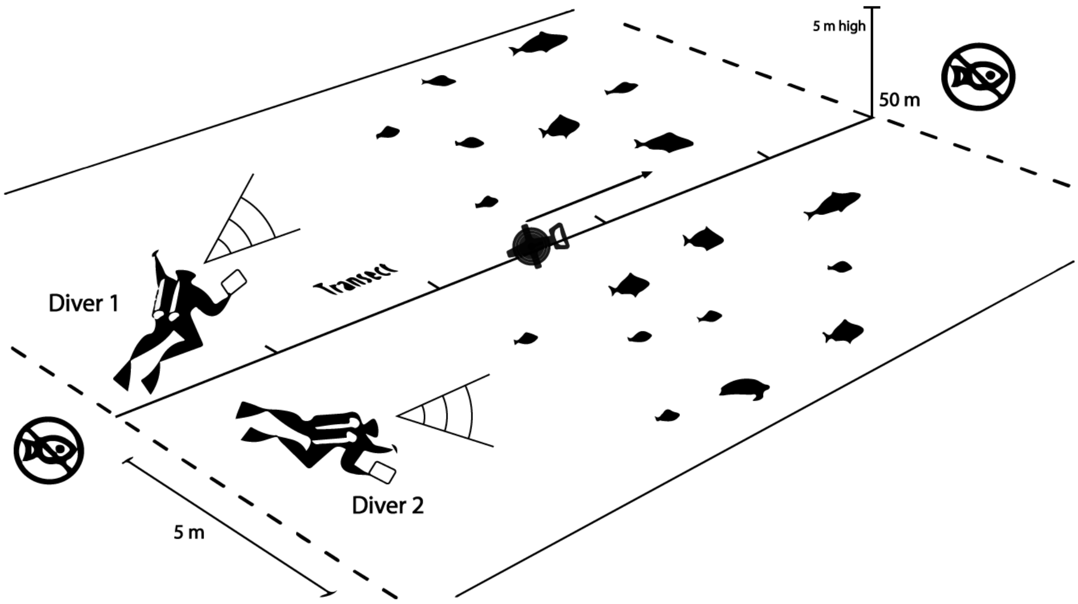


Figure 2. Stylised representation of method 1 survey technique

MACROALGAL AND SESSILE INVERTEBRATE SURVEYS (METHOD 2)

Information on the percentage cover of sessile animals and seaweeds along the transect lines set for fish and invertebrate censuses was recorded using photo-quadrats taken sequentially each 2.5 m (or 5 m, see below) along the 50 m transect. Digital photo-quadrats were taken vertically-downward from a height sufficient to encompass an area of at least 0.3 m x 0.3 m. When a wide-angle lens was used and the photo-quadrats encompassed at least 0.5 m x 0.5 m, only 10 images were taken (one every 5 m). The percentage cover of different macroalgal, coral, sponge and other attached invertebrate species in photo-quadrats was digitally quantified in the laboratory using the Coral Point Count with Excel extensions (CPCe) software (Kohler and Gill, 2006). A grid of 5 points was overlaid on each image and the taxon lying directly below each point recorded. Identification was to the lowest possible taxonomic resolution, with taxa for which identification was uncertain grouped with congeners or other members of the family or order.

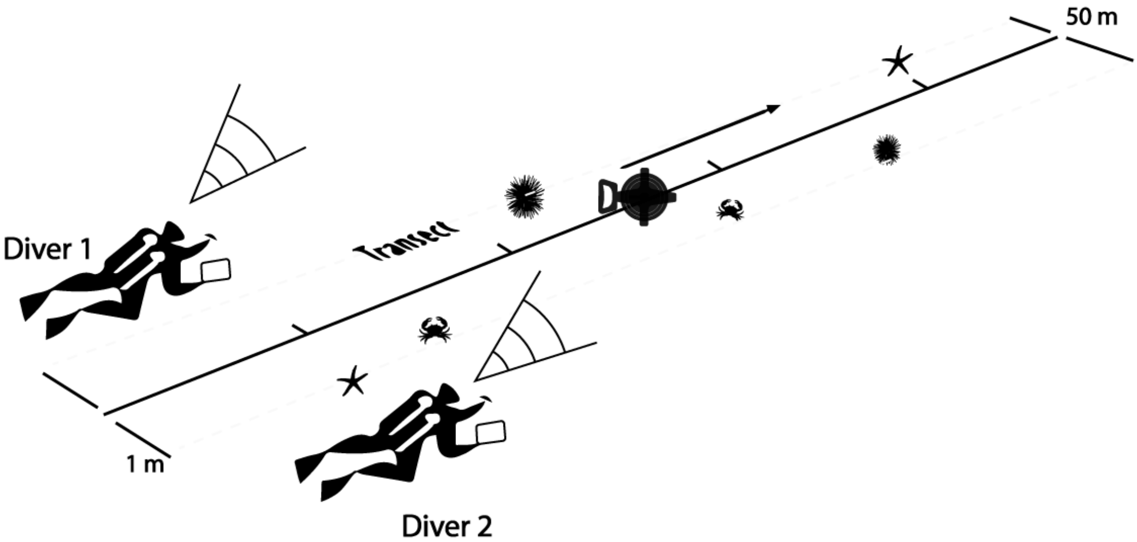


Figure 3. Stylised representation of method 2 survey technique

INDICATORS

Three indicators of reef condition were calculated for each survey: the biomass of large reef fishes (B20), the community temperature index (CTI), and an IUCN threatened species index. The biomass of large fishes (B20) is an indicator of fishing impacts, with previous analyses revealing lower values found in regions of higher impact around Australia. It is calculated as the sum of biomass for all individuals on any survey that are in the 20 cm size class or larger, regardless of identity. CTI is an indicator of the thermal affinities of the species, and is a sensitive indicator of temperature changes. It is thus most useful for time series analyses, although spatial comparison can provide an indication of potential relative vulnerabilities to warming (e.g., Stuart-Smith et al. 2015). For its calculation, the midpoint of each species' thermal distribution (i.e. temperature at the centre of its range) is used as a value of thermal affinity. The mean thermal affinity of species recorded on a survey is then taken, weighted by the log of their abundance on the survey. The IUCN threatened species index is calculated using the species list from the combined Method 1 and Method 2 data for a given survey, as the proportion of those species which are listed on the IUCN red list under the categories Vulnerable, Endangered, or Critically Endangered.

STATISTICAL ANALYSES

At most sites, multiple transects were surveyed at different depths (see APPENDIX 1). Because community types encountered along individual transects within a site generally matched more closely with transects at similar depths at other sites, rather than transects at other depths within the same site, each transect was regarded as an independent sample in analyses. Thus, the unit of replication was total value(s) per pair of adjoining transect blocks (i.e. per 500 m^2 for fishes and per 100 m^2 for mobile macroinvertebrates). Sessile biota percent cover was expressed as % per transect (i.e. 2 blocks).

Separate univariate analyses and data exploration techniques were used for fish, mobile macroinvertebrate communities, and sessile communities. Univariate metrics that described important community characteristics were calculated for each transect and compared between transects surveyed. Metrics examined for fishes were: relative abundance, estimated total biomass (see below for biomass estimation), biomass of fishes > 20 cm TL, and number of species. Mobile invertebrate metrics were: total relative abundance of mobile invertebrates and number of species. Sessile community/benthic cover metrics were: % crustose coralline algae, % bare rock, total sessile invertebrate cover, number of biotic taxa/groups and % cover of the dominant cover categories.

Univariate metrics were applied in separate ANOVAs, with Reef as a fixed factor. All dependent variables were log(x+1) transformed. To explore patterns in fish community trophic structure, the abundance and biomass of fishes in different trophic groups were estimated. Trophic groups used in this analysis were: benthic invertivores, carnivores (preying on both invertebrates and fishes), piscivores (mostly preying on fishes), omnivores (consuming plant and animal matter), planktivores, corallivores, grazers (including algal turf croppers, detritivores, macroalgal browsers, and scraping and excavating parrotfishes) and farmers (territorial damselfishes). Biomass estimates were made for each species on each transect block using fish abundance counts, size estimates, and the length-weight relationships presented for each species (in some cases genus and family) in Fishbase (Froese and Pauly 2016).

Relationships between 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 biotic 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, therefore allowing less abundant species to also contribute to the plots. MDS was accompanied by ANOSIM to test the significance of community-level differences between reefs.

3 Results

FISH SURVEYS

Transects across the Temperate East CMR Network and LHI reference sites revealed 295 species of reef fishes along a total of 173 transects (APPENDIX 2). Elizabeth and Middleton Reefs had the greatest numbers of species in total (185 and 190, respectively), with lower numbers at Lord Howe Island (165), and half the number of species at Norfolk Island (90). Among the five most abundant species, all four locations shared the one-spot puller *Chromis hypsilepis* and the orange wrasse *Pseudolabrus luculentus*. Middleton Reef, Elizabeth Reef and Lord Howe Island also shared the Coral Sea gregory *Stegastes gascoynei*. Species that differed in each location in terms of high abundance were Doederlein's cardinalfish *Ostorhinchus doederleini* at Middleton Reef, the blue knifefish *Labracoglossa nitida* at Elizabeth Reef, the multispine damselfish *Neoglyphidodon polyacanthus* and the Norfolk cardinalfish *Apogon norfolcensis* at Lord Howe Island, and the smokey chromis *Chromis fumea* and Lea's cardinalfish *Taeniamia leai* at Norfolk Island. All locations were characterised by a mix of tropical and temperate species, plus the regional endemics that are considered subtropical.

Middleton and Elizabeth reefs (Lord Howe CMR IUCN II and IV), Lord Howe Island (Reference sites) and Norfolk Island CMR (IUCN VI) formed three separate groups defined by key differences in their reef fish assemblages (Figure 4). Elizabeth and Middleton Reefs were dominated by a mix of tropical and subtropical species, with some species common to the Great Barrier Reef and other Indo-Pacific coral reefs (e.g. *Chlorurus sordidus*, *Thalassoma lunare*, *T. lutescens*), some particular to this subtropical eastern region (e.g. *Coris bulbifrons*), and some large-bodied species of conservation significance (*Carcharhinus galapagensis*, *Epinephelus daemelii*). Norfolk Island, at the opposite end of the spectrum, was characterised by endemic, subtropical and temperate species such as *Parma polylepis*, *Trachypoma macracanthus* and *Aplodactylus etheridgii*. Lord Howe Island appeared to have a representation of both faunas, and a higher biomass of *Neoglyphidodon polyacanthus* and *Apogon norfolcensis*.

Reef fish abundance was significantly lower at Lord Howe Island than at the other three locations, but Norfolk Island had the lowest biomass and species richness, as well as lowest biomass of large (>20 cm) fishes (Figure 5, Table 1). The biomass of all functional groups except benthic invertivores varied significantly between CMR zones and reference sites (Figure 6, Table 2). Generally, the dominant functional groups were benthic invertivores, planktivores, piscivores and grazers. Middleton Reef was dominated by benthic invertivores, piscivores and grazers; Elizabeth Reef had high biomass of planktivores, piscivores and grazers, and at Lord Howe CMR reference sites grazers dominated the reef fish biomass. Norfolk Island tended to have lower biomass of most functional groups. Planktivores were especially prevalent at Elizabeth Reef, and piscivores at Middleton Reef. The Lord Howe reference sites and Norfolk Island CMR had higher biomass of farming damselfishes than Elizabeth and Middleton Reefs, and Norfolk Island CMR had the lowest biomass of grazers.

Community temperature index (CTI) scores were similar between Elizabeth and Middleton Reefs; both were significantly higher than the Lord Howe Island reference sites and Norfolk Island CMR, in part due to limited representation of temperate species. CTI values were lowest at the Norfolk Island CMR, largely reflecting a lower proportion of widespread Indo-Pacific tropical species. The proportion of threatened IUCN Red-Listed species was highest at Middleton Reef – the most protected by zoning – and similar at the other locations (Figure 7).

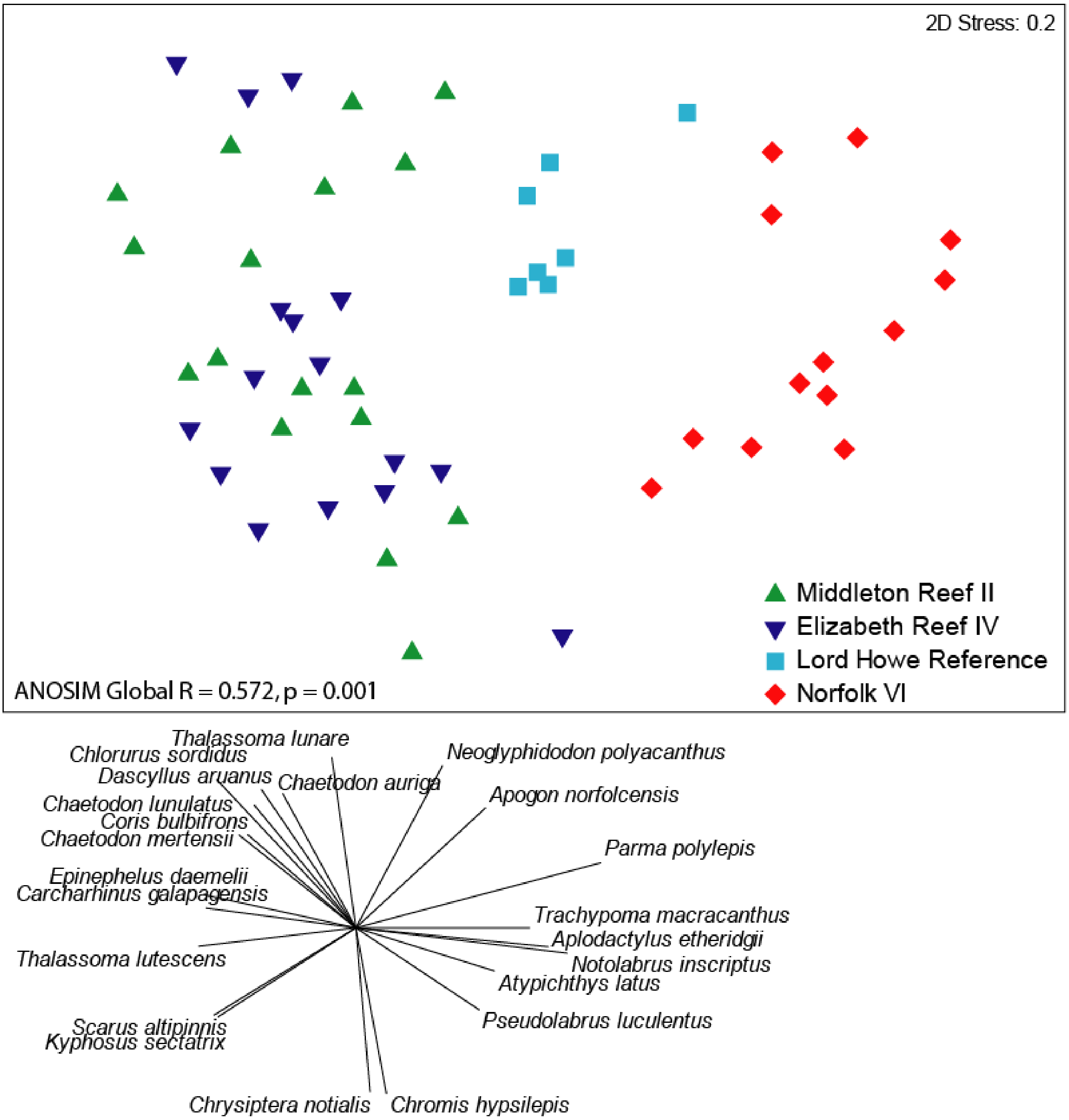


Figure 4. Multidimensional Scaling (MDS) plot of reef fish biomass in the Temperate East CMR Network, showing CMRs with location names and IUCN categories, performed on the Bray-Curtis similarity matrix of the log(x+1) transformed data. Species vectors are shown if they had a correlation value of at least 0.5.

