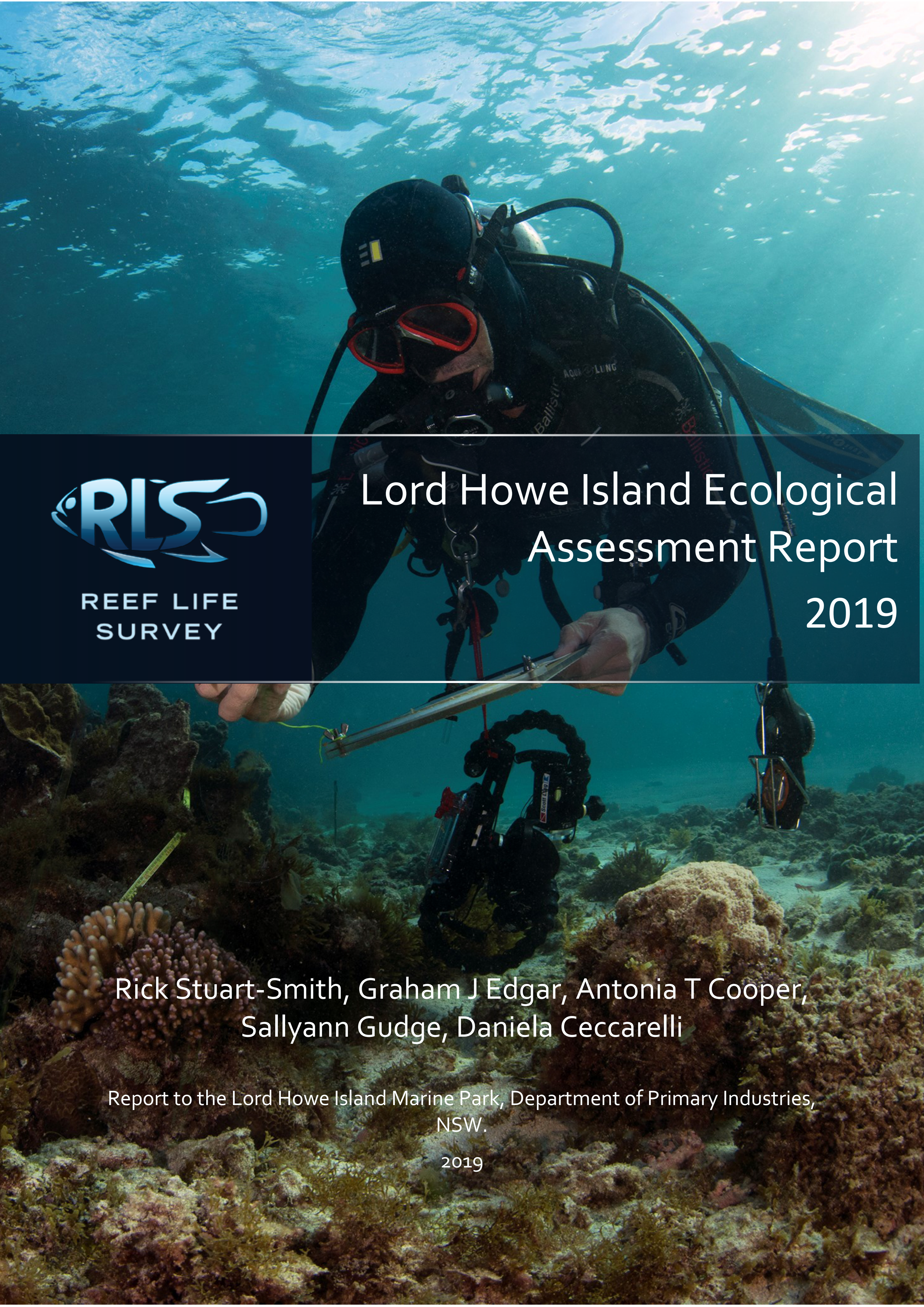

REEF LIFE
SURVEY

Lord Howe Island Ecological Assessment Report
2019

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Report to the Lord Howe Island Marine Park, Department of Primary Industries, NSW.

2019

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Images

Cover: Diver surveying LHI lagoon, Rick Stuart-Smith; Inside cover: *Pterois volitans*, Antonia Cooper; Contents page: Diver surveying Comet’s Hole, Antonia Cooper; Page vi: Gower Island, Antonia Cooper; Page viii: *Genicanthus semicinctus*, Rick Stuart-Smith; Page x: *Enchelycore ramosa*, Rick Stuart-Smith; Page 7, *Plotosus lineatus*, Antonia Cooper; Page 38: *Coris Bulbifrons*, Rick Stuart-Smith.

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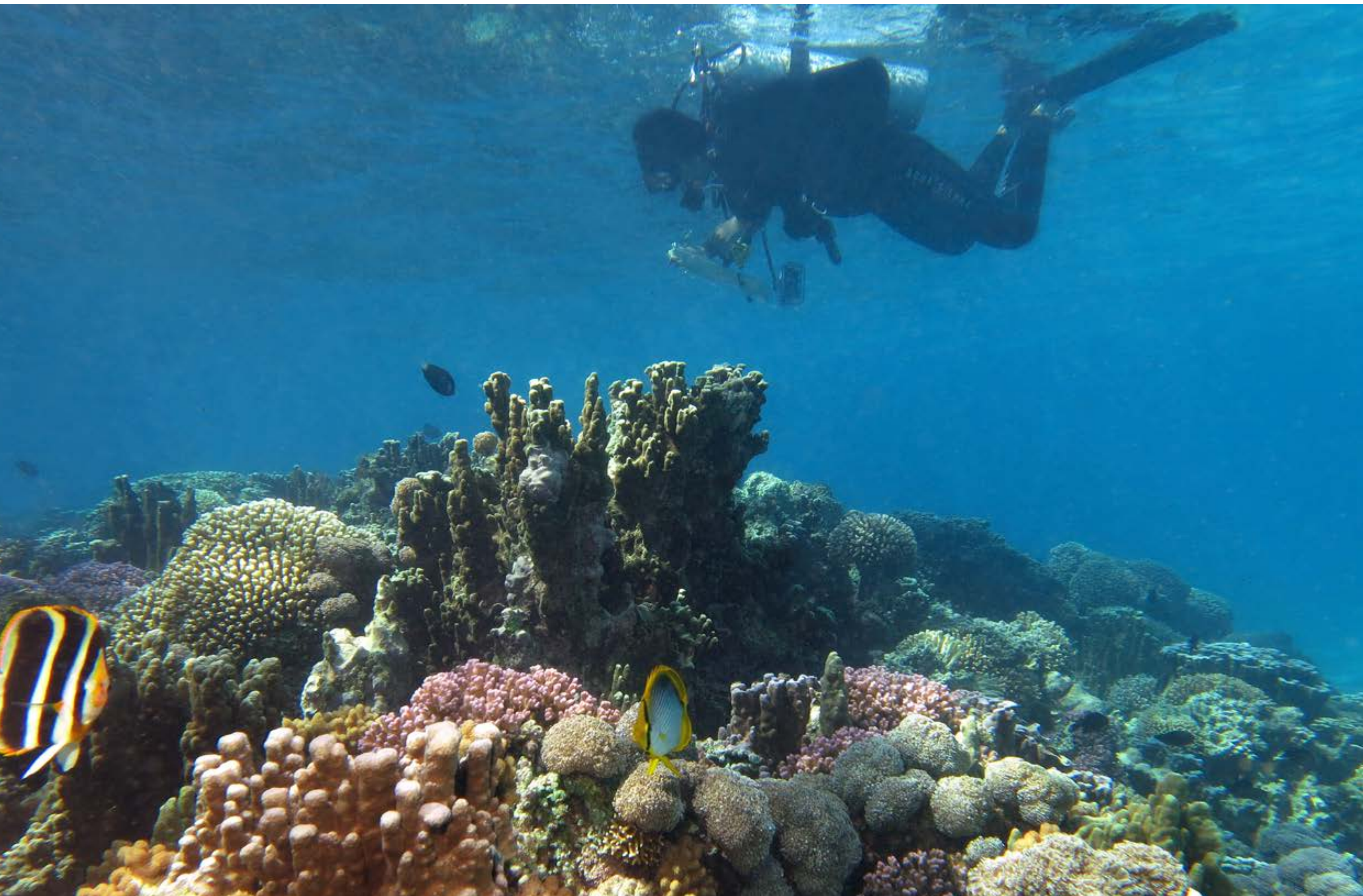