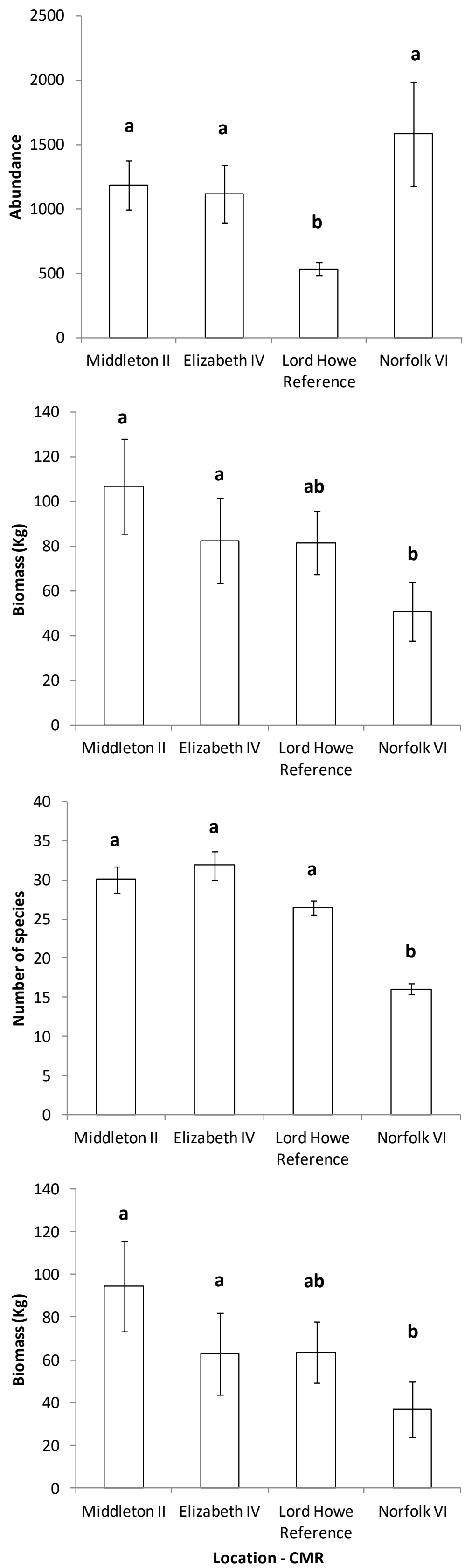


Figure 5. Abundance, biomass, species richness and biomass of large (>20cm) reef fishes at in the Temperate East CMR Network (per 500m^2). Error Bars = 1 SE.

Table 1. ANOVA results on key metrics of the fish community in the Temperate East CMR Network, with CMR as the factor. Data were log(x+1) transformed.

Metric	MS	$F_{3,169}$	p
Abundance	0.89	6.25	<0.001
Biomass	1.02	4.77	0.003
Biomass >20	2.46	6.68	<0.001
Species richness	0.62	33.59	<0.001

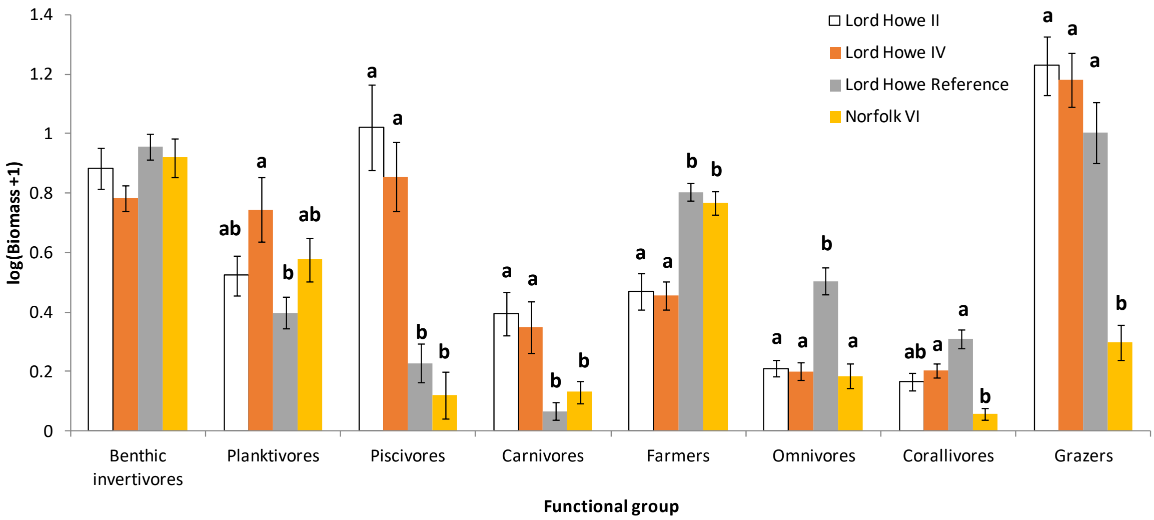


Figure 6. Biomass in kg / 500m² (log x+1 transformed) of key functional groups of reef fishes at in the Temperate East CMR Network. CMR zones with the same biomass values are grouped with the same letters. Benthic invertivores were not significantly different. Error Bars = 1 SE.

Table 2. ANOVA results on key functional groups of the fish community in the Temperate East CMR Network, with CMR as the factor. Data were log(x+1) transformed.

Functional group	MS	$F_{3,169}$	p
Benthic invertivores	0.22	1.67	0.174
Planktivores	0.90	3.99	0.009
Piscivores	8.01	20.74	<0.001
Carnivores	1.11	9.54	<0.001
Farmers	1.46	19.48	<0.001
Omnivores	1.28	16.87	<0.001
Corallivores	0.56	14.58	<0.001
Grazers	7.36	18.22	<0.001

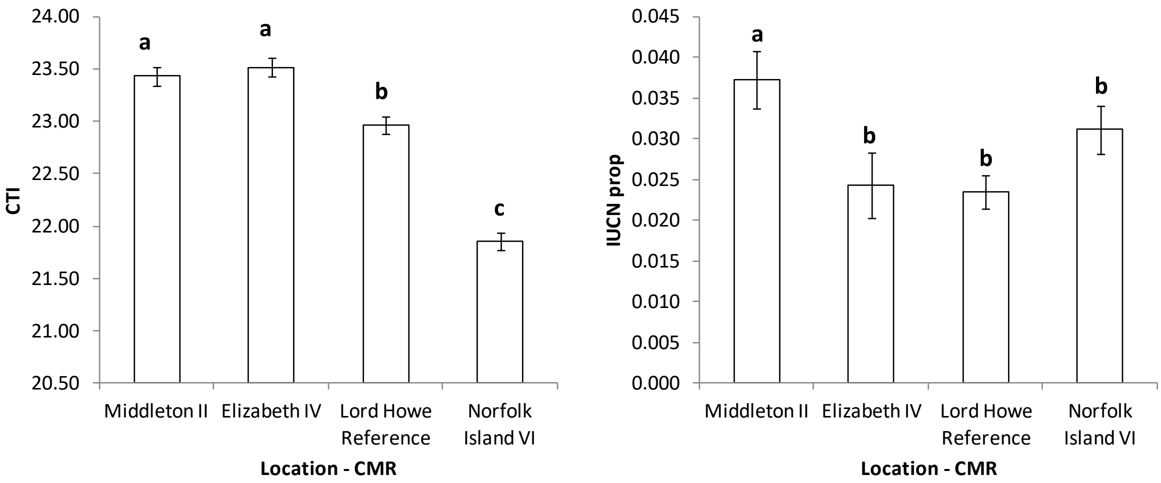


Figure 7. Indicators of reef condition – baseline values. CTI (warming indicator) and the proportion of threatened species listed in the IUCN Red List in the CMRs and reference sites. CTI ANOVA $F_{3,157} = 77.24$, $p < 0.001$; IUCN ANOVA $F_{3,157} = 4.43$, $p = 0.005$. Error Bars = 1 SE.

BENTHIC COMMUNITY

Benthic community composition was surveyed along a total of 112 transects; 34 at Middleton Reef (Lord Howe CMR Zone II), 32 at Elizabeth Reef (Lord Howe CMR Zone IV), six at Lord Howe reference sites and 40 at Norfolk Island CMR. Across all transects, the highest average cover was for turf (39.4%), followed by live hard coral (24.8%) and abiotic substrata such as bare rock, rubble or sand (11.6%). Elizabeth and Middleton Reefs had similar benthic communities overall, but sites were spread over a wide range of benthic community types. Some sites were dominated by abiotic substrata such as rubble and sand, whilst others had high cover of soft corals, crustose coralline algae and encrusting corals. A high proportion of turf at Elizabeth and Middleton Reefs distinguished them from the other sites. The Lord Howe reference sites and Norfolk Island CMR grouped together more closely, with a benthic community of erect and tabular corals, a diverse algal assemblage, and a high proportion of anemones and zoanthids (Figure 8).

No significant differences were evident between CMRs in the cover of all live sessile biota, and in the cover of crustose coralline algae, although both had highest values at Elizabeth Reef (Figure 9). The number of benthic categories recorded at each site, however, was significantly higher at Elizabeth than Middleton Reefs, and higher still at both Lord Howe Island and Norfolk Island. The cover of macroalgae was also much higher on the island fringing reefs than the platform reefs, both of which had negligible cover of fleshy macroalgae. The platform reefs were instead dominated by turf. Middleton Reef had the highest cover of turf (60%), followed by Elizabeth Reef (45%) and the two islands (20-23%). Live hard coral cover was highest at Elizabeth Reef. Live coral cover at Middleton Reef was approximately half of Elizabeth Reef. Lord Howe and Norfolk Islands had intermediate cover of live coral, between 19 and 25%.

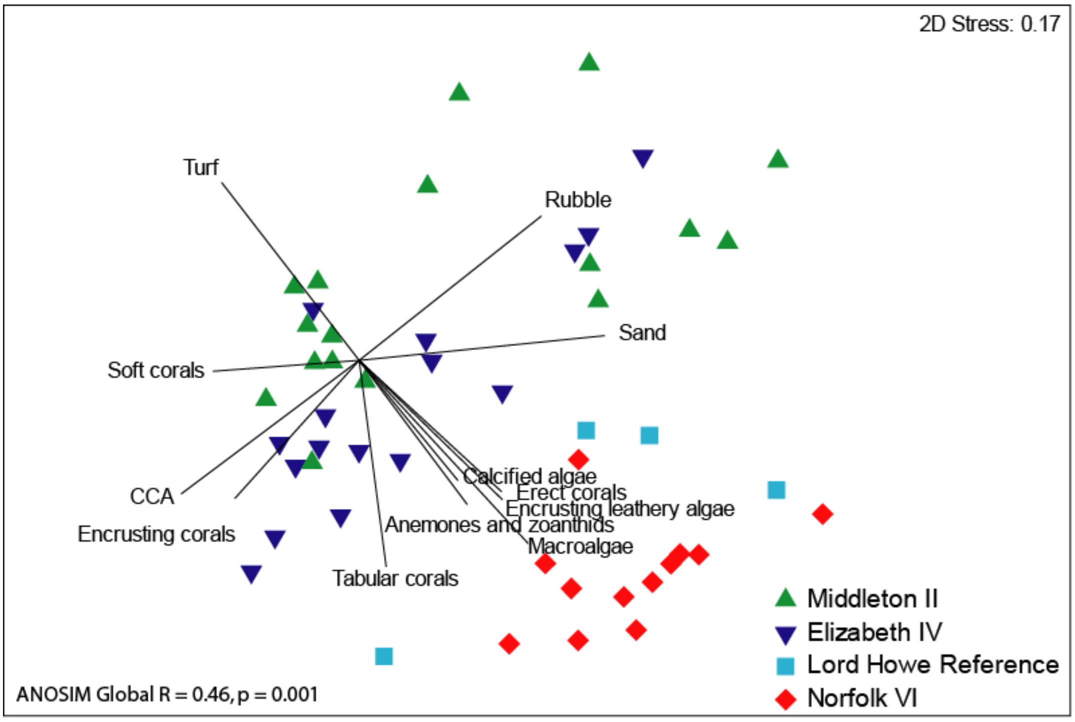


Figure 8. Multidimensional Scaling (MDS) plot of benthic percent cover in the Temperate East CMR Network, showing CMRs with location names and IUCN categories, performed on the Bray-Curtis similarity matrix of the log(x+1) transformed data. Benthic category vectors are shown if they had a correlation value of at least 0.5.

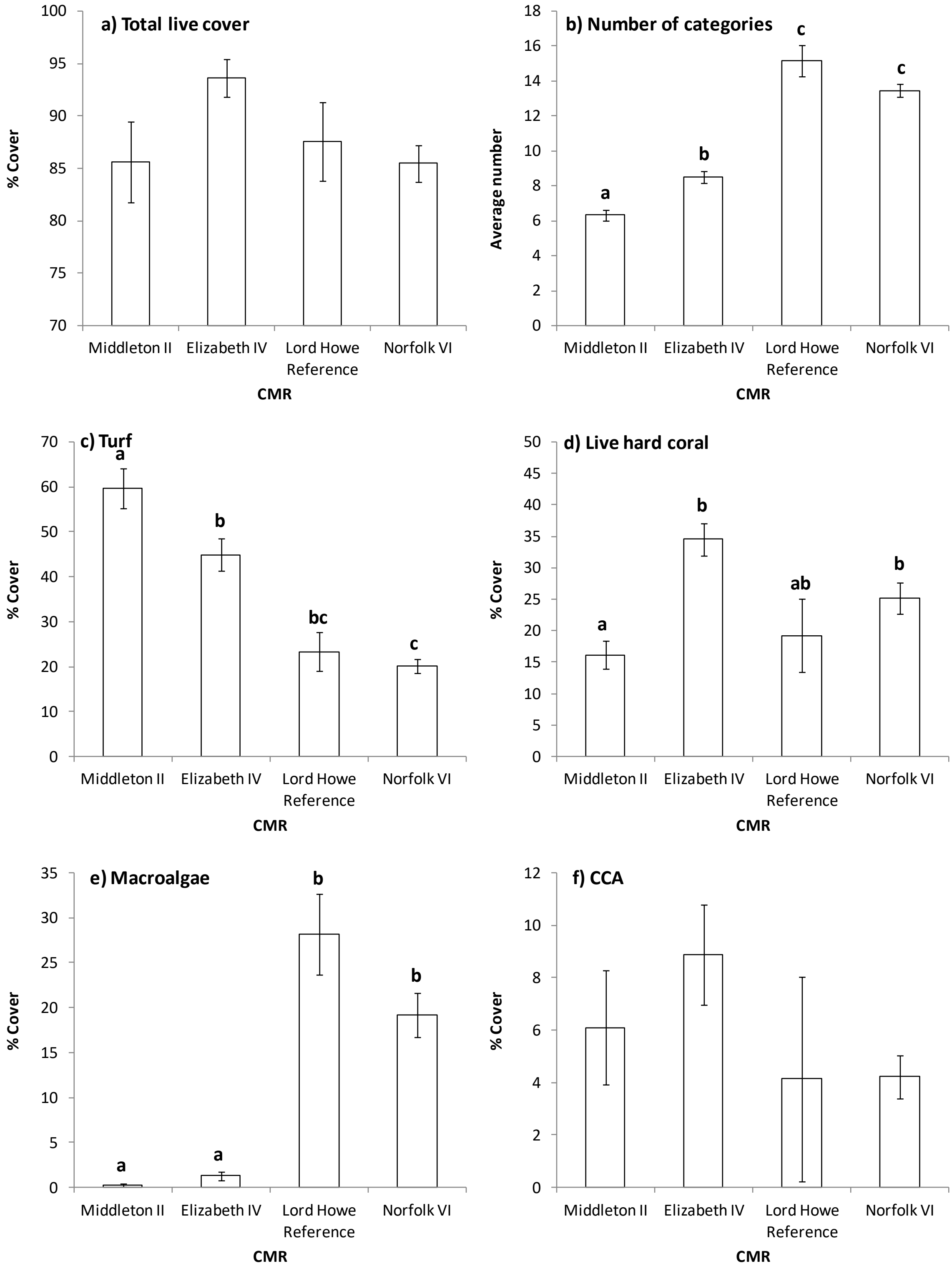


Figure 9. Percentage cover of a) total cover of live biota, b) number of benthic categories, c) turf, d) live hard coral, e) macroalgae and f) crustose coralline algae recorded on transects inside the CMRs and at reference sites. Y-axes represent mean values (+SE) per transect (100 random points).

Table 3. ANOVA results on key categories of the benthic community in the Temperate East CMR Network, with CMR as the factor. Data were log(x+1) transformed.

Benthic category	MS	$F_{3,106}$	p
Total live cover	485.4	2.05	0.112
Number of benthic categories	375.7	87.65	<0.001
Turf	10476	28.18	<0.001
Live hard coral	1.10	10.09	<0.001
Macroalgae	10.51	116.1	<0.001
Crustose coralline algae	0.46	1.69	0.173

MOBILE MACROINVERTEBRATE SURVEYS

Across all transects, 97 species of macroinvertebrates were recorded in the Temperate East CMR Network (APPENDIX 3). More species were recorded close to the two islands (Lord Howe Island and Norfolk Island, 46 and 42, respectively) than at the two platform reefs of Elizabeth and Middleton (33 and 35, respectively). Echinoderms dominated among the most abundant species at Middleton Reef, including the sea urchins *Echinostrephus* sp., *Echinometra mathaei*, *Diadema savignyi* and the sea stars *Ophidiaster confertus* and *Linckia multifora*. The same species were abundant at Elizabeth Reef, but the sea cucumber *Holothuria edulis* was also among the most abundant species, whilst *Linckia multifora* was rare. At Lord Howe and Norfolk Islands, *Centrostephanus rodgersii* was among the most abundant species, much like areas closer to the mainland.

The differences between CMRs were evident at the assemblage level, with the primary differences separating the platform reefs (Elizabeth and Middleton) from the island fringing reefs (Lord Howe and Norfolk Islands) (Figure 10). The key species of sea urchins dominating abundance records at the different locations were the main drivers of the differences between the reefs and the islands (APPENDIX 3). There was a slight separation between Elizabeth and Middleton reefs driven by a higher abundance of *Holothuria edulis* at Elizabeth Reef, and a separation between Lord Howe and Norfolk Islands driven by higher abundance of *Holothuria hilla* and *Thalamita* spp. at Norfolk Island.

Elizabeth Reef had the lowest abundance and species richness of invertebrates; the other locations had similar abundance, but there were further differences in species richness (Figure 11, Table 4). Higher species richness was recorded at Middleton Reef and Norfolk Island, and lower species richness was found at Elizabeth Reef and Lord Howe Island. Echinoderms dominated the invertebrate assemblage at all locations. Crustaceans and molluscs were most abundant and species-rich at Norfolk Island; Middleton Reef had especially low numbers and species of crustaceans. Elizabeth Reef had the least echinoderms, both in abundance and species richness (Figure 12, Table 4).

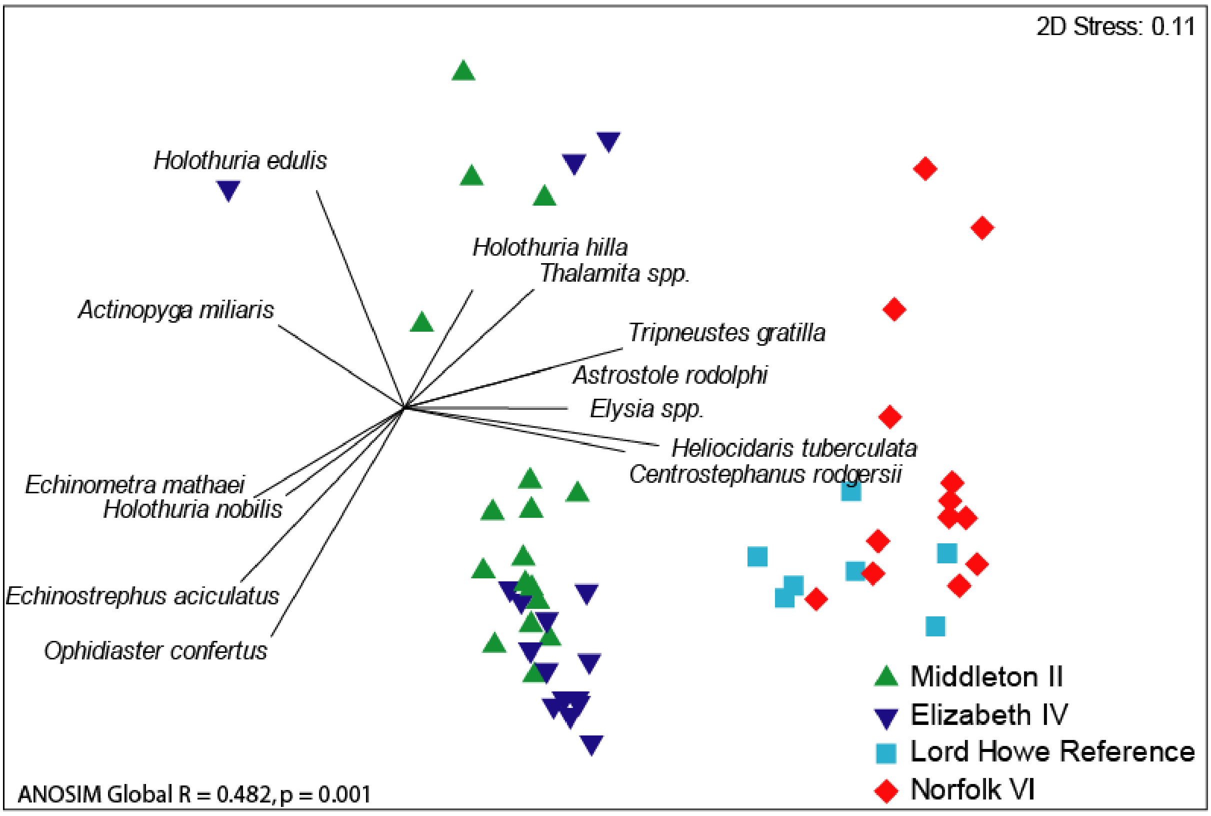


Figure 10. Multidimensional Scaling (MDS) plot of macroinvertebrate abundance in the Temperate East CMR Network, showing CMRs with location names and IUCN categories, performed on the Bray-Curtis similarity matrix of the log(x+1) transformed data. Species vectors are shown if they had a correlation value of at least 0.4.

Table 4. ANOVA results on key metrics and taxonomic groups of the invertebrate community, and abundance and species richness of cryptic fishes in the Temperate East CMR Network, with CMR as the factor. Data were log(x+1) transformed.

Metric	Taxa	MS	$F_{3,169}$	p
Abundance	**Total**	317.7	6.55	<0.001
	Crustaceans	0.30	3.78	0.011
	Echinoderms	2.59	7.47	<0.001
	Molluscs	1.89	12.58	<0.001
	Cryptic fishes	2.25	7.59	<0.001
Species richness	**Total**	1.81	5.60	0.001
	Crustaceans	0.14	3.86	0.011
	Echinoderms	0.17	6.33	<0.001
	Molluscs	0.15	3.32	0.021
	Cryptic fishes	0.01	0.22	0.885

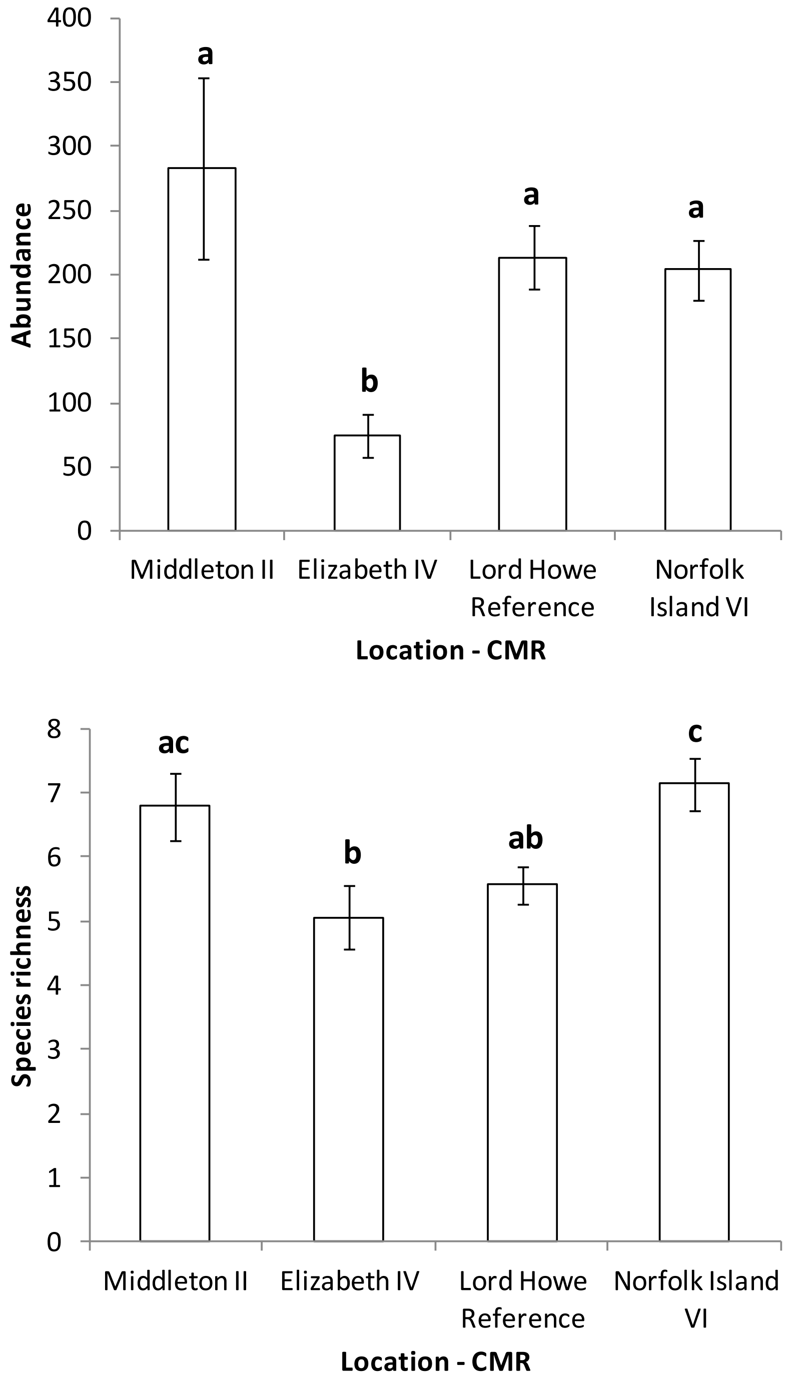


Figure 11. Abundance and species richness of macroinvertebrates in the Temperate East CMR Network (per 100m^2). Error Bars = 1 SE.