Figures

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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
LHI	Lord Howe Island
CTI	Community Temperature Index

Executive summary

This report provides an overview of condition and trends in shallow reef biodiversity within the Lord Howe Island Marine Park (LHIMP) obtained from Reef Life Survey monitoring in 2018. Data from 121 transects at 45 sites in 2016 and 108 transects at 51 sites in 2018 were analysed in combination with the monitoring data collected since 2006. These include data from reef fish surveys that cover all reef species, size and biomass information, finer-scale targeted surveys of large mobile invertebrates and cryptic fishes closely associated with the substratum, and analysis of percentage cover of coral, macroalgae and other sessile organisms from photoquadrats. These surveys form part of a globally-standardised methodology, and allow assessment of linkages between different taxonomic components and trophic groups surveyed at the same place and time.

Particular aims of analyses reported here, as requested by the LHIMP management team, were investigation of trends in sea urchin and bluefish densities, and recovery from the 2010 coral bleaching event. The key findings of these analyses are:

- The outbreak of the sea urchin *Tripneustes gratilla* at the Admiralty Islands and wave-exposed sites subsided in 2014, and this species has remained largely absent in 2016 and 2018. However, the macroalgal cover that was reduced at sites affected by the outbreak remains low.

- Sea urchin densities in the Algal Holes area (mostly *Heliocidaris tuberculata*) declined from 2010 to 2014, but began to increase again in 2018.

- Macroalgae appear to be declining at the Algal Holes sites; between 2014 and 2018, macroalgal cover was reduced from ~84% to 60%. This may be linked to a return of sea urchins that had boomed in 2010, and then declined in 2014 and 2016, and/or environmental factors. The risk of extinction of endemic macroalgae is of concern.

- Bluefish (*Girella cyanea*) densities remained as low in 2018 as they were in 2010 and 2014. Doubleheader wrasse (*Coris bulbifrons*) were higher in HPZs than SZs in 2018, but populations showed no clear trends. Both species remain a potential concern, even within SZs.

- Coral cover at sites affected by the substantial bleaching event in 2010 appears to be recovering; the ca. 15% loss of live corals at ‘Horseshoe Reef’ (site LHI40) is now a 8% loss (51.6% total coral cover in 2010, 36.3% in 2014, 43.5% in 2018). North Bay, however, has shown continued decline in live hard corals. No large changes in invertebrate and fish communities have been observed at coral loss sites. Sylphs Hole experienced a substantial recovery, from ~2% live coral cover in 2010, to 29% in 2016 and 43% in 2018.

Other important results identified in these analyses include:

- The decline in fish biomass in sanctuary zones (SZs) between 2012 and 2014 indicated a loss of a substantial 'reserve effect' that had built up to 2012. This decline has not continued, and biomass has remained stable in 2016 and 2018, suggesting a return of effective compliance and recovering populations; it is likely to take time for biomass to build again. Fish community structure was generally very stable throughout all survey years.

- A cyclical trend in planktivores has become clearer with two additional surveys; this trend mirrors the overall trends in fish biomass. Planktivores contribute at least one-third of the total fish biomass, and these temporal dynamics suggest that cycles in plankton delivery to the island or planktivore recruitment success may be important in shaping overall fish productivity.

- A sharp decline in Galapagos sharks (*Carcharhinus galapagensis*) was evident inside and outside SZs from 2014 to 2018.

- Kingfish (*Seriola lalandi*) declined in frequency between 2014 and 2018, from being observed in 9.4% of transect blocks to 6.5% of transect blocks. Black cod (*Epinephelus daemelii*) frequency remained the same (1.9%) between 2014 and 2018.

- There was evidence of a return of drummer biomass (*Kyphosus* species) in both HPZ and SZ sites. This trend was less clear in other important herbivorous fishes in SZs, including sawtail surgeonfish (*Prionurus maculatus*) and bluefish.

- There was a general decline in *Caulerpa* cover in all habitats, back to the sparse cover originally recorded in earlier survey years.

RECOMMENDATIONS

These findings collectively suggest possible ecological instabilities associated with interactions between herbivorous fishes, *Caulerpa* and coral cover, and between sea urchins and endemic macroalgae, as well as potential issues with fishing pressure (including inside sanctuary zones). The management recommendations arising from the results of monitoring to date are summarised as follows:

1. The previous recommendation of creating a sanctuary zone that includes the unique Algal Holes community type is affirmed. Further to this, additional transects should be added to the two monitoring sites at the Algal Holes to more closely track urchin densities at this location. Two additional transects would be most feasible initially. In the event that ongoing monitoring identifies further substantial increases in urchin densities, then it may be necessary to consider urchin removal as a management option.
2. Additional research should investigate other (not urchin-related) potential causes of macroalgae loss, especially environmental factors associated with nutrient input to the region, and with climate change.
3. Targeted research should be considered to better understand the population dynamics of bluefish and doubleheader wrasse.
4. Mortality and population dynamics of Galapagos shark, including identification of prey, should be investigated.
5. Monitoring should be continued through the long-term on a two-yearly basis, or more frequently.
6. Additional surveys of impacted and reference sites should be undertaken following exceptional events (e.g. oil spills, extreme bleaching).
7. With the exception of suggested modification of boundaries associated with the Algal Holes, the boundaries of sanctuary zones should remain stable through the long term.
8. Potential illegal fishing activities should be investigated, and consideration given to an education campaign to raise awareness in the local community of ecological and conservation importance of bluefish and doubleheader, in particular. Populations of these species appear to have declined to ~1/3 of their 2006 biomass and, regardless of the ultimate cause of declines, the local fishing community has an important role to play in bringing these species back to densities needed to play their natural roles in the ecosystem.

1 Introduction

Monitoring of Lord Howe Island shallow rocky and coral reef systems using visual census methods was initiated in 2006, when the consulting company Aquenal Pty Ltd was engaged by the NSW Marine Parks Authority to establish monitoring protocols and sites across the Lord Howe Island Marine Park (LHIMP). The monitoring design was established in such a way to (a) assess the suitability of the zoning scheme, (b) assess the performance of sanctuary zones with respect to protection and recovery of ecological processes and conservation values, and (c) provide general condition reporting for shallow reef biodiversity around LHI.

Following the surveys in 2006 and 2008 in which Aquenal staff, LHIMP and LHI Board staff established sites and protocols, Reef Life Survey (RLS) took over Aquenal's role in 2009, leading the shallow reef monitoring in collaboration with the LHIMP. RLS uses the same methodology, but surveys are undertaken by a small team of volunteer divers who contribute their time and expertise at no cost. RLS dive teams have resurveyed existing long-term monitoring sites and established new sites in two-week survey expeditions in 2009, 2010, 2012, 2014, 2016 and 2018, with current arrangements to continue this every two years, as support from the LHIMP, LHI Board and RLS Foundation allows.