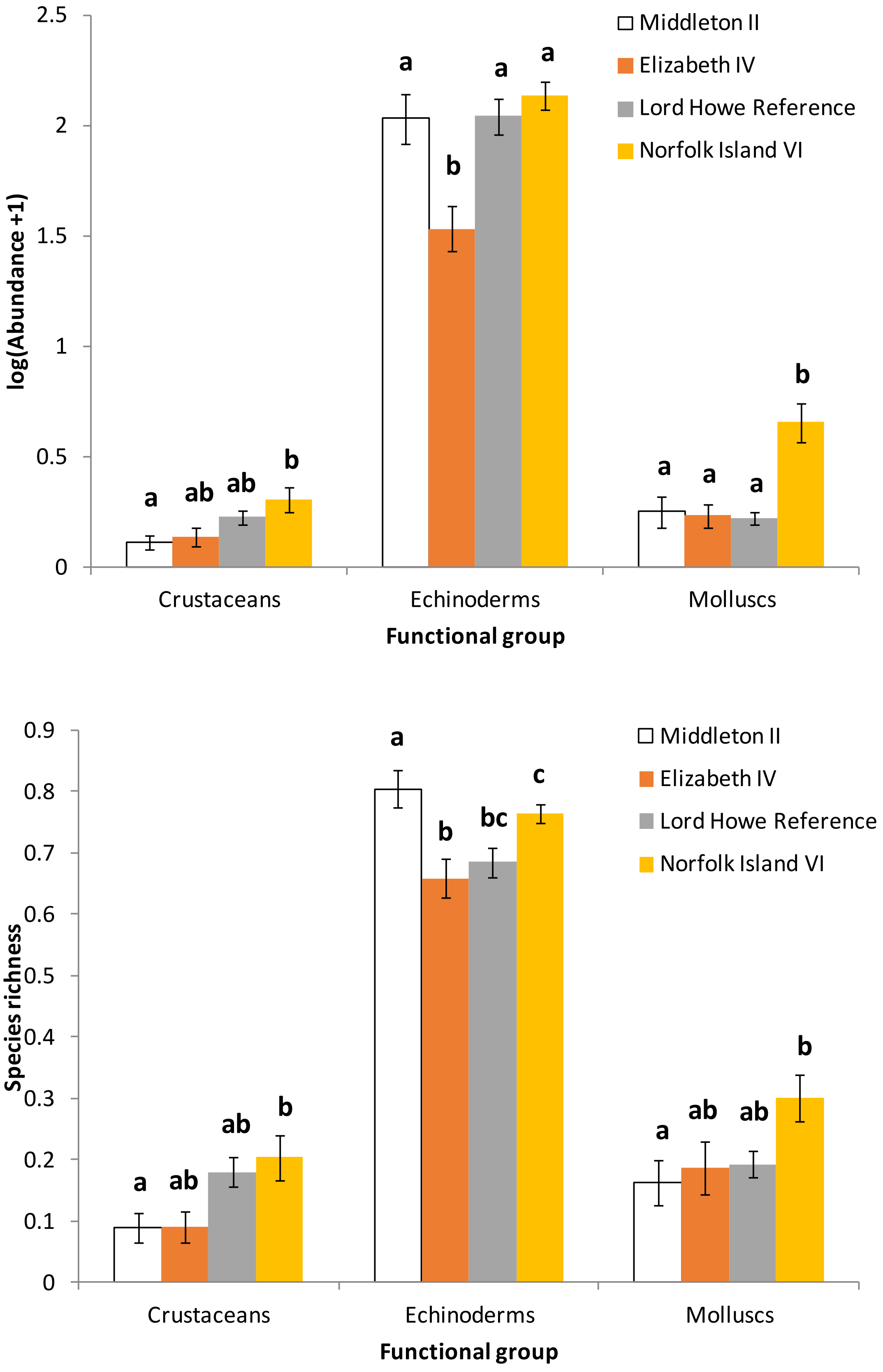


Figure 12. Abundance and species richness (per 100m^2) of key macroinvertebrates taxa in the Temperate East CMR Network. Error Bars = 1 SE.

CRYPTIC FISH SURVEYS

Temperate East CMR Network surveys recorded 75 species of cryptic fishes along the transects, using Method 2 (APPENDIX 4). The lowest number of species (20) was recorded at Norfolk Island, followed by Middleton Reef (26), Elizabeth Reef (38) and the Lord Howe Island reference sites (45). Dominant species included *Eviota fasciola*, *Ecsenius fourmanouri* and *Apogon doederleini* at Middleton Reef and Elizabeth Reef, and a combination of blennies and cardinalfishes at Lord Howe Island and Norfolk Island. Middleton and Elizabeth Reefs had significantly lower abundance of cryptic fishes than Lord Howe and Norfolk Islands, but species richness was similar throughout all four locations (Figure 13, Table 4).

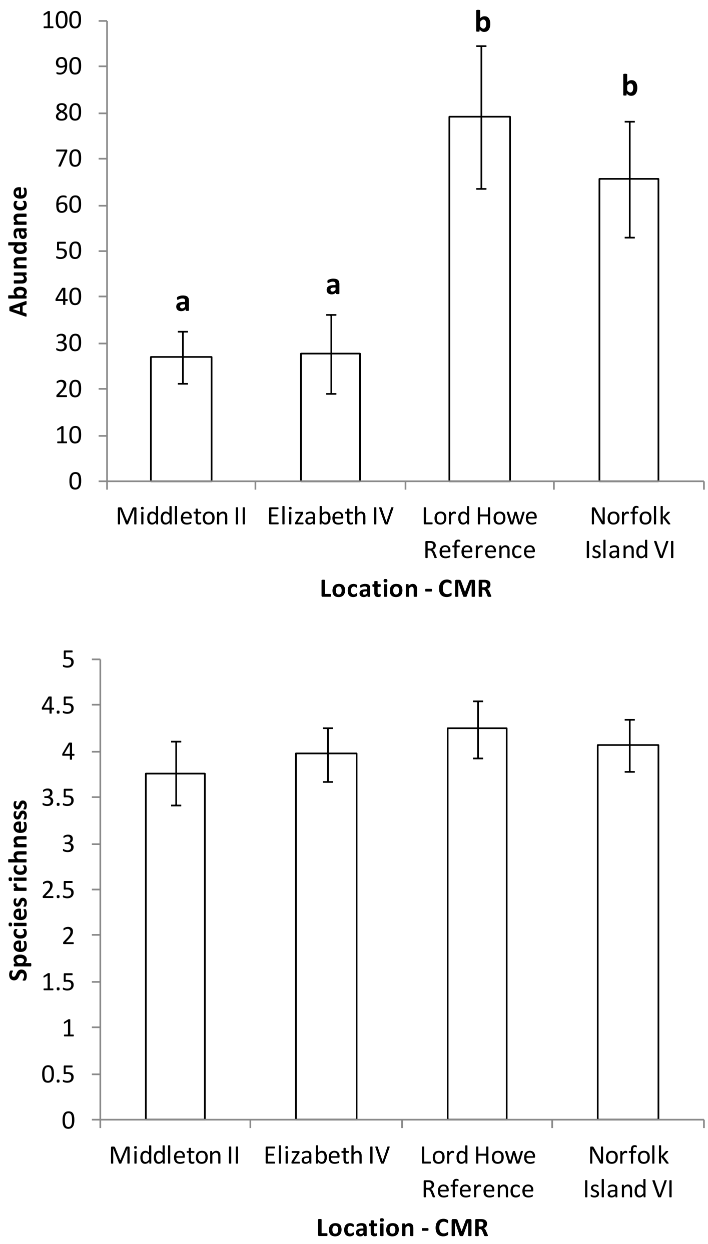


Figure 13. Abundance and species richness of cryptic fishes in the Temperate East CMR Network (per 100m^2). Error Bars = 1 SE.

THREATENED AND PROTECTED SPECIES

Few species listed under the EPBC Act were recorded in the Temperate East CMR Network. The green turtle *Chelonia mydas* (Vulnerable) was recorded in low numbers everywhere except Lord Howe Island. The sea krait *Laticauda colubrina*, listed as a Protected Marine species, was recorded at Norfolk Island. The black cod *Epinephelus daemelii*, listed as Vulnerable, was abundant at Elizabeth and Middleton Reefs, but absent from Lord Howe Island and Norfolk Island during these surveys (Figure 14) (but has been recorded on many occasions in regular monitoring of inshore Lord Howe Island sites by RLS).

Chelonia mydas and *E. daemelii* are also listed in the IUCN Red List, as Endangered and Near Threatened, respectively. The Galapagos shark *Carcharhinus galapagensis* is also Near Threatened, and occurs at Middleton Reef in high abundance. The other CMRs and reference sites also had small numbers of *C. galapagensis* (Figure 14). The Near Threatened *Epinephelus polyphekadion* was encountered once, at Lord Howe Island.

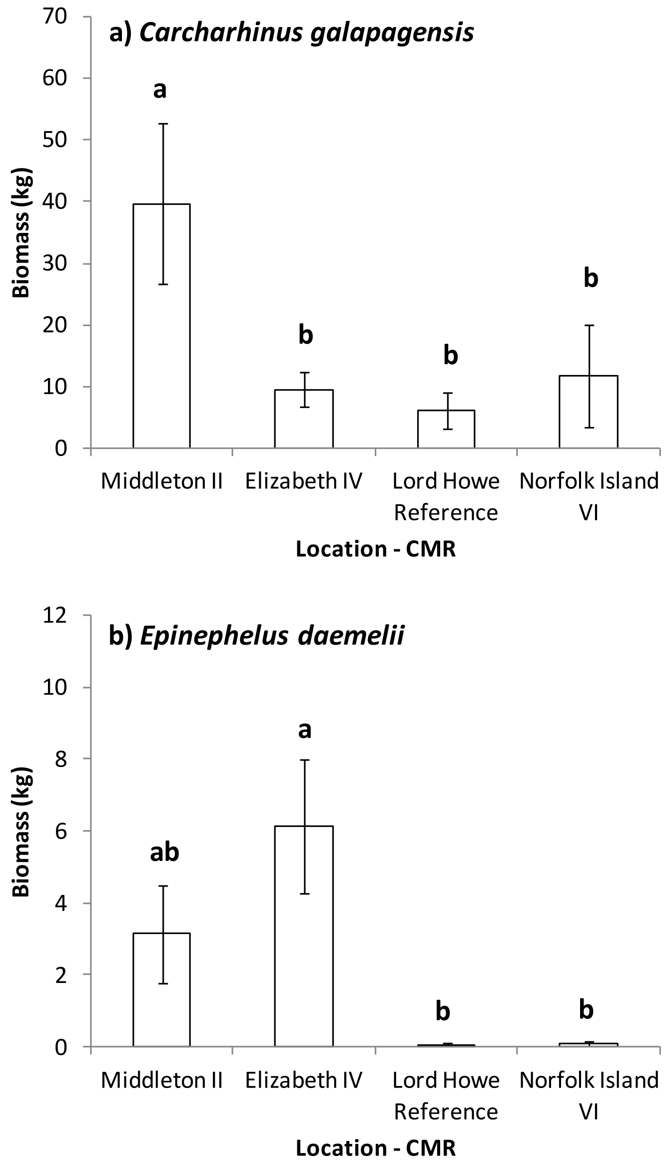


Figure 14. Biomass of a) *Carcharhinus galapagensis* and b) *Epinephelus daemelii* across the Temperate East CMR Network (per 500m2). *C. galapagensis* ANOVA F3,169 = 4.38, p = 0.005; *E. daemelii* ANOVA F3,169 = 10.01, p < 0.001. Error Bars = 1 SE.

4 Discussion

The reefs of the Temperate East CMR Network have developed on the latitudinal boundary of coral reef formation, between tropical, subtropical and temperate influences (Choat et al. 2006). Despite their relatively high latitude, they are greatly influenced by the relatively warm East Australian Current and its eddies, which bring warmer water and tropical larvae into this region. This is reflected in the fish, macroinvertebrate and benthic assemblages recorded during these surveys. Reef communities are further structured according to their isolation and the dominant habitat; in many cases major differences reflect differences in the geomorphology of the reefs, such as different communities that may develop on open-ocean platform reefs against island fringing reefs. In many cases, therefore, Elizabeth and Middleton Reefs had broadly similar reef communities that differed from those at Lord Howe Island and Norfolk Island; the two islands often also differed from each other (Choat et al. 2006; Stuart-Smith et al. 2015).

Fish communities shared similarities and differences between the four locations; some of the numerically dominant species were the same, but each location had a set of distinguishing characteristics. Elizabeth and Middleton Reefs had more tropical species commonly found on the Great Barrier Reef, Lord Howe Island hosted a mix of tropical, subtropical and temperate species, and Norfolk Island was dominated by regional subtropical endemic and temperate species. Interestingly, the reef fish community was different between Lord Howe and Norfolk Islands, while benthic and macroinvertebrate assemblages were largely similar. The isolation of these reefs from each other and from the surrounding reef bioregions has also contributed to the presence of endemic fauna, and high abundance of species that may be rare or unusual elsewhere (Oxley et al. 2004).

Despite the abundance of some tropical reef fishes, some key factors distinguish Elizabeth and Middleton from lower latitude reefs: the lack of high-intensity pulse disturbances typical in the tropics (e.g. cyclones and bleaching events); the high abundance of scraping and excavating fishes at Elizabeth and Middleton Reefs, whose effects on coral are both beneficial (by removing algal biomass) and detrimental (by removing live coral and coral recruits); and a historically low cover of live hard corals (Choat et al. 2006).

Elizabeth and Middleton reefs did not necessarily have the highest abundances of reef fishes, but had among the highest species richness and biomass of fishes, including the subset of fishes >20 cm. Functionally important fishes recorded in high densities included the regional endemic doubleheader wrasse *Coris bulbifrons* (Randall and Kuiter 1982), excavating and scraping parrotfishes, and large herbivorous browsing fishes (Choat et al. 2006). Middleton Reef in particular had very high fish biomass, likely driven by a high abundance of top-order piscivores such as the Galapagos shark *Carcharhinus galapagensis* and black cod *Epinephelus daemelii*. Grazers contributed to high biomass in all areas except Norfolk Island. To some degree this is reflected in the benthic communities, as macroalgal cover was highest at Norfolk Island, which had the lowest biomass of grazers. It was not true, however, of Lord Howe Island, where grazers were abundant but macroalgal cover was also high.

Biogeographically, Elizabeth and Middleton Reefs appear to have some connectivity to Lord Howe Island, but less than would be expected given their geographic proximity. In their regional analysis of *Acanthaster* *planci* genetics, Benzie and Stoddart (1992) found that unlike Lord Howe Island, which appeared as an outlier, Elizabeth and Middleton formed a subgroup within the reefs of the Great Barrier Reef (GBR). Furthermore, larval recruitment from external sources, including long-range migrants from the GBR, rather than from Lord Howe Island, serve to replenish Elizabeth and Middleton's coral populations (Noreen et al. 2009). Even in the case of large species such as Galapagos sharks and black cod, which could be expected to move between reefs, the Elizabeth and Middleton Reef populations were found to be genetically distinct from Lord Howe Island (Appleyard and Ward 2007; van Herwerden et al. 2009). Lord Howe Island reef fauna is thought to have relatively low genetic diversity; populations of corals, for example, are genetically isolated and most probably derived from few colonists, especially for brooding corals (Ayre and Hughes 2004; Noreen et al. 2009). Norfolk Island is the most isolated, with expected high levels of self-replenishment and peripheral populations highly vulnerable to extinction (van der Meer et al. 2013).

A more important reason for the difference between Lord Howe Island and Elizabeth and Middleton Reefs, however, is the position of the thermal gradient and the resulting shift from temperate to tropical fauna. Lord Howe Island is at the northern limit for many species with temperate affinities, and these species are absent from Elizabeth and Middleton Reefs. Elizabeth and Middleton Reefs are therefore unique among the temperate CMR Networks, with a more mixed tropical / subtropical fauna.

Differences in fish community structure may also have been driven by underlying reef geomorphology and exposure to prevailing wind and swell. This was certainly reflected in the benthic community composition, with low-lying turfs and encrusting corals dominating the oceanic platform reefs, and a wider variety of sessile biota recorded on the fringing reefs of Lord Howe and Norfolk Islands. Erect and tabular corals, and calcified algae (e.g. *Halimeda* spp.) rather than crustose coralline algae, are often typical of sheltered habitats, as is a high cover of fleshy macroalgae (Roff et al. 2015). Elizabeth and Middleton appear to have the typical low-relief structure of highly exposed reef fronts, with more delicate sessile biota restricted to the lagoons.

Threats and uses of these reefs include recreational fishing – including gamefishing – everywhere except Middleton Reef, scientific research activities and recreational boating, snorkeling and diving, as well as land-based pollution and run-off from the islands (Ceccarelli 2010). Surrounding areas support commercial demersal and pelagic longline fisheries (Commonwealth of Australia 2006); there is also potential for illegal fishing at Middleton Reef (Choat et al. 2006). Potential future threats are those associated with rising sea surface temperatures, range expansion of marine pests, increased storm activity, and petroleum and mineral exploration and mining (Lawrence et al. 2007). A major concern for this Reserve in the future will be climate change induced changes to the East Australian Current, potentially leading to significant changes in larval supply and physical environmental conditions (Lawrence et al. 2007). These reefs remain a stronghold for Galapagos sharks and black cod because their isolation potentially protects them from illegal fishing. However, illegal and unreported fishing is still an issue, and sharks are often killed because they take fishers' catch. Given their globally crucial role in protecting these populations, enforcement of no-take regulations is critically important here.

5 Recommendations

- Undertake regular monitoring of physical characteristics – monthly or seasonal reporting of water quality, nutrients, turbidity, light and other physical parameters that support ecological processes;
- Undertake ongoing ecological monitoring at intervals of 1-3 years to build up a temporal dataset to assess changes relative to data provided by this survey, with results reported using a comprehensive suite of sensitive environmental indicators;
- Include timed swims for more accurate assessment of Galapagos sharks and black cod populations;
- Support involvement of Lord Howe rangers in the monitoring of Elizabeth and Middleton, as they have the opportunity to coincide with suitable weather conditions in which to undertake surveys,
- Examine levels of gene flow between Elizabeth and Middleton and protected areas off the NSW coast, Norfolk Island, New Zealand and Lord Howe Island, to establish possible pathways of stock replenishment,
- Investigate seasonal changes in diversity, abundance and functional groups or productivity of fish and invertebrate communities, to further understand the dynamics of these highly dynamic systems and processes associated with recruitment and stock fluctuations,
- Investigate food webs, including addressing the question of whether large biomasses of sharks were also the norm elsewhere in previous decades, and how a large biomass of sharks influences the reef community.

6 Acknowledgements

The contributions of all divers and vessel crew who contributed their time and expertise to field data collection are gratefully acknowledged: Aaron Ralph, Andrew Green, Antonia Cooper, Ashley Smith, Bill Barker, Brian Busteed, Christo Hastelden, Dave Arthur, German Soler, Ian Kerr, Ian Shaw, Jasmin Knight, Jemina-Stuart-Smith, Jimmy Maher, Simon Talbot, Margo Smith, Mark Green, Martin Filleul, Michelle Crighton, Nick Mooney, Nicola Davis, Sallyann Gudge, Scott Ling, Simon Talbot, Tasman Douglass, Tim Crawford, Tom Davis also collated reef area data used in analyses. Just Berkhout provided database support. Antonia Cooper provided maps.

7 References

Allen GR, Hoese DF, Paxton JR, Randall JE, Russell C, Starck WA, Talbot FH, Whitley GP (1977) Annotated checklist of the fishes of Lord Howe Island. Records of the Australian Museum 30:365–454

Anderson MJ, Gorley RN, Clarke KR (2008) PERMANOVA+ for PRIMER: Guide to software and statistical methods. PRIMER-E, Plymouth, UK

Appleyard S, Ward R (2007) Genetic connectedness between black cod (*E. daemelii*) collections along the NSW coast and the Elizabeth & Middleton Reefs Reserve. Report to the Department of Environment and Water Resources by CSIRO, Canberra

Australian Museum (1992) Reef Biology - A survey of Elizabeth and Middleton Reefs, South Pacific. Kowari 3. The Australian Museum, Sydney - An Australian National Parks and Wildlife Service publication

Ayre DJ, Hughes TP (2004) Climate change, genotypic diversity and gene flow in reef-building corals. Ecology Letters 7:273-278

Benzie JAH, Stoddart JA (1992) Genetic structure of crown-of-thorns starfish (*Acanthaster planci*) in Australia. Marine Biology 112:631-639

Brewer DT, Flynn A, Skewes TD, Corfield J, Pearson B, Alawo J, Young JW (2007) Ecosystems of the East Marine Planning Region. Report to Department of Environment and Water Resources by CSIRO, Cleveland

Ceccarelli DM (2010) Research and monitoring in Australia's Commonwealth Marine Protected Areas: A review. Report to the Department of the Environment, Water, Heritage and the Arts, Canberra

Choat JH, van Herwerden L, Robbins WD, Hobbs JP, Ayling AM (2006) A report on the ecological surveys conducted at Middleton and Elizabeth Reefs, February 2006. Report to the Australian Government Department of Environment and Heritage by James Cook University and Sea Research, Townsville

Clark MR, Rowden AA, Schlacher T, Williams A, Consalvey M, Stocks KI, Rogers AD, O'Hara TD, White M, Shank TM, Hall-Spencer JM (2010) The ecology of seamounts: structure, function, and human impacts. Annual Review of Marine Science 2:253-278

Commonwealth of Australia (2006) Elizabeth and Middleton Reefs National Nature Reserve Management Plan 2006-2013. Director of National Parks, Canberra

Dickson ME (2006) Shore platform development around Lord Howe Island, southwest Pacific. Geomoephology 76:295-315

Edgar GJ, Davey A, Kelly G, Mawbey RB, Parsons K (2010) Biogeographical and ecological context for managing threats to coral and rocky reef communities in the Lord Howe Island Marine Park, south-western Pacific. Aquatic Conservation: Marine and Freshwater Ecosystems 20:378-396

Exon NF, Quilty PG, Lafoy Y, Crawford AJ, Auzende J-M (2004) Miocene volcanic seamounts on northern Lord Howe Rise: lithology, age and origin. Australian Journal of Earth Sciences 51:291-300

Froese R, Pauly D (eds.) (2016) FishBase. World Wide Web electronic publication. www.fishbase.org, version (04/2009).

Keene J, Baker C, Tran M, Potter A (2008) Sedimentology and geomorphology of the East Marine region of Australia - A spatial analysis. Record 2008/10. Geoscience Australia, Canberra

Kennedy DM, Woodroffe CD (2004) Carbonate sediments of Elizabeth and Middleton Reefs close to the southern limits of reef growth in the southwest Pacific. Australian Journal of Earth Sciences 51:847-857

Kennedy DM, Woodroffe CD, Zhao J-X (2007) Reef development at high-latitudes during multiple interglacial cycles: new evidence from Lord Howe Island, Southwestern Pacific. Carbonates and Evaporites 22:24-33

Lawrence M, Ridley J, Lunty K (2007) The impacts and management implications of climate change for the Australian Government's protected areas. Report to the Department of the Environment and Water Resources by Hyder Consulting, Sydney

Lee Long W (2009) Information sheet on Ramsar wetlands - Elizabeth and Middleton Reefs National Nature Reserve. Department of the Environment, Water, Heritage and the Arts, Canberra

McDougall I, Green DH (1988) Research summary - RV Franklin. CSIRO, Hobart

Millar AJK, Kraft GT (1993) Catalogue of marine red algae (Rhodophyta) of New South Wales, including Lord Howe Island, South-western Pacific. Australian Systematic Botany 7:1-46

Noreen AME, Harrison PL, Van Oppen MJH (2009) Genetic diversity and connectivity in a brooding reef coral at the limit of its distribution. Proceedings of the Royal Society B: Biological Sciences 276:3927-3935

Oxley WG, Ayling AM, Cheal AJ, Osborne K (2004) Marine surveys undertaken in the Elizabeth Middleton Reefs Marine National Nature Reserve, December 2003. Report to the Australian Government Department of Environment and Heritage by the Australian Institute of Marine Science and Sea Research, Townsville

Randall JE, Kuiter RH (1982) Three new labrid fishes of the Genus *Coris* from the western Pacific. Pacific Science 36:159-173

Richer de Forges B, Koslow JA, Poore GCB (2000) Diversity and endemismof the benthic seamount fauna in the southwest Pacific. Nature 405:944-947

Roff G, Chollett I, Doropoulos C, Golbuu Y, Steneck RS, Isechal AL, van Woesik R, Mumby PJ (2015) Exposure-driven macroalgal phase shift following catastrophic disturbance on coral reefs. Coral Reefs 34:715-725

Speare P, Cappo M, Rees M, Brownlie J, Oxley WG (2004) Deeper water fish and benthic surveys in the Lord Howe Island Marine Park (Commonwealth Waters): February 2004. Report to the Department of the Environment and Heritage by the Australian Institute of Marine Science, Townsville

Stuart-Smith RD, Edgar GJ, Cooper AT, Gudge SA, Douglass T (2015) Reef biodiversity monitoring at Lord Howe Island 2015. Page 52. The Reef Life Survey Foundation, Hobart, Tasmania

van der Meer MH, Horne JB, Gardner MG, Hobbs JPA, Pratchett M, van Herwerden L (2013) Limited contemporary gene flow and high self-replenishment drives peripheral isolation in an endemic coral reef fish. Ecology and Evolution 3:1653-1666

van Herwerden L, Klanten OS, Choat JH, Jerry DR, Robbins WD (2009) Connectivity of black cod *Epinephelus daemelii* between Elizabeth and Middleton Reefs (as measured by population genetic structure based on microsatellites). Report to the Department of the Environment, Water, Heritage and the Arts by James Cook University, Townsville

Veron JEN, Done TJ (1979) Corals and coral communities of Lord Howe Island. Marine and Freshwater Research 30:203-236

Woodroffe CD, Kennedy DM, Jones BG, Phipps CVG (2004) Geomorphology and Late Quaternary development of Middleton and Elizabeth Reefs. Coral Reefs 23:249-262

Zann LP (2000) The eastern Australian region: a dynamic tropical / temperate biotone. Marine Pollution Bulletin 41:188-20

Appendices

APPENDIX 1 – LIST OF SITES AND SITE DETAILS SURVEYED ACROSS TEMPERATE EAST NETWORK.

Site Code	Site name	Latitude	Longitude	CMR status	Depth	Survey date
EMR1	Lagoon Inner Wreck Middleton Reef	-29.45103	159.06227	Lord Howe II	3	15/01/2013
					3.5	15/01/2013
EMR2	Lagoon 2 Middleton Reef	-29.45683	159.0622	Lord Howe II	2	15/01/2013
EMR3	SW Lagoon Middleton Reef	-29.46451	159.06873	Lord Howe II	2	15/01/2013
EMR4	Wreck 1	-29.44751	159.05391	Lord Howe II	9	15/01/2013
					14	15/01/2013
EMR5	Wreck 2	-29.44269	159.06088	Lord Howe II	5	15/01/2013
					11	15/01/2013
EMR6	North West Horn	-29.44366	159.06796	Lord Howe II	5	15/01/2013
					12	15/01/2013
EMR7	Back reef bommie Middleton Reef	-29.44	159.09315	Lord Howe II	5	15/01/2013
					6	15/01/2013
EMR8	Back Reef 1	-29.44563	159.09369	Lord Howe II	4.5	15/01/2013
					5	15/01/2013
EMR9	Blue Holes W	-29.44278	159.11231	Lord Howe II	5	16/01/2013
					6	16/01/2013
EMR10	Blue Holes N	-29.44246	159.11843	Lord Howe II	3	16/01/2013
					4	16/01/2013
EMR11	Blue Holes 3	-29.44803	159.11499	Lord Howe II	7	16/01/2013
					8	16/01/2013
EMR12	NW outer reef1 Middleton Reef	-29.42234	159.11073	Lord Howe II	10	16/01/2013
					13	16/01/2013
EMR13	NW outer reef2 Middleton Reef	-29.42655	159.12611	Lord Howe II	10	16/01/2013

Site Code	Site name	Latitude	Longitude	CMR status	Depth	Survey date
					13	16/01/2013
EMR14	NW outer reef3 Middleton Reef	-29.43351	159.13542	Lord Howe II	8	16/01/2013
					12	16/01/2013
EMR15	NW inner bommie Middleton Reef	-29.4341	159.09479	Lord Howe II	8	16/01/2013
					10	16/01/2013
EMR16	Wreck 3	-29.45407	159.04857	Lord Howe II	7	16/01/2013
					13	16/01/2013
EMR17	Wreck outer reef4 Middleton Reef	-29.45221	159.04988	Lord Howe II	8	16/01/2013
					11	16/01/2013
EMR18	North Cay Elizabeth Reef	-29.92554	159.0511	Lord Howe IV	5	17/01/2013
					6	17/01/2013
EMR19	Lagoon blue hole Elizabeth Reef	-29.93329	159.0561	Lord Howe IV	5	17/01/2013
					6	17/01/2013
					2.5	15/01/2013
EMR20	Cay Bommie Elizabeth Reef	-29.93192	159.06155	Lord Howe IV	4	17/01/2013
					7	17/01/2013
EMR21	Elizabeth SW	-29.95787	159.02814	Lord Howe IV	9	17/01/2013
					11	17/01/2013
EMR22	Elizabeth SW2	-29.96119	159.03659	Lord Howe IV	9	17/01/2013
					11	17/01/2013
EMR23	Wreck Flank	-29.92823	159.02745	Lord Howe IV	5	17/01/2013
					11	17/01/2013
EMR24	North Point Elizabeth Reef	-29.911	159.0691	Lord Howe IV	6	17/01/2013
					10	17/01/2013
EMR25	Northern Tip	-29.91181	159.08131	Lord Howe IV	8	17/01/2013
					11	17/01/2013
EMR26	Elizabeth Anchorage South	-29.92682	159.04417	Lord Howe IV	6	18/01/2013
					10	18/01/2013
EMR27	Elizabeth Anchorage East	-29.91731	159.06029	Lord Howe IV	5	18/01/2013

Site Code	Site name	Latitude	Longitude	CMR status	Depth	Survey date
					8	18/01/2013
EMR28	Elizabeth Hole	-29.9305	159.06213	Lord Howe IV	5	18/01/2013
					8	18/01/2013
EMR29	NW anchorage Elizabeth Reef	-29.91656	159.05681	Lord Howe IV	15	18/01/2013
					16	18/01/2013
					2.5	15/01/2013
EMR30	NE Wreck Elizabeth Reef	-29.92296	159.09285	Lord Howe IV	8	18/01/2013
					14	18/01/2013
EMR31	NE Inlet Elizabeth Reef	-29.93369	159.09714	Lord Howe IV	4	18/01/2013
					13	18/01/2013
EMR32	East Elizabeth North	-29.95612	159.12732	Lord Howe IV	7	18/01/2013
					10	18/01/2013
EMR33	South Elizabeth Reef	-29.95796	159.12759	Lord Howe IV	7	18/01/2013
					12	18/01/2013
LHI36	Stephen's Hole	-31.53225	159.05403	Lord Howe Reference	1.5	21/02/2012
						16/02/2014
						21/02/2016
					2	21/02/2012
						16/02/2014
						21/02/2016
LHI39	Yellow Rock Slope	-31.52794	159.04575	Lord Howe Reference	6	17/02/2014
					6.5	8/02/2009
					7	8/02/2009
						25/02/2012
						17/02/2014
					8	17/02/2014
						22/02/2016
					10	8/02/2009