RLS represents a highly cost-effective means to collect data on shallow reef biodiversity that is rich in detail, while also maintaining a high standard of data quality and allowing LHI monitoring to fit within the context of a globally-standardised system. RLS is also used by other Marine Protected Area (MPA) management teams, state management agencies and the Australian Government, and contributes to national State of the Environment reporting. The RLS global dataset has provided numerous scientific insights and valuable direction for management, particularly for marine protected areas. For example, the management insights provided by Edgar et al. (2014) could only be obtained through collection of data over a global scale, covering MPAs of varying design and with varying levels of protection from fishing. Thus, by engaging RLS, LHIMP monitoring can contribute to broader management, research and public engagement outcomes, in addition to assessing local condition and trends and obtaining data to feed into the five-yearly management cycle.

The primary aims of this report are to provide an overview of condition and trends in shallow reef biodiversity at LHI. Specific priorities requested under the contract with the LHIMP were to include recent data from 2016 and 2018, investigation of patterns in urchin and bluefish densities, and the extent of ecosystem recovery from the 2010 coral bleaching event.

2 Methods

Following the field survey activities covered in the previous report (Stuart-Smith et al. 2015c), Reef Life Survey teams undertook monitoring over 2 week periods in 2016 (February 15th to 24th) and 2018 (from February 11th to March 4th). The teams consisted of experienced trained RLS volunteers from the mainland and local LHIMP and LHI Board staff. The teams surveyed 121 transects at 45 sites in 2016 and 108 transects at 51 sites in 2018, taking the total number of transects surveyed during LHI UVC reef monitoring from 2006 to 2018 to 785. All sites with years surveyed are shown in Table 1 and the distribution of sites in Figure 1.

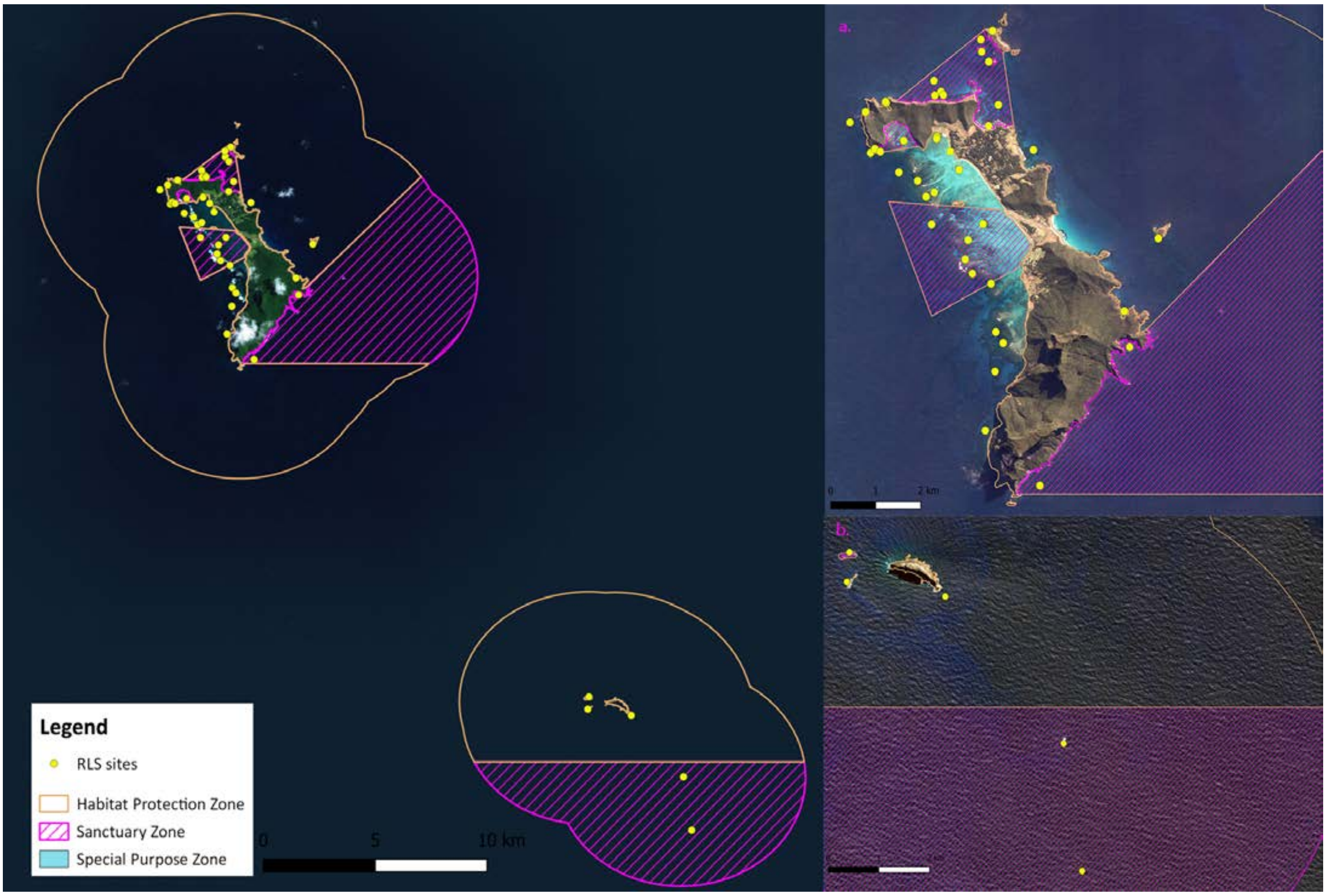

Figure 1. Map of reef monitoring sites and zones in the Lord Howe Island Marine Park (a.), including Balls Pyramid and SE Rock (b.).

Table 1. Site details and years surveyed. Site codes shown in bold represent the core sites that were included in time series analyses. Some of the previous ‘double sites’ have now been combined into a single site, with all transects considered together in analyses. These are identified in the ‘New Site Code’ column.