Site Code	Site name	Latitude	Longitude	CMR status	Depth	Survey date
						25/02/2012
						17/02/2014
						22/02/2016
					10.1	8/02/2009
					12	8/02/2009
					15	8/02/2009
LHI41	Stephen's Hole NE	-31.5332	159.05212	Lord Howe Reference	2	19/02/2014
						21/02/2016
					2.1	28/02/2012
						21/02/2016
					2.7	8/02/2010
					2.8	8/02/2010
					3	8/02/2010
						28/02/2012
						19/02/2014
						21/02/2016
					3.1	21/02/2016
LHI42	Stephen's Hole SE	-31.5332	159.05212	Lord Howe Reference	2	29/02/2012
						19/02/2014
					3	19/02/2014
					3.5	29/02/2012
					4	8/02/2010
					11	9/02/2010
LHI50	Le Merthe Hole	-31.52979	159.05013	Lord Howe Reference	3	27/02/2012
					3.1	27/02/2012
					4	27/02/2012
						21/02/2014

Site Code	Site name	Latitude	Longitude	CMR status	Depth	Survey date
					5	21/02/2014
					11	27/02/2012
						21/02/2014
LHI7	Erscotts Passage South	-31.55193	159.06731	Lord Howe Reference	5	27/02/2014
					6	9/02/2010
						27/02/2012
						16/02/2016
					7	27/02/2014
					8	6/02/2009
						9/02/2010
						27/02/2012
						27/02/2014
						16/02/2016
LHI8	Erscotts Passage South	-31.55193	159.06731	Lord Howe Reference	2	6/02/2009
						9/02/2010
						27/02/2012
						16/02/2016
					5	6/02/2009
						9/02/2010
						27/02/2012
						16/02/2016
					6	6/02/2009
						27/02/2014
					7	6/02/2009
NI1	The Crack Nepean Island	-29.07193	167.96139	Norfolk VI	10	1/02/2009
						9/01/2013
					10.5	9/01/2013
					11	1/02/2009

Site Code	Site name	Latitude	Longitude	CMR status	Depth	Survey date
						9/01/2013
NI10	Slaughterhouse Bay	-29.05875	167.95792	Norfolk VI	1.3	5/02/2009
					1.4	5/02/2009
					1.9	5/02/2009
					2	5/02/2009
					2.1	5/02/2009
					2.5	5/02/2009
NI12	Lone Pine	-29.06139	167.96269	Norfolk VI	1.5	6/02/2009
NI13	Emily Bay Salthouse	-29.060078	167.961658	Norfolk VI	2.5	6/02/2009
NI14	Sydney Bay Anchorage	-29.06172	167.95021	Norfolk VI	8	10/01/2013
					12	10/01/2013
NI2	Kawa 200m west Kingston Jetty	-29.05856	167.95106	Norfolk VI	6	1/02/2009
						10/01/2013
					6.5	1/02/2009
						10/01/2013
NI3	Kawa 2 Shark Gully	-28.9996	167.91903	Norfolk VI	8	2/02/2009
					8.5	2/02/2009
					11	2/02/2009
NI4	Kawa 3 Mullins Bay	-28.99774	167.92	Norfolk VI	7	2/02/2009
					7.5	2/02/2009
					10	2/02/2009
NI5	King Jim	-28.9995	167.93832	Norfolk VI	9.5	3/02/2009
					10.5	3/02/2009
					14	3/02/2009
NI6	Anson Bay	-29.01054	167.91784	Norfolk VI	7.5	3/02/2009
					8	3/02/2009
					8.5	3/02/2009
NI7	Shark Point Phillip Island	-29.11731	167.94171	Norfolk VI	12	4/02/2009
						10/01/2013

Site Code	Site name	Latitude	Longitude	CMR status	Depth	Survey date
					14	4/02/2009
						10/01/2013
NI8	The Hoof, Phillip Island	-29.11641	167.96309	Norfolk VI	11	4/02/2009
						10/01/2013
					11.1	4/02/2009
					12	4/02/2009
						10/01/2013
NI9	Emily Bay	-29.06141	167.96094	Norfolk VI	1.5	4/02/2009
					1.7	4/02/2009

APPENDIX 2 – FREQUENCY AND TOTAL BIOMASS OF FISH SPECIES RECORDED AT ALL SITES IN DIFFERENT CMRS USING METHOD 1 (PER 500 M2), EXCLUDING UNIDENTIFIED SPECIES, BUT INCLUDING BLENNIIDAE, GOBIIDAE, MURAENIDAE AND TRYPTERIGIIDAE.

Species	Transects				Abundance				Biomass (kg)			
	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI
Abudefduf bengalensis	0	0	2	0	0	0	7	0	0	0	0.6	0
Abudefduf sexfasciatus	0	0	3	3	0	0	56	3	0	0	3.8	0.1
Abudefduf sordidus	0	0	0	3	0	0	0	9	0	0	0	2.6
Abudefduf vaigiensis	0	0	4	0	0	0	16	0	0	0	0.9	0
Acanthistius cinctus	0	0	2	12	0	0	2	16	0	0	0.7	4.9
Acanthurus albipectoralis	1	3	0	0	6	26	0	0	0.4	6.5	0	0
Acanthurus dussumieri	25	11	1	3	123	70	1	5	68	48.7	0.1	0.2
Acanthurus nigrofuscus	7	6	0	0	15	17	0	0	1.1	0.7	0	0
Acanthurus nigroris	1	0	0	0	46	0	0	0	3.4	0	0	0
Acanthurus olivaceus	3	0	0	0	4	0	0	0	1.5	0	0	0
Acanthurus thompsoni	1	0	0	0	1	0	0	0	0.3	0	0	0
Amblyglyphidodon curacao	0	1	0	0	0	2	0	0	0	0	0	0
Amblygobius phalaena	0	2	1	0	0	2	1	0	0	0	0	0
Amphichaetodon howensis	0	0	2	3	0	0	2	4	0	0	0	0.5
Amphiprion latezonatus	0	0	0	20	0	0	0	69	0	0	0	2.9
Amphiprion mccullochi	6	7	27	0	19	22	197	0	0.1	0.3	4.9	0
Anampses caeruleopunctatus	2	1	6	0	4	1	8	0	0.2	0.1	1.8	0
Anampses elegans	14	17	55	22	140	48	547	100	4.2	0.9	28	6.8
Anampses femininus	22	18	3	0	107	75	14	0	1	0.7	0.3	0
Anampses geographicus	2	1	6	0	2	1	14	0	0	0	0.5	0
Anampses neoguinaicus	13	31	25	0	49	111	156	0	0.6	1.4	5.7	0
Aplodactylus etheridgii	0	0	8	45	0	0	9	83	0	0	4.2	22.5
Apogon capricornis	1	0	0	0	15	0	0	0	0.2	0	0	0

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Apogon doederleini	3	1	11	6	5015	1	20	46	1.7	0	0.9	1.6
Apogon flavus	0	0	41	5	0	0	926	28	0	0	28.6	0.6
Apogon norfolcensis	8	14	99	51	16	395	2406	1084	0.8	8.7	129.1	53.8
Aprion virescens	2	3	0	0	2	3	0	0	3.9	1.8	0	0
Asterropteryx semipunctata	0	1	0	0	0	2	0	0	0	0	0	0
Atypichthys latus	0	0	8	36	0	0	17	263	0	0	2.6	15.4
Aulostomus chinensis	4	8	1	2	7	11	1	2	1.3	2.6	0	0.4
Bathystethus cultratus	0	0	0	1	0	0	0	25	0	0	0	5.5
Bodianus axillaris	4	3	0	0	5	4	0	0	0.2	0.2	0	0
Bodianus perditio	4	1	0	0	5	1	0	0	0	0	0	0
Bothus mancus	0	0	1	0	0	0	1	0	0	0	0	0
Cantherhines dumerilii	0	3	1	0	0	3	2	0	0	1.5	0.8	0
Cantherhines pardalis	1	4	0	1	1	6	0	1	0.1	0.3	0	0.3
Canthigaster axiologus	2	3	0	0	2	5	0	0	0	0.1	0	0
Canthigaster callisterna	0	3	5	0	0	7	6	0	0	0	0.1	0
Canthigaster janthinoptera	1	2	2	0	1	2	2	0	0	0	0	0
Canthigaster valentini	18	15	15	0	24	30	27	0	0.2	0.3	1.1	0
Carangoides orthogrammus	1	0	0	1	2	0	0	2	1	0	0	0.7
Caranx lugubris	3	0	0	0	4	0	0	0	4.7	0	0	0
Caranx sexfasciatus	1	0	0	0	2	0	0	0	1.6	0	0	0
Carcharhinus galapagensis	27	19	13	2	84	29	20	5	1349.8	304.4	397.9	494.1
Centropyge bispinosa	4	2	0	0	9	4	0	0	0.2	0.1	0	0
Centropyge flavissima	0	1	0	0	0	1	0	0	0	0	0	0
Centropyge tibicen	15	22	19	0	71	74	22	0	1.3	1.5	1.7	0
Centropyge vrolikii	0	1	0	0	0	1	0	0	0	0	0	0
Cephalopholis argus	8	8	0	0	11	9	0	0	5.9	4.3	0	0
Cephalopholis miniata	2	0	0	0	5	0	0	0	2.6	0	0	0
Chaetodon auriga	27	20	8	9	67	44	9	28	7.1	4.1	0.8	3.4
Chaetodon baronessa	0	1	0	0	0	1	0	0	0	0.1	0	0

Species	Transects				Abundance				Biomass (kg)			
	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI
Chaetodon citrinellus	13	14	3	0	31	23	3	0	1.2	0.7	0.1	0
Chaetodon ephippium	1	0	0	0	4	0	0	0	0.4	0	0	0
Chaetodon flavirostris	17	15	21	2	37	31	78	9	6.8	5.8	11.5	2.8
Chaetodon guentheri	1	1	2	0	1	2	4	0	0.1	0.1	0.2	0
Chaetodon kleinii	2	3	0	0	2	4	0	0	0.1	0.1	0	0
Chaetodon lineolatus	2	4	1	0	8	7	1	0	2.1	0.9	0.3	0
Chaetodon lunula	0	1	0	0	0	2	0	0	0	0.2	0	0
Chaetodon lunulatus	11	11	1	0	37	57	1	0	2.1	2.8	0.1	0
Chaetodon melannotus	3	5	33	0	3	7	189	0	0.3	0.4	22.4	0
Chaetodon mertensii	27	19	2	0	61	35	2	0	4.6	2.3	0.1	0
Chaetodon ornatissimus	0	1	0	0	0	3	0	0	0	0.2	0	0
Chaetodon pelewensis	14	23	16	0	30	45	26	0	1.6	2.1	1	0
Chaetodon plebeius	18	17	16	10	38	38	35	23	1.8	1.7	1.5	1.9
Chaetodon rainfordi	0	0	1	0	0	0	2	0	0	0	0.2	0
Chaetodon speculum	1	1	2	0	2	1	2	0	0.1	0.1	0.2	0
Chaetodon tricinctus	23	28	96	11	64	92	524	51	9.6	9.8	71	6.5
Chaetodon trifascialis	8	21	4	0	24	52	7	0	1.3	2.9	0.4	0
Chaetodon ulietensis	4	2	0	0	5	3	0	0	0.6	0.2	0	0
Chaetodon unimaculatus	2	1	0	0	4	1	0	0	0.4	0.1	0	0
Chaetodon vagabundus	2	0	1	1	3	0	1	1	0.3	0	0	0.1
Chaetodontoplus conspicillatus	5	4	0	0	6	5	0	0	1.9	0.9	0	0
Cheilinus chlorourus	0	1	1	0	0	1	1	0	0	0.2	0.1	0
Cheilinus fasciatus	0	3	0	0	0	3	0	0	0	0.5	0	0
Cheilinus trilobatus	1	2	0	0	1	2	0	0	0.4	0.3	0	0
Cheilio inermis	0	0	4	0	0	0	6	0	0	0	0.9	0
Cheilodactylus ephippium	3	2	46	43	4	4	194	121	2.4	2.2	120.1	43.7
Cheilodactylus francisi	23	13	2	0	55	23	2	0	19.6	8.2	0.2	0
Cheilodipterus macrodon	0	3	0	0	0	10	0	0	0	0.4	0	0
Cheilodipterus quinquelineatus	0	2	2	0	0	3	22	0	0	0	0	0

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Chilomycterus affinis	0	0	0	1	0	0	0	1	0	0	0	2.3
Chlorurus microrhinos	9	16	0	0	47	42	0	0	39.5	45.2	0	0
Chlorurus sordidus	36	40	32	0	1460	821	388	0	82	45.8	88.7	0
Chromis agilis	1	2	0	0	1	2	0	0	0	0	0	0
Chromis atripectoralis	5	2	36	0	98	2	738	0	0.4	0	18	0
Chromis atripes	1	0	0	0	2	0	0	0	0	0	0	0
Chromis chrysura	7	0	0	0	73	0	0	0	0.7	0	0	0
Chromis flavomaculata	17	15	6	1	817	1722	29	6	9.1	14.5	0.5	0.2
Chromis fumea	0	0	0	11	0	0	0	2417	0	0	0	6.6
Chromis hypsilepis	36	36	61	54	8762	14180	3827	14826	70.8	116.7	138.2	179.2
Chromis margaritifer	8	5	0	0	17	8	0	0	0	0	0	0
Chromis vanderbilti	5	10	1	0	14	204	1	0	0	0.7	0	0
Chromis viridis	1	0	2	0	4	0	51	0	0	0	0.3	0
Chrysiptera notialis	49	44	66	59	5718	5463	1786	6998	20.5	25.8	14.5	39.9
Cirrhilabrus laboutei	3	2	0	0	7	13	0	0	0	0.2	0	0
Cirrhilabrus punctatus	6	7	2	0	96	25	7	0	0.3	0.2	0	0
Cirrhitichthys falco	7	5	0	0	8	7	0	0	0.1	0	0	0
Cirripectes alboapicalis	0	0	9	3	0	0	31	4	0	0	0.3	0.2
Cirripectes castaneus	0	1	0	0	0	3	0	0	0	0	0	0
Cirripectes chelomatus	0	0	2	0	0	0	2	0	0	0	0	0
Cirripectes filamentosus	0	0	1	0	0	0	1	0	0	0	0	0
Coris aygula	3	3	0	0	24	4	0	0	5	0.5	0	0
Coris bulbifrons	39	33	70	8	169	85	206	12	48.4	29.1	105.9	0.9
Coris dorsomacula	5	1	0	0	15	1	0	0	0.3	0	0	0
Coris picta	9	3	29	1	82	13	74	1	0.3	0	1.5	0
Coris sandeyeri	0	0	0	46	0	0	0	494	0	0	0	6.4
Crossosalarias macrospilus	2	1	0	0	2	1	0	0	0	0	0	0
Ctenochaetus striatus	4	1	0	0	6	1	0	0	0.5	0.1	0	0
Cypho purpurascens	0	1	0	0	0	1	0	0	0	0	0	0