Original Site Code	New Site Code	Site Name	Zone	Latitude	Longitude	2006	2008	2009	2010	2012	2014	2016	2018
LHI1	**LHI1**	North Bommie	HPZ	**-31.52379**	159.03913	Y	Y	Y	Y	Y	Y	Y	Y
LHI2	**LHI2**	North Bommie 2	HPZ	**-31.52352**	159.04141	Y	Y	Y	Y	Y	Y	Y	Y
LHI3	**LHI3**	Erscotts Blind Passage	**SZ**	**-31.54974**	159.06295	Y	Y	Y	Y	Y	Y	Y	Y
LHI4		Erscotts Blind Passage	**SZ**	**-31.54974**	159.06295	Y	Y	Y	Y	Y	Y	Y	Y
LHI5	**LHI5**	Comets Hole	**SZ**	**-31.53908**	159.06543	Y	Y	Y	Y	Y	Y	Y	Y
LHI6		Comets Hole	**SZ**	**-31.53908**	159.06543	Y	Y	Y	Y	Y	Y	Y	Y
LHI7	**LHI7**	Erscotts Passage South	**HPZ**	**-31.55193**	159.06731	Y	Y	Y	Y	Y	Y	Y	Y
LHI8		Erscotts Passage South	**HPZ**	**-31.55193**	159.06731	Y	Y	Y	Y	Y	Y	Y	Y
LHI9	**LHI9**	Ruperts Reef	**SZ**	**-31.49935**	159.06494	Y	Y	Y	Y	Y	Y	Y	Y
LHI10	**LHI10**	Noddy Island	**SZ**	**-31.50197**	159.06513	Y	Y	Y	Y	Y	Y	Y	Y
LHI11	**LHI11**	Little Slope	**HPZ**	**-31.58355**	159.06596	Y	Y	Y	Y	Y	Y	Y	Y
LHI12		Little Slope	**HPZ**	**-31.58355**	159.06596	Y	Y	Y	Y	Y	Y	Y	Y
LHI13	**LHI13**	Little Island	**HPZ**	**-31.57082**	159.06824	Y	Y	Y	Y	Y	Y	Y	Y
LHI14	**LHI14**	Algal Hole North	**HPZ**	**-31.56235**	159.06843	Y	Y	Y	Y	Y	Y	Y	Y
LHI15	**LHI15**	Algal Hole South	**HPZ**	**-31.56469**	159.07015	Y	Y	Y	Y	Y	Y	Y	Y
LHI16	**LHI16**	Rabbit Island	**SZ**	**-31.53915**	159.05341	Y	Y	Y	Y	Y	Y	Y	Y
LHI17	**LHI17**	North Head inside	**SZ**	**-31.52289**	159.04014	Y	Y	Y	Y	Y	Y	Y	Y
LHI18	**LHI18**	Keyhole North	**HPZ**	**-31.49747**	159.06767	Y	Y	Y	Y	Y	Y	Y	Y
LHI19	**LHI19**	Sugarloaf West	**SZ**	**-31.50414**	159.06679	Y	Y	Y	Y	Y	Y	Y	Y
LHI20		Sugarloaf West	**SZ**	**-31.50414**	159.06679	Y	Y	Y	Y	Y		Y	Y
LHI21	**LHI21**	Big Slope	**SZ**	**-31.5954**	159.07875	Y	Y		Y	Y	Y	Y	Y
LHI22	**LHI22**	Georges Bay	**SZ**	**-31.56557**	159.09975	Y	Y		Y	Y	Y	Y	Y
LHI23	**LHI23**	Boat Harbour NW	**HPZ**	**-31.55782**	159.09852	Y	Y		Y	Y	Y		Y
LHI24	**LHI24**	Phillip Rock North	**HPZ**	**-31.51721**	159.0343	Y	Y		Y	Y	Y	Y	Y
LHI25		Phillip Rock South	**HPZ**	**-31.51721**	159.0343	Y	Y		Y	Y	Y	Y	Y
LHI26	**LHI26**	Sylphs Hole	**SZ**	**-31.520319**	159.054661	Y	Y	Y	Y	Y	Y	Y	Y
LHI27		Sylphs Hole	**SZ**	**-31.5207**	159.05458	Y	Y	Y	Y	Y	Y	Y	Y
LHI28	**LHI28**	Old Gulch N	**HPZ**	**-31.51293**	159.0428	Y	Y	Y	Y	Y	Y	Y	Y
LHI29		Old Gulch	**HPZ**	**-31.51293**	159.0428	Y	Y	Y	Y	Y	Y	Y	Y
LHI30	**LHI30**	Malabar	**SZ**	**-31.51059**	159.0556	Y	Y	Y	Y	Y	Y	Y	Y
LHI31	**LHI31**	Wheatsheaf	**HPZ**	**-31.75636**	159.23627	Y	Y		Y	Y	Y	Y	Y
LHI32	**LHI32**	Observatory	**SZ**	**-31.75067**	159.23682	Y	Y		Y	Y	Y	Y	Y
LHI33	**LHI33**	Signal Point	**HPZ**	**-31.52736**	159.05983	Y	Y		Y	Y	Y	Y	Y
LHI34	**LHI34**	Neds Beach	**SZ**	**-31.5134**	159.06903		Y		Y	Y	Y	Y	Y
LHI35	**LHI35**	Middle Beach	**HPZ**	**-31.5231**	159.07723		Y		Y	Y	Y	Y	Y
LHI36	**LHI36**	Stephen's Hole	**HPZ**	**-31.53225**	159.05403		Y			Y	Y	Y	Y
LHI37	LHI37	Malabar 2	**SZ**	**-31.5113**	159.05615		Y			Y		Y	Y
LHI38	LHI38	North Bay 2	**SZ**	**-31.52113**	159.04688		Y	Y	Y	Y	Y	Y	Y
LHI39	LHI39	Yellow Rock Slope	**HPZ**	**-31.52794**	159.04575			Y		Y	Y	Y	Y
LHI40	LHI40	Horseshoe Reef	**HPZ**	**-31.54252**	159.06194			Y	Y	Y	Y	Y	Y

Original Site Code	New Site Code	Site Name	Zone	Latitude	Longitude	2006	2008	2009	2010	2012	2014	2016	2018
LHI41	LHI41	Stephen's Hole NE	**HPZ**	**-31.5332**	159.05212				Y	Y	Y	Y	Y
LHI42		Stephen's Hole SE	**HPZ**	**-31.5332**	159.05212				Y	Y	Y		Y
LHI43	LHI43	South East Rock	**SZ**	**-31.7875**	159.28145				Y	Y			Y
LHI44	LHI44	Old Gultch West	**HPZ**	**-31.51272**	159.04262				Y	Y		Y	Y
LHI45	LHI45	Malabar Deep	**SZ**	**-31.50823**	159.05395				Y		Y		
LHI46	LHI46	Mutton Bird Island	**HPZ**	**-31.542183**	159.10646				Y	Y	Y		Y
LHI47	LHI47	Neds Beach	**SZ**	**-31.51793**	159.06675				Y	Y	Y	Y	Y
LHI48	LHI48	Malabar West	**SZ**	**-31.51139**	159.05416				Y	Y	Y	Y	Y
LHI49	LHI49	Erscotts Hole	**HPZ**	**-31.54666**	159.06128				Y	Y	Y	Y	Y
LHI50	LHI50	Le Merthe Hole	**HPZ**	**-31.52979**	159.05013					Y	Y		Y
LHI51	LHI51	Pyramid South Bommie	**HPZ**	**-31.759199**	159.256792					Y			
LHI52	LHI52	Sunken Rock	**SZ**	**-31.81209**	159.2853								Y
LHI53	LHI53	Pot O' Gold	**HPZ**	**-31.523464**	159.057773								Y
LHI54	LHI54	New Gulch	**HPZ**	**-31.51492**	159.03793							Y	

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.

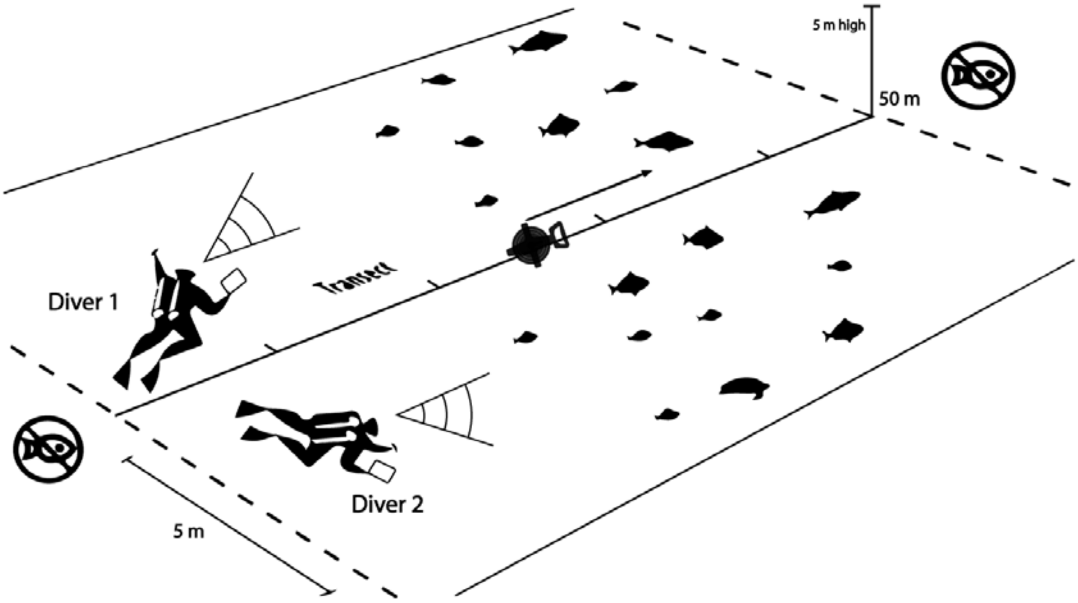

Figure 2. Stylised representation of method 1 survey technique

MACROALGAL AND SESSILE INVERTEBRATE SURVEYS (METHOD 2 AND METHOD 3)

Large macro-invertebrates (molluscs, echinoderms and crustaceans > 2.5 cm) and cryptic fishes were surveyed along the same transect lines set for fish surveys. Divers swam along the bottom, up each side of the transect line, recording all mobile macroinvertebrates and cryptic fishes on the reef surface within 1 m of the line. This required brushing aside the algal canopy when present and searching among corals, along crevices and undercuts, but without moving rocks. Cryptic fishes include those from a set of pre-defined families that are inconspicuous and closely associated with the seabed (and are thus likely to be overlooked during general fish surveys). The global list of families defined as cryptic for the purpose of RLS surveys can be found in the online methods manual.

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.

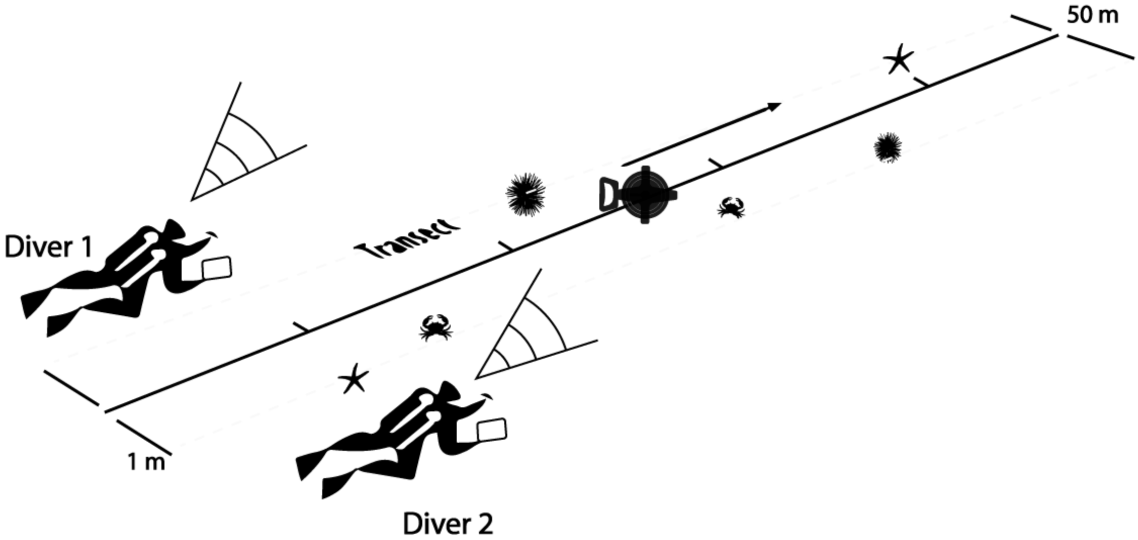

Figure 3. Stylised representation of method 2 survey technique

STATISTICAL ANALYSES

Given new sites have been added through time as a result of larger teams and favourable weather conditions in recent years (see Table 1), these were carefully considered for analyses. Only sites analysed in the previous reports (those repeated across most or all years, shown in bold in Table 1) were included in time series analyses, as initial data exploration suggested that the inclusion of new sites introduced new site biases that interfered with comparisons between years. Data on fish densities and size structure were used to estimate species-specific biomass values, which were also aggregated to transect level biomass, or that associated with subsets of the fish community, such as trophic groups or large fishes only. Species' length-weight relationships provided in Fishbase were used, following the same calculation as for previous papers and reports (Edgar et al. 2009, Edgar and Stuart-Smith 2009, Edgar et al. 2011). Note that length-weight coefficients used for some species here may be different to those used for previous reports, where additional information has been obtained in the intervening period. This means biomass values may differ very slightly from those reported previously, if compared directly between reports. Biomass values for past years (2006-2010) used in analyses for this report were calculated using consistent coefficients however, specifically for this report, so values reported here are directly comparable across all years (i.e. plots and analyses presented here are not biased by different biomass calculations).

Multivariate analyses

All analyses which used multivariate community structure data as the response variable were based on Bray-Curtis similarity of log(x+1) transformed abundance or biomass data. Preliminary data exploration and patterns shown in previous reports showed clear divisions in community types between sites based on wave exposure (Edgar et al. 2010), separating sites located in the lagoon, Algal Holes area, Balls Pyramid area and other locations. Thus, to visualise general trends through time in fish and invertebrate community structure in relation to zonation, sites were aggregated within sanctuary and habitat protection zones in each of these locations/habitat types. Principal components analysis (PCO) was then used to represent the data in two dimensions.

PERMANOVA was used to test for significant differences in fish and invertebrate community structure, with fixed factors 'zone' (2 levels; sanctuary zone, habitat protection zone) and 'year' (2 levels; 2006, 2018). The year x zone interaction was the factor of interest for assessing responses to closure from fishing. Photoquadrat data were analysed as for the fish and invertebrate multivariate data. Due to the recent development of a standardised protocol for classification of higher taxa and functional groups in marine imagery, CATAMI (Althaus et al. 2015), there were some differences in the classification of some of the non-species level categories from photoquadrats processed for the more recent data (2012 to 2018) from those previously analysed. Thus, those groups which were inconsistently classified between years were omitted from multivariate analyses. These included dead coral, turf and filamentous algal categories.

Univariate metrics

Biodiversity data were also summarised in important univariate metrics. For fishes these included trophic group biomass, large fish biomass, species richness and biomass of some of the key species. All univariate metrics are listed in Tables 2 and 3 of the results, and were also analysed by PERMANOVA, based on Euclidean distance matrices. All metrics except species richness were log transformed.

Community temperature Index

The community temperature index (CTI) has recently been applied as a way to measure biodiversity change specifically related to changing sea temperatures (Cheung et al. 2013, Stuart-Smith et al. 2015a). Although not previously included in monitoring programs for shallow reef biodiversity, the necessary thermal distribution information for reef species is now available to allow the CTI to be calculated for RLS monitoring at any location. Given the coral bleaching events at the LHIMP and potential for changing fish community composition with any long-term warming trends or unusual oceanographic events, the CTI was calculated for RLS monitoring data from LHI. The midpoint of the thermal distribution for each fish species was obtained from global occurrence records from the RLS database and Global Biodiversity Information Facility (www.gbif.org), with CTI representing the mean of these values for species recorded on each RLS transect, weighted by the log of their abundance. Full details of calculation of CTI can be found in Stuart-Smith et al. (2015b).

3 Results

THREATENED AND INVASIVE SPECIES

Species sighted on transects that are listed as threatened on the IUCN Red List or Commonwealth and NSW lists comprised green turtles (*Chelonia mydas*), black cod (*Epinephelus daemelii*) and the blotched fantail ray (*Taeniura meyeni*), as reported previously, as well as a hawksbill turtle (*Eretmochelys imbricata*). Galapagos sharks (*Carcharhinus galapagensis*) were observed in lower frequency in 2018 than in the previous three years. Galapagos sharks scored on 10 transect blocks in 2009, rose to 43 and 40 in 2012 and 2014, respectively; sighting frequency was maintained in 2016 (45 blocks), but then declined to 15 blocks in 2018. Abundance changed in a similar way: (average 2.05 per 500m^2 in 2006-2010, 2.23 per 500m^2 in 2012-2014, maintained at 2.19 per 500m^2 in 2016 and declining to 1.5 per 500m^2 in 2018). However, 11 individuals were sighted off-transect in 2018. According to the IUCN Red List, this species "is classified globally as Near Threatened (just failing to meet Vulnerable A2acd, and likely to be A3d in the near future)", hence is regarded as possessing conservation concern at the global level.