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Dascyllus aruanus	15	12	0	0	260	720	0	0	2	5.2	0	0
Dascyllus reticulatus	1	8	1	0	3	22	1	0	0	0.2	0	0
Dascyllus trimaculatus	8	1	1	1	22	2	1	4	0.3	0	0	0.4
Diodon holocanthus	0	0	1	0	0	0	1	0	0	0	0.4	0
Diodon hystrix	1	1	2	4	1	1	2	4	1.3	1.9	2.5	4.6
Echeneis naucrates	0	3	0	0	0	3	0	0	0	0.2	0	0
Echidna nebulosa	1	0	0	0	1	0	0	0	0.1	0	0	0
Ecsenius fourmanoiri	7	6	0	0	21	9	0	0	0	0	0	0
Enchelycore ramosa	0	0	1	1	0	0	1	1	0	0	0.9	0.3
Enneapterygius rufopileus	3	3	13	8	5	4	322	42	0	0	0.2	0.1
Epibulus insidiator	0	2	2	0	0	2	2	0	0	0.1	0.3	0
Epinephelus cyanopodus	0	1	1	0	0	1	1	0	0	1.7	0.8	0
Epinephelus daemelii	10	19	1	1	12	25	1	2	106.7	195.9	4.2	3.7
Epinephelus fasciatus	10	6	0	1	16	8	0	1	5.5	2.6	0	0.2
Epinephelus maculatus	0	1	0	0	0	1	0	0	0	0.2	0	0
Epinephelus merra	1	0	0	0	1	0	0	0	0.4	0	0	0
Epinephelus octofasciatus	0	0	0	1	0	0	0	1	0	0	0	1.6
Epinephelus polyphekadion	0	1	0	0	0	1	0	0	0	0.6	0	0
Epinephelus rivulatus	0	0	0	1	0	0	0	1	0	0	0	0.3
Eviota fasciola	19	5	0	0	179	44	0	0	0.1	0	0	0
Eviota hoesei	0	0	1	6	0	0	2	62	0	0	0	0.5
Exallias brevis	0	1	0	0	0	1	0	0	0	0	0	0
Fistularia commersonii	3	2	2	0	4	2	2	0	1.1	0.6	0	0
Forcipiger flavissimus	5	3	0	0	15	5	0	0	0.6	0.1	0	0
Girella cyanea	4	5	37	4	18	62	216	16	11.5	30.3	81.7	5.8
Gnatholepis anjerensis	0	0	1	0	0	0	6	0	0	0	0.2	0
Gnatholepis cauerensis	6	2	1	0	13	3	1	0	0	0	0	0
Gomphosus varius	17	24	59	6	49	45	344	43	0.5	0.6	7.6	0.5
Grammistes sexlineatus	2	1	0	0	2	1	0	0	0	0.1	0	0

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Gymnocranius euanus	4	3	0	0	6	5	0	0	4.8	3.7	0	0
Gymnothorax annasona	1	2	0	0	1	2	0	0	0.4	0.4	0	0
Gymnothorax eurostus	0	4	2	0	0	4	2	0	0	0.3	0.4	0
Gymnothorax nubilus	0	0	0	3	0	0	0	3	0	0	0	2.1
Gymnothorax porphyreus	0	0	0	1	0	0	0	1	0	0	0	0
Gymnothorax prionodon	0	0	1	0	0	0	1	0	0	0	0.2	0
Gymnothorax thrysoideus	0	1	0	0	0	1	0	0	0	0	0	0
Halichoeres margaritaceus	0	0	1	0	0	0	1	0	0	0	0	0
Halichoeres marginatus	0	0	1	0	0	0	1	0	0	0	0.1	0
Halichoeres nebulosus	1	0	0	0	1	0	0	0	0	0	0	0
Halichoeres trimaculatus	10	1	7	1	63	4	60	3	0.7	0.1	1.2	0.7
Helcogramma chica	1	0	0	0	1	0	0	0	0	0	0	0
Hemigymnus fasciatus	3	3	2	0	3	3	2	0	0.2	0.2	0.7	0
Hemigymnus melapterus	3	11	17	0	7	40	35	0	1	17.7	5.1	0
Heniochus chrysostomus	1	0	0	0	1	0	0	0	0.2	0	0	0
Heniochus monoceros	0	0	0	1	0	0	0	1	0	0	0	0.4
Hologymnosus annulatus	0	0	1	0	0	0	1	0	0	0	0.4	0
Hologymnosus doliatus	2	0	0	0	2	0	0	0	0	0	0	0
Hyporhamphus affinis	0	0	0	1	0	0	0	1	0	0	0	0
Kyphosus bigibbus	1	0	34	0	2	0	303	0	1.1	0	323.8	0
Kyphosus sectatrix	35	31	25	5	782	612	630	38	525.7	381.7	470.2	10.6
Kyphosus sydneyanus	0	0	3	2	0	0	43	104	0	0	38.6	117.4
Kyphosus vaigiensis	0	0	0	1	0	0	0	26	0	0	0	8.2
Labracoglossa nitida	11	7	4	3	221	3693	73	84	28.4	630.5	4.7	0.3
Labrichthys unilineatus	1	5	18	0	1	8	90	0	0	0.1	2.6	0
Labroides bicolor	7	11	12	0	8	14	12	0	0.1	0.1	0.3	0
Labroides dimidiatus	35	31	82	0	107	79	226	0	0.4	0.3	4.1	0
Labropsis australis	3	7	0	0	5	25	0	0	0	0.3	0	0
Lethrinus nebulosus	0	0	2	0	0	0	5	0	0	0	12.1	0

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Limnichthys fasciatus	0	0	4	0	0	0	408	0	0	0	0.1	0
Lutjanus bohar	3	8	0	0	6	46	0	0	2.7	26.5	0	0
Lutjanus kasmira	0	2	0	0	0	259	0	0	0	58.4	0	0
Macropharyngodon meleagris	2	1	13	0	3	1	54	0	0	0	2	0
Macropharyngodon negrosensis	1	0	0	0	1	0	0	0	0	0	0	0
Malacanthus brevirostris	0	1	0	0	0	2	0	0	0	0.2	0	0
Meiacanthus atrodorsalis	0	0	1	0	0	0	1	0	0	0	0	0
Meiacanthus phaeus	6	9	0	0	13	14	0	0	0.1	0.1	0	0
Microcanthus strigatus	0	0	1	0	0	0	1	0	0	0	0.3	0
Monotaxis grandoculis	3	1	0	0	3	2	0	0	0.2	0.5	0	0
Mugil cephalus	0	0	0	2	0	0	0	3	0	0	0	2.2
Mulloidichthys flavolineatus	0	0	11	0	0	0	51	0	0	0	8.7	0
Mulloidichthys vanicolensis	0	0	1	0	0	0	6	0	0	0	0.4	0
Myrichthys maculosus	0	1	0	0	0	1	0	0	0	0	0	0
Myripristis kuntee	0	2	0	0	0	14	0	0	0	4.7	0	0
Myripristis murdjan	0	1	0	0	0	1	0	0	0	0.1	0	0
Naso brevirostris	0	1	5	0	0	1	135	0	0	0.1	64.1	0
Naso hexacanthus	0	1	0	0	0	4	0	0	0	0.4	0	0
Naso lituratus	1	2	0	0	8	2	0	0	3.1	0.2	0	0
Naso tonganus	3	2	0	0	6	6	0	0	5.3	3	0	0
Naso unicornis	25	20	2	1	111	44	2	3	31.7	17.8	0.4	2.5
Naso vlamingii	0	0	1	0	0	0	1	0	0	0	0.7	0
Nemateleotris magnifica	1	0	0	0	2	0	0	0	0	0	0	0
Neoglyphidodon polyacanthus	21	15	119	29	254	283	4583	729	2.7	7	225.3	28.1
Neoniphon sammara	4	0	1	0	10	0	1	0	3.2	0	0.1	0
Notocirrhitus splendens	0	1	3	20	0	1	4	30	0	0.2	0.7	5.8
Notolabrus gymnogenis	0	0	1	0	0	0	1	0	0	0	0	0
Notolabrus inscriptus	0	0	30	64	0	0	54	199	0	0	8.9	48.7
Notolabrus tetricus	0	0	0	1	0	0	0	58	0	0	0	0.5

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Ostorhinchus angustatus	1	0	0	0	1	0	0	0	0	0	0	0
Ostracion cubicus	2	2	3	1	2	2	3	1	1	0.9	1	0.1
Oxycheilinus bimaculatus	2	0	0	0	2	0	0	0	0	0	0	0
Oxycheilinus digrammus	1	3	1	0	1	4	1	0	0.1	0.3	0	0
Oxycheilinus orientalis	1	1	0	0	1	1	0	0	0	0	0	0
Oxycheilinus unifasciatus	1	1	0	0	1	1	0	0	0.1	0.1	0	0
Oxymonacanthus longirostris	1	1	1	0	2	2	1	0	0	0	0	0
Parablennius serratolineatus	0	0	0	40	0	0	0	230	0	0	0	0.6
Paracaesio xanthura	3	10	1	0	327	80	8	0	0.7	7.7	0.3	0
Paracanthurus hepatus	2	0	0	0	2	0	0	0	0.2	0	0	0
Paracirrhites arcatus	0	6	0	0	0	6	0	0	0	0.1	0	0
Paracirrhites forsteri	0	4	0	0	0	5	0	0	0	0.3	0	0
Parapercis australis	5	0	0	0	9	0	0	0	0	0	0	0
Parapercis queenslandica	0	2	0	0	0	2	0	0	0	0.1	0	0
Parapriacanthus ransonneti	0	0	1	0	0	0	20	0	0	0	0.1	0
Parma alboscapularis	0	0	1	1	0	0	1	1	0	0	0.3	0.2
Parma polylepis	15	12	127	80	44	14	686	839	18.1	3.7	198.2	216.1
Parupeneus barberinus	0	0	1	0	0	0	1	0	0	0	0.1	0
Parupeneus ciliatus	1	0	4	1	1	0	9	2	0.7	0	2.4	0.4
Parupeneus cyclostomus	3	1	0	0	4	2	0	0	1	0.3	0	0
Parupeneus multifasciatus	10	8	2	0	28	14	4	0	2	1.2	0	0
Parupeneus pleurostigma	5	4	0	0	12	13	0	0	2.6	2.1	0	0
Parupeneus spilurus	12	8	24	1	71	28	113	2	16.7	9	8.1	0.6
Pempheris analis	0	0	31	3	0	0	322	31	0	0	17	0.3
Pempheris oualensis	0	0	3	0	0	0	11	0	0	0	0.4	0
Pervagor alternans	0	1	0	0	0	1	0	0	0	0	0	0
Pervagor janthinosoma	0	2	1	0	0	2	1	0	0	0	0	0
Plagiotremus rhinorhynchos	3	0	7	1	9	0	13	1	0	0	0.1	0
Plagiotremus tapeinosoma	20	12	42	71	71	30	106	441	0.1	0	0.5	1.9

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Plectorhinchus picus	10	10	12	0	39	16	13	0	16.7	7.7	33.8	0
Plectroglyphidodon dickii	2	10	18	1	2	23	50	3	0	0.2	1.4	0.2
Plectroglyphidodon johnstonianus	15	31	37	2	75	172	92	16	0.9	1.3	10.5	0.3
Plotosus lineatus	2	0	2	0	110	0	220	0	0.2	0	20.7	0
Pomacentrus australis	0	0	1	0	0	0	4	0	0	0	0	0
Pomacentrus coelestis	1	1	12	2	1	1	95	4	0	0	0.4	0
Pomacentrus vaiuli	2	0	0	0	3	0	0	0	0	0	0	0
Prionurus maculatus	14	14	50	3	227	165	1970	5	139.5	126.7	1933.9	1.3
Prionurus microlepidotus	0	0	1	0	0	0	1	0	0	0	0	0
Pseudanthias pictilis	2	0	0	0	75	0	0	0	0.4	0	0	0
Pseudanthias squamipinnis	2	0	0	1	54	0	0	2	0.2	0	0	0
Pseudocaranx georgianus	15	8	5	4	250	232	122	27	57.3	78.9	37.6	6.6
Pseudocheilinus hexataenia	5	3	13	0	6	3	18	0	0	0	0.1	0
Pseudochromis fuscus	1	7	0	0	1	9	0	0	0	0	0	0
Pseudocoris yamashiroi	1	0	0	0	125	0	0	0	0.5	0	0	0
Pseudolabrus luculentus	65	62	127	80	3059	1895	3215	4201	37.4	38.1	87.9	66.9
Pteragogus cryptus	0	1	0	0	0	1	0	0	0	0	0	0
Ptereleotris evides	1	1	3	1	4	1	6	2	0	0	0.3	0.1
Pterois volitans	3	0	1	0	3	0	1	0	1.2	0	0.8	0
Salarias fasciatus	3	3	0	0	4	3	0	0	0	0	0	0
Sarda australis	0	0	0	2	0	0	0	2	0	0	0	0.6
Sargocentron diadema	0	1	0	0	0	1	0	0	0	0.1	0	0
Scarus altipinnis	29	21	8	0	99	71	44	0	85	53.8	34.8	0
Scarus chameleon	16	7	4	0	141	18	126	0	17.3	2.3	15.3	0
Scarus dimidiatus	0	1	0	0	0	1	0	0	0	0.3	0	0
Scarus frenatus	9	15	6	0	15	29	8	0	9	15.1	5.1	0
Scarus ghobban	11	9	7	0	18	17	67	0	6.7	2.4	24.1	0
Scarus globiceps	9	3	5	0	11	4	6	0	3.2	0.6	2.3	0