Green turtles have previously been reported from LHI reef monitoring, and five additional sightings of this species were made at monitoring sites in 2016 and 2018. It is listed as 'Vulnerable' under New South Wales and Commonwealth legislation, and 'Endangered' on the IUCN Red List. Two hawksbill turtles were also recorded as a "method 0" (off transect record) in 2016. This species was recorded only once before in RLS surveys at LHI, although this species was and is frequently observed in the lagoon, outside of formal surveys (S. Gudge pers. obs.). The hawksbill turtle is listed as vulnerable under the EPBC act and Critically Endangered on the IUCN red list.

Five black cod were recorded on transects in 2016 and 2018. Black cod have been totally protected in NSW waters since 1983, and are listed as 'Vulnerable' under the NSW Fisheries Management Act and by Pogonoski et al. (2002) in a threat assessment of Australian fishes. None of these threatened species recorded were in sufficient numbers for analysis of population trends here, but targeted monitoring of black cod is undertaken every two to three years by NSW DPI.

Fish species protected under New South Wales fisheries regulations include the elegant wrasse (*Anampses elegans*), bluefish (*Girella cyanea*), which is protected off the NSW continental coast, and Ballina angelfish (*Chaetodontoplus ballinae*); only the first two species were recorded on transects in 2016 and 2018. Booth's pipefish (*Halicampus boothae*) was recorded on the deeper transect at Rabbit Island again in 2018 (it was recorded here in 2009 and 2014).

No introduced fish or invertebrate species were sighted during surveys, but *Caulerpa taxifolia* was recorded in photoquadrats between 2012 and 2018 (see results for 'Sessile communities' below). This species is presently assumed to be native to tropical Australia, but an invader in cooler regions. It is considered cryptogenic in the waters of LHIMP (as per Aquenal 2006)

FISH COMMUNITIES

A total 293 fish taxa were scored on surveys in 2016 and 2018, adding to the previous list to represent 407 taxa (353 named species) recorded on surveys from 2006 to 2018. Species lists separated by survey method and class are provided in Appendices 1 and 2.

PCO of the multivariate fish community structure data showed the fish community in 2016 and 2018 to be very similar to previous years; the only evidence of a temporal shift was in the fished Algal Hole sites (Figure 4). There continued to be very clear differences between sites in different habitat types, with major separation of communities in the lagoon, the Algal Holes, in the Balls Pyramid area, and at the remaining sites. The largest separation was the difference in lagoon sites from the other sites along PCO1, which explained 30% of the variability in the fish community. This axis showed that sites tended to have either a lagoonal assemblage of small corallivores (genus *Chaetodon*) and omnivorous and farming damselfishes (e.g. *Stegastes*, *Neoglyphidodon*), or a combination of planktivorous damselfishes and large herbivores (e.g. *Chromis*, *Kyphosus*). The Algal Holes were further separated along PCO2 (13.2% of the variability) by a dominance of the large herbivore *Prionurus maculatus*. Relative positions of SZ and HPZ sites within the PCO were consistent, except in the lagoon, where SZ and HPZ sites formed distinct groups.

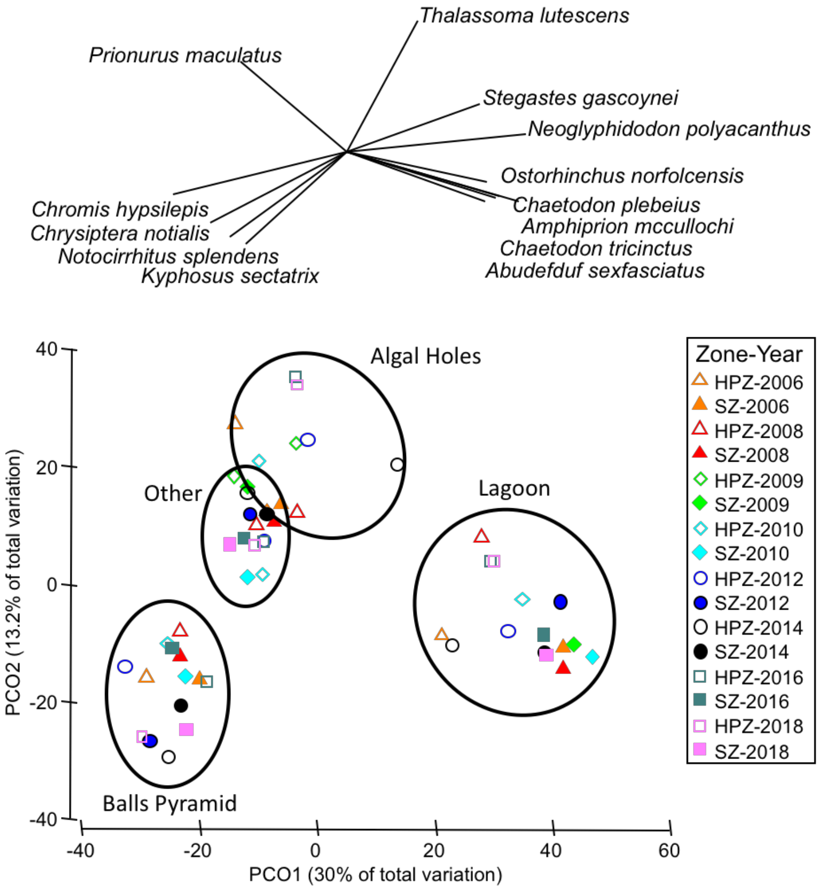

Figure 4. PCO showing relationships in reef fish community structure based on the Bray-Curtis resemblance matrix of mean biomass (log x + 1 transformed) across sites within zones and habitat types. Symbol colour differs among years, and SZ symbols are filled, while HPZ symbols are open. Vectors are for species with correlation to PCO axes >0.7.

Changes in key univariate metrics from fish surveys between 2006 and 2018 occurred for fish species richness and the biomass of large fishes (Figure 5), but the year x zone interaction term was not significant for any metric (Table 2). There was a spike in the abundance of all fishes and the biomass of large fishes in 2012, which dropped sharply in 2014. This spike occurred only in Sanctuary Zones, in contrast to a decline in Habitat Protection Zones during the same period. In 2016 and 2018, fish abundance, species richness and biomass stabilised and showed the beginning of a recovering trend, but this was not apparent in the biomass of large fishes, which continued to decline (and was not significantly higher in 2018 than in 2006 Table 2, Figure 5). Nevertheless, total biomass was higher in both zones in 2018 than in 2006 (Table 2).

Table 2. Results of PERMANOVAs using data from fish surveys at each of the core sites surveyed from 2006 to 2018, with the fixed factors 'zone' (2 levels; sanctuary zone, habitat protection zone) and 'year' (2 levels; 2006, 2018). Degrees of freedom for F-tests are 1/49. ***, p<0.001; ** 0.001<p<0.01; *, 0.01<p<0.05.

Variable	Zone		Year		Zone*Year		Error
	MS	F	MS	F	MS	F	MS
<u>Community</u>							
Community structure (Multivariate biomass)	2083.6	1.08	4776.4	2.47**	1035	0.95	1931.9
Fish species richness	29.59	2.52	311.67	26.50***	4.00	0.34	11.76
Benthic carnivores	152	0.91	11.39	0.07	260.69	1.56	166.76
Higher carnivores	1945.9	4.57*	939.38	2.20	263.26	0.62	426.15
Herbivores	74.28	0.33	340.48	1.54	18.94	0.09	221.5
Planktivores	3155.9	3.38*	659.75	0.71	370.43	0.40	933.92
Total Biomass	110.35	1.25	404.71	4.59*	17.80	0.20	88.16
Biomass Fish > 20cm	1.62	0.01	566.14	2.21	33.69	0.13	255.79
CTI	0.10	2.01	0.08	1.57	0.05	1.03	0.05
<u>Species</u>							
Anampses elegans	18.19	0.21	15.85	0.18	7.34	0.09	86.09
Carcharhinus galapagensis	72.67	0.20	1131.7	3.13	123.97	0.34	362.13
Chromis hypsilepis	657.18	1.19	67.83	0.12	131.61	0.24	550.68
Coris bulbifrons	16.20	0.06	114.69	0.43	187.76	0.71	264.23
Girella cyanea	959.57	2.88	118.75	0.36	145.64	0.44	332.8
Kyphosus spp.	306.04	0.47	1365.4	2.08	263.97	0.40	656.27
Prionurus maculatus	2131.2	4.17*	355.48	0.70	28.69	0.06	511.3
Pseudolabrus luculentus	106.95	1.61	100.93	1.52	60.16	0.91	66.39