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Scarus longipinnis	0	1	0	0	0	4	0	0	0	0.8	0	0
Scarus niger	4	4	0	0	6	8	0	0	1.1	0.8	0	0
Scarus oviceps	0	1	0	0	0	1	0	0	0	0.5	0	0
Scarus psittacus	9	14	1	0	32	29	1	0	6.4	5.1	0.4	0
Scarus rivulatus	0	0	4	0	0	0	14	0	0	0	3.6	0
Scarus schlegeli	17	10	1	0	73	65	2	0	16.9	10.5	1.3	0
Scolopsis bilineata	0	1	1	0	0	1	1	0	0	0.1	0	0
Scorpaena cardinalis	0	0	2	0	0	0	3	0	0	0	1.2	0
Scorpaena cookii	0	1	1	2	0	1	2	2	0	0.5	2.5	1.9
Seriola lalandi	9	7	0	7	16	15	0	22	39	14.8	0	18.9
Seriola rivoliana	1	1	1	0	1	1	1	0	0.9	1.8	0.4	0
Siganus argenteus	0	1	0	0	0	2	0	0	0	0.5	0	0
Stanulus talboti	0	0	2	0	0	0	40	0	0	0	0.3	0
Stegastes fasciolatus	3	18	105	33	5	301	1836	112	0.1	10	105.9	9.4
Stegastes gascoynei	58	60	126	50	3636	3009	2031	341	85.3	64.7	106.4	20.4
Stethojulis bandanensis	32	35	63	5	98	97	267	143	0.9	0.9	4.4	1.5
Stethojulis interrupta	6	0	4	0	15	0	13	0	0.1	0	0.5	0
Stethojulis strigiventer	0	0	6	0	0	0	39	0	0	0	1.2	0
Suezichthys arquatus	2	0	0	0	2	0	0	0	0	0	0	0
Sufflamen bursa	1	0	0	0	1	0	0	0	0.2	0	0	0
Sufflamen chrysopterum	19	6	0	0	36	10	0	0	7	2.4	0	0
Sufflamen fraenatum	24	20	1	0	37	31	1	0	0	0	0.3	0
Synodus binotatus	0	0	1	0	0	0	1	0	0	0	0	0
Synodus dermatogenys	5	3	0	0	7	3	0	0	0.2	0.1	0	0
Synodus variegatus	1	3	6	0	1	3	9	0	0	0.1	1.5	0
Taeniamia leai	0	0	0	28	0	0	0	1927	0	0	0	29.9
Taeniura meyeni	1	0	0	2	1	0	0	2	463.6	0	0	519.9
Thalassoma amblycephalum	19	18	34	3	514	409	367	10	6.4	10.2	8.4	0.3
Thalassoma hardwicke	9	7	52	2	36	24	565	2	0.4	0.2	14	0

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI	Biomass (kg) Mid II	Eliz IV	LHI	NI
Thalassoma jansenii	11	11	1	0	21	24	1	0	0	0	0	0
Thalassoma lunare	29	21	77	10	360	312	1166	80	6.7	6.9	52	2.5
Thalassoma lutescens	63	54	99	28	1463	1521	1044	95	26.3	31.9	38.7	5.8
Thalassoma nigrofasciatum	0	0	11	0	0	0	20	0	0	0	1	0
Thalassoma purpureum	1	0	24	1	1	0	32	1	0.3	0	7.5	0.3
Thalassoma quinquevittatum	1	1	0	0	1	1	0	0	0	0	0	0
Thalassoma trilobatum	0	0	1	0	0	0	1	0	0	0	0.3	0
Trachypoma macracanthus	0	0	9	31	0	0	11	54	0	0	1.1	8.2
Variola louti	3	3	0	0	3	3	0	0	3.1	6.2	0	0
Zanclus cornutus	6	2	7	1	12	3	8	3	5.1	2.1	2.7	1.7
Zebrasoma scopas	6	6	4	0	30	102	5	0	1.9	6.5	0.5	0
Zebrasoma velifer	3	4	0	0	6	31	0	0	1.9	1.8	0	0

APPENDIX 3 – FREQUENCY AND TOTAL ABUNDANCE OF INVERTEBRATE SPECIES RECORDED AT ALL SITES IN DIFFERENT CMRS (PER 100 M2), EXCLUDING UNIDENTIFIED FAMILIES.

Species	Transects				Abundance			
	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI
Calcinus imperialis	1	0	4	0	1	0	11	0
Daira perlata	0	0	2	0	0	0	2	0
Dardanus lagopodes	0	0	1	0	0	0	2	0
Dardanus megistos	0	0	2	0	0	0	3	0
Dardanus spp.	0	0	1	0	0	0	1	0
Panulirus longipes	0	2	5	0	0	7	7	0
Percnon planissimum	0	0	1	0	0	0	1	0
Petrolisthes spp.	0	0	0	7	0	0	0	17
Pseudoliomera spp.	0	0	1	0	0	0	1	0
Schizophrys aspera	0	0	1	0	0	0	1	0
Scyllarides haanii	0	0	1	0	0	0	1	0
Stenopus hispidus	1	0	5	1	2	0	9	2
Thalamita spp.	0	0	1	11	0	0	2	36
Trapezia septata	0	0	2	0	0	0	6	0
Trapezia spp.	0	0	1	0	0	0	1	0
Acanthaster planci	1	0	1	0	1	0	1	0
Actinopyga miliaris	14	3	0	0	39	5	0	0
Astrostole rodolphi	0	0	1	9	0	0	1	10
Bohadschia argus	3	0	0	0	14	0	0	0
Cenolia glebosus	0	0	4	5	0	0	9	9
Centrostephanus rodgersii	3	1	60	31	6	2	3836	1363
Colobometra perspinosa	1	0	0	0	1	0	0	0
Comanthus spp.	0	1	3	0	0	1	6	0
Comanthus wahlbergi	0	0	0	5	0	0	0	14
Culcita novaeguineae	1	2	0	0	1	2	0	0
Diadema savignyi	21	9	43	8	626	116	179	12

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI
Echinometra mathaei	22	22	21	7	655	203	43	11
Echinoneus cyclostomus	0	0	1	0	0	0	1	0
Echinostrephus spp.	26	25	37	13	7371	1425	571	64
Echinothrix calamaris	1	1	0	0	1	2	0	0
Heliocidaris tuberculata	0	0	52	40	0	0	8911	5187
Holothuria atra	19	8	0	0	122	12	0	0
Holothuria difficilis	0	0	0	2	0	0	0	22
Holothuria edulis	7	5	0	0	120	17	0	0
Holothuria fuscocinerea	4	2	0	5	13	2	0	7
Holothuria hilla	4	0	0	6	9	0	0	21
Holothuria impatiens	3	1	1	0	5	1	1	0
Holothuria leucospilota	2	2	6	1	3	2	7	1
Holothuria nobilis	13	6	3	0	28	7	3	0
Leiaster leachii	0	0	0	1	0	0	0	1
Linckia guildingi	6	1	2	0	7	1	2	0
Linckia laevigata	3	1	0	0	37	1	0	0
Linckia multifora	16	1	0	1	131	1	0	1
Mithrodia clavigera	1	0	0	0	1	0	0	0
Ophidiaster confertus	19	26	27	19	286	493	119	40
Prionocidaris callista	0	1	0	0	0	1	0	0
Stichopus hermanni	0	1	0	0	0	1	0	0
Stichopus horrens	0	1	0	0	0	1	0	0
Tripneustes gratilla	0	0	10	36	0	0	55	282
Aplysia dactylomela	2	0	2	1	5	0	3	4
Aplysia juliana	0	0	1	0	0	0	1	0
Aplysia spp.	0	0	1	0	0	0	2	0
Astraea spp.	3	4	0	0	4	11	0	0
Atagema intecta	0	0	0	1	0	0	0	1
Berthellina citrina	0	0	0	2	0	0	0	2

Species	Transects				Abundance			
	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI
Cabestana spengleri	0	0	0	1	0	0	0	1
Chelidonura inornata	0	0	3	1	0	0	4	3
Chromodoris spp.	0	0	0	1	0	0	0	1
Conus capitaneus	1	0	0	0	1	0	0	0
Conus miles	0	1	0	0	0	2	0	0
Conus rattus	1	0	0	0	1	0	0	0
Conus spp.	2	2	0	0	8	3	0	0
Coriocella nigra	0	4	1	0	0	5	1	0
Cypraea tigris	1	0	0	0	1	0	0	0
Doriprismatica atromarginata	1	0	0	0	1	0	0	0
Drupella cornus	0	0	4	0	0	0	8	0
Drupella spp.	0	0	2	0	0	0	5	0
Elysia spp.	0	0	0	23	0	0	0	357
Goniobranchus collingwoodi	0	0	0	1	0	0	0	2
Gymnodoris okinawae	0	0	0	1	0	0	0	1
Halgerda willeyi	0	0	0	3	0	0	0	3
Hexabranchus sanguineus	0	2	0	0	0	2	0	0
Hypselodoris spp.	0	0	0	2	0	0	0	2
Miamira flavicostata	0	0	0	1	0	0	0	1
Miamira sinuata	0	0	0	1	0	0	0	1
Micromelo undatus	0	0	1	0	0	0	1	0
Nudibranchia spp.	2	3	0	2	3	3	0	3
Octopus tetricus	0	2	0	0	0	2	0	0
Phyllidia spp.	0	0	2	0	0	0	2	0
Phyllidiella pustulosa	0	0	3	1	0	0	3	2
Phyllidiella spp.	0	0	0	4	0	0	0	7
Pleurobranchus spp.	0	0	0	1	0	0	0	2
Ranella australasia	0	0	0	1	0	0	0	1
Roboastra gracilis	0	0	0	4	0	0	0	6

Species	Transects				Abundance			
	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI
Roboastra luteolineata	0	0	1	0	0	0	1	0
Sagaminopteron ornatum	0	0	0	1	0	0	0	1
Siraius immonda	0	0	0	1	0	0	0	1
Stylocheilus longicauda [?]	3	0	0	0	76	0	0	0
Thuridilla albopustulosa	0	0	0	1	0	0	0	2
Thuridilla neona	0	0	1	0	0	0	1	0
Thuridilla splendens	0	0	1	0	0	0	1	0
Thuridilla undula	0	0	0	1	0	0	0	1
Tridacna derasa	0	3	0	0	0	5	0	0
Tridacna maxima	4	2	4	0	5	3	4	0
Turbo cepoides	2	3	16	0	2	5	19	0

APPENDIX 4 – FREQUENCY AND TOTAL ABUNDANCE OF CRYPTIC FISH SPECIES RECORDED AT ALL SITES IN DIFFERENT CMRS (PER 100 M2), EXCLUDING UNIDENTIFIED FAMILIES.

Species	Transects				Abundance			
	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI
Acanthistius cinctus	0	0	1	4	0	0	1	5
Amblygobius phalaena	0	1	1	0	0	2	37	0
Aplodactylus etheridgii	0	0	1	0	0	0	1	0
Apogon capricornis	0	1	0	0	0	1	0	0
Apogon doederleini	5	3	8	0	53	20	32	0
Apogon flavus	0	0	10	0	0	0	102	0
Apogon norfolcensis	3	8	33	4	3	282	565	8
Aptychotrema rostrata	0	0	0	1	0	0	0	1
Atrosalarias holomelas	0	1	0	0	0	6	0	0
Canthigaster bennetti	0	0	1	0	0	0	1	0
Canthigaster callisterna	0	0	2	0	0	0	2	0
Cheilodipterus macrodon	0	1	2	0	0	10	2	0
Cheilodipterus quinquelineatus	1	2	1	0	1	20	1	0
Cirrhitichthys falco	12	6	0	0	33	12	0	0
Cirripectes alboapicalis	0	0	4	1	0	0	18	1
Cirripectes castaneus	0	1	0	0	0	1	0	0
Cirripectes chelomatus	0	1	4	0	0	1	6	0
Cirripectes filamentosus	0	0	2	0	0	0	3	0
Cirripectes spp.	0	0	3	0	0	0	25	0
Cirripectes stigmaticus	0	0	2	0	0	0	3	0
Crossosalarias macrospilus	2	2	0	0	2	3	0	0
Cypho purpurascens	2	0	0	0	2	0	0	0
Echidna nebulosa	0	1	0	0	0	1	0	0
Ecsenius fourmanoiri	19	16	1	0	85	41	1	0
Enchelycore ramosa	0	0	2	2	0	0	2	2

Species	Transects Mid II	Eliz IV	LHI	NI	Abundance Mid II	Eliz IV	LHI	NI
Enneapterygius howensis	0	0	12	0	0	0	217	0
Enneapterygius rufopileus	2	6	47	32	8	12	2377	802
Eviota fasciola	22	24	0	0	510	335	0	0
Eviota hoesei	0	0	13	24	0	0	396	898
Eviota spp.	4	1	12	1	82	7	205	8
Exallias brevis	0	3	0	0	0	3	0	0
Fusigobius neophytus	3	4	0	0	9	19	0	0
Gnatholepis anjerensis	0	0	4	0	0	0	81	0
Gnatholepis cauerensis	8	5	2	0	26	16	7	0
Gobiodon quinquestrigatus	0	1	0	0	0	9	0	0
Grammistes sexlineatus	0	1	0	0	0	1	0	0
Gymnothorax annasona	1	2	3	5	1	2	3	5
Gymnothorax eurostus	4	4	8	9	4	5	9	12
Gymnothorax meleagris	0	0	1	1	0	0	1	1
Gymnothorax nubilus	0	0	0	9	0	0	0	14
Gymnothorax porphyreus	0	0	1	0	0	0	1	0
Gymnothorax spp.	0	0	1	2	0	0	1	2
Gymnothorax thrysoideus	1	0	0	0	1	0	0	0
Helcogramma chica	0	4	0	0	0	14	0	0
Istigobius decoratus	0	0	1	0	0	0	1	0
Istigobius spp.	0	0	1	0	0	0	17	0
Limnichthys fasciatus	0	0	6	0	0	0	450	0
Myripristis kuntee	0	1	0	0	0	9	0	0
Notocirrhitus splendens	0	1	2	7	0	1	2	13
Ostorhinchus angustatus	1	0	0	0	1	0	0	0
Parablennius serratolineatus	0	0	0	27	0	0	0	836
Paracirrhites arcatus	0	1	0	0	0	1	0	0
Paracirrhites forsteri	0	1	0	0	0	1	0	0
Paragobiodon echinocephalus	1	1	0	0	3	5	0	0

Species	Transects				Abundance			
	Mid II	Eliz IV	LHI	NI	Mid II	Eliz IV	LHI	NI
Pempheris analis	0	0	6	0	0	0	41	0
Plagiotremus rhinorhynchos	3	0	1	0	3	0	2	0
Plagiotremus tapeinosoma	1	0	4	0	1	0	5	0
Plesiops insularis	0	0	1	1	0	0	1	1
Pseudochromis fuscus	1	1	0	0	1	1	0	0
Pterois volitans	0	1	0	0	0	1	0	0
Salarias fasciatus	1	2	0	0	5	5	0	0
Saurida gracilis	4	0	0	0	4	0	0	0
Scorpaena cardinalis	0	0	5	0	0	0	5	0
Scorpaena cookii	0	0	13	6	0	0	15	9
Scorpaenid spp.	1	1	0	0	1	1	0	0
Scorpaenopsis spp.	0	1	0	0	0	1	0	0
Stanulus talboti	1	2	7	0	13	2	239	0
Synodus binotatus	0	0	1	0	0	0	1	0
Synodus dermatogenys	6	2	1	0	10	2	1	0
Synodus spp.	0	0	1	0	0	0	1	0
Synodus variegatus	4	4	9	0	5	4	9	0
Taeniamia leai	0	0	0	5	0	0	0	15
Trachypoma macracanthus	0	1	24	27	0	1	42	71
Trinorfolkia clarkei	0	0	0	1	0	0	0	2