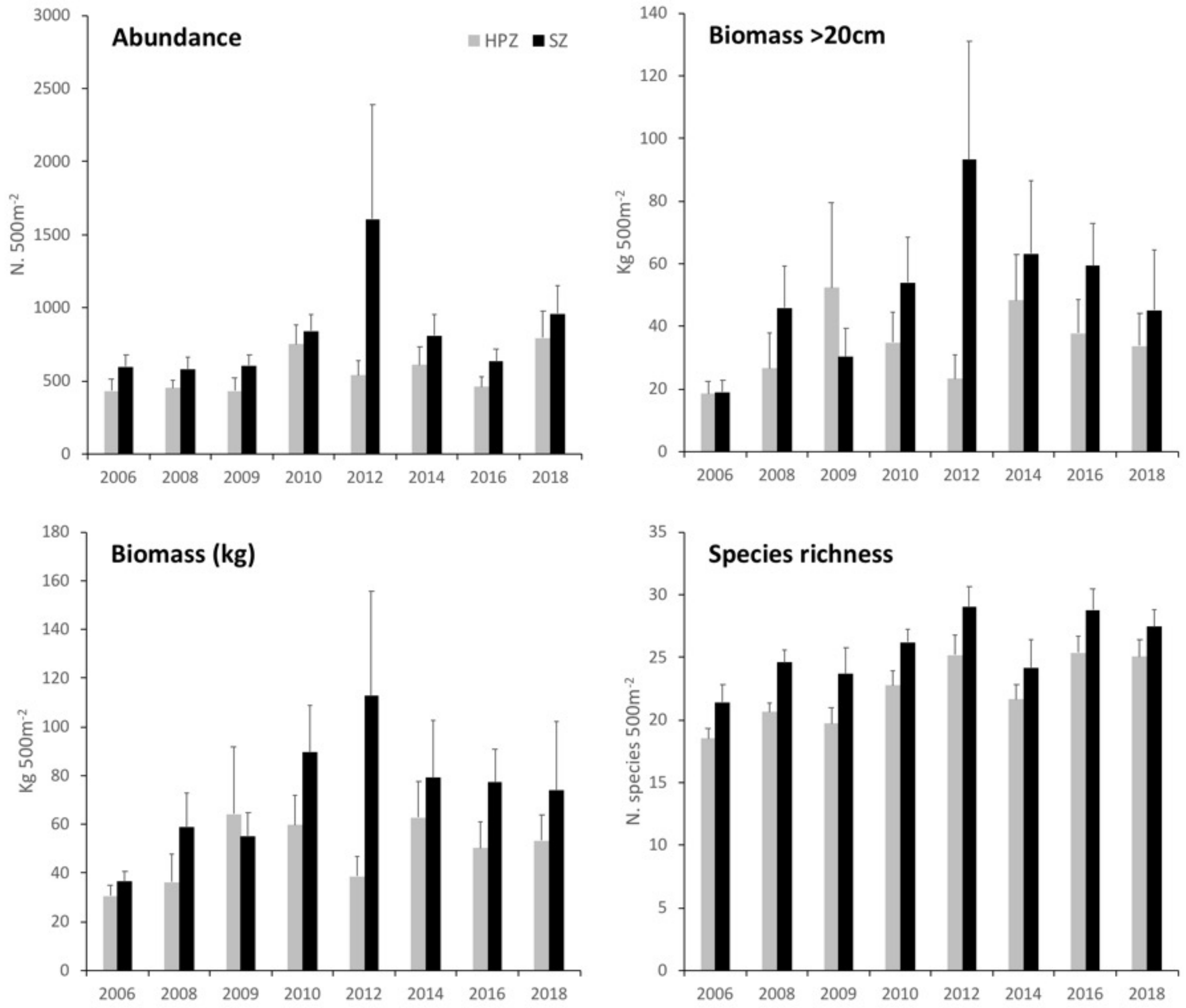

Figure 5. Trends in densities, biomass of large (>20cm) fishes, biomass of all fishes and fish species richness (+ SE of site means) at sites in the two major management zones across survey years. Only sites used in previous 2006-2014 analyses have been included for consistency in comparisons between years.

When the biomass of trophic groups and particular species were considered separately (Figure 6, Figure 7), a significant increase occurred in the biomass of higher carnivores from 2008 to 2014, followed by a sharp decline in both zones in 2016 and 2018. The increase was largely driven by the sharp increase in Galapagos sharks (Table 2) in 2012 and 2014; however, in 2016 and 2018 the biomass of this species declined dramatically, initially in HPZs and then also in SZs. Higher carnivore biomass was significantly higher in SZs than HPZs but was not significantly different between the original (2006) and latest (2018) surveys (Table 2, Figure 6). Apparent increases in herbivore and planktivore biomass in sanctuary zones from 2008 to 2012 were largely lost by 2014, driven in part a sudden drop in drummers (*Kyphosus* spp.) and fewer sawtail surgeons (*Prionurus* spp.) in SZs. Some recovery was apparent in 2016 and 2018 and planktivore biomass remained significantly higher in SZs than HPZs (Table 2). Benthic carnivore biomass fluctuated in HPZs and remained relatively stable in SZs, apart from a spike in 2016. The substantial drop in drummers from the 2012 to the 2014 surveys, especially in the SZs, was clearly evident when undertaking surveys in locations where these herbivores had been highly abundant, such as around the Admiralty Islands and exposed rocky sites on the north and east coasts, but was not significant when compared with low drummer biomass from 2008 surveys. The biomass of *Kyphosus* spp. gradually increased during the 2016 and 2018 surveys, but biomass of *Prionurus maculatus* remained significantly lower in SZs (Table 2). Doubleheader wrasse (*Coris* *bulbifrons*) biomass also declined considerably in 2012, although this was not statistically significant, likely due to the very patchy distribution of this species, occurring in high biomass at only a few sites. The biomass of this species remained relatively stable overall in 2016 and 2018. A cyclical pattern was evident in the abundant one-spot puller (*Chromis hypsilepis*) population that forms an important component of the trend in planktivores. Kingfish (*Seriola lalandi*) declined in frequency between 2014 and 2018, from being oserved in 9.4% of transect blocks to 6.5% of transect blocks. Black cod (*Epinephelus daemelii*) frequency remained the same (1.9%) between 2014 and 2018. The abundance of these two commercially important species was too low for formal analyses.

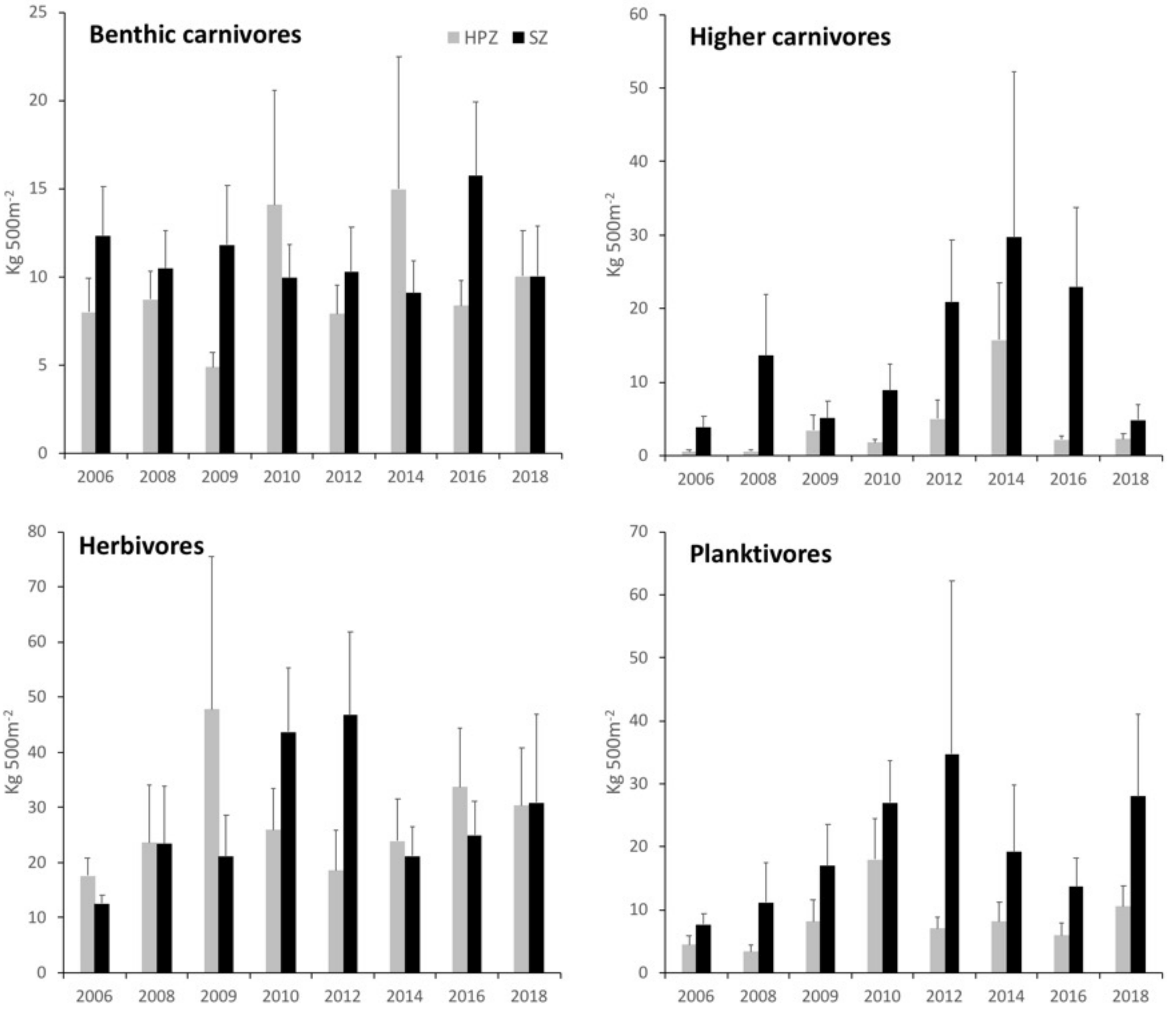

Figure 6. Trends in the biomass (+ SE of site means) of fish species belonging to different trophic groups across years in the two major management zones. Only sites used in previous 2006-2014 analyses have been included for consistency in comparisons between years.

Although bluefish (*Girella cyanea*) biomass at sites in SZs appeared to be healthy relative to HPZ sites in 2012, biomass in 2018 appears to be no greater across both zones than following the decline in 2014, and was no longer significantly different between zones (Table 2, Figure 7). When viewed across the last four years (2014-2018), bluefish biomass has been low regardless of zone. In contrast, elegant wrasse (*Anampses elegans*) appear to be increasing again following the dip in biomass in 2012; however, their biomass was not significantly different from 2006 in either of the zones (Table 2).

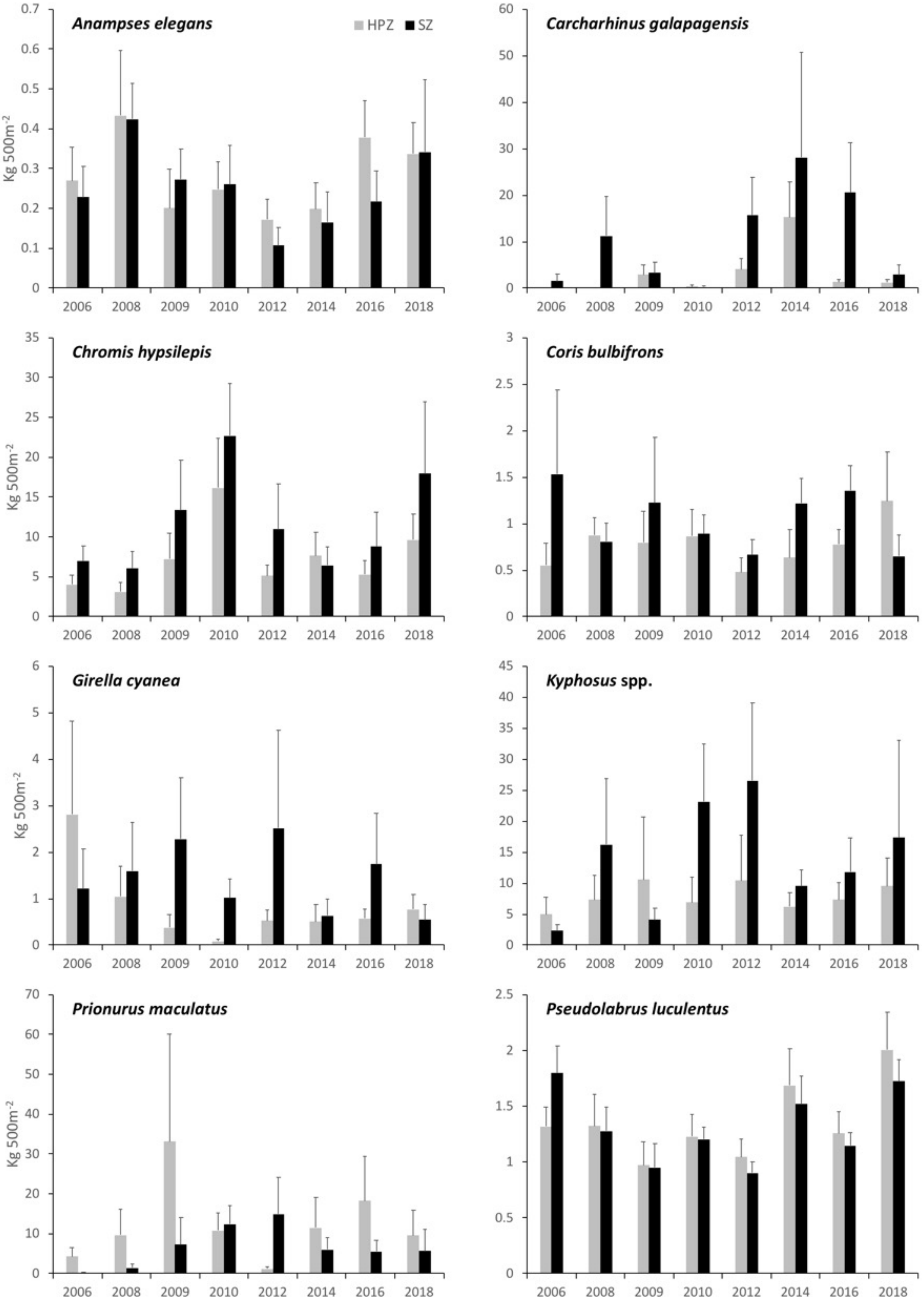

Figure 7. Trends in biomass of particular fish species (+ SE of site means) from surveys in the two major management zones across years. Only sites used in previous 2006-2014 analyses have been included for consistency in comparisons between years.

Values of the CTI for fishes were stable across years, varying by only a fraction of a degree (Figure 8). A 'warmer' fish community appeared to be re-occurring in SZs during a number of the survey years, especially 2012 and 2018, but differences were not significant overall (Table 2).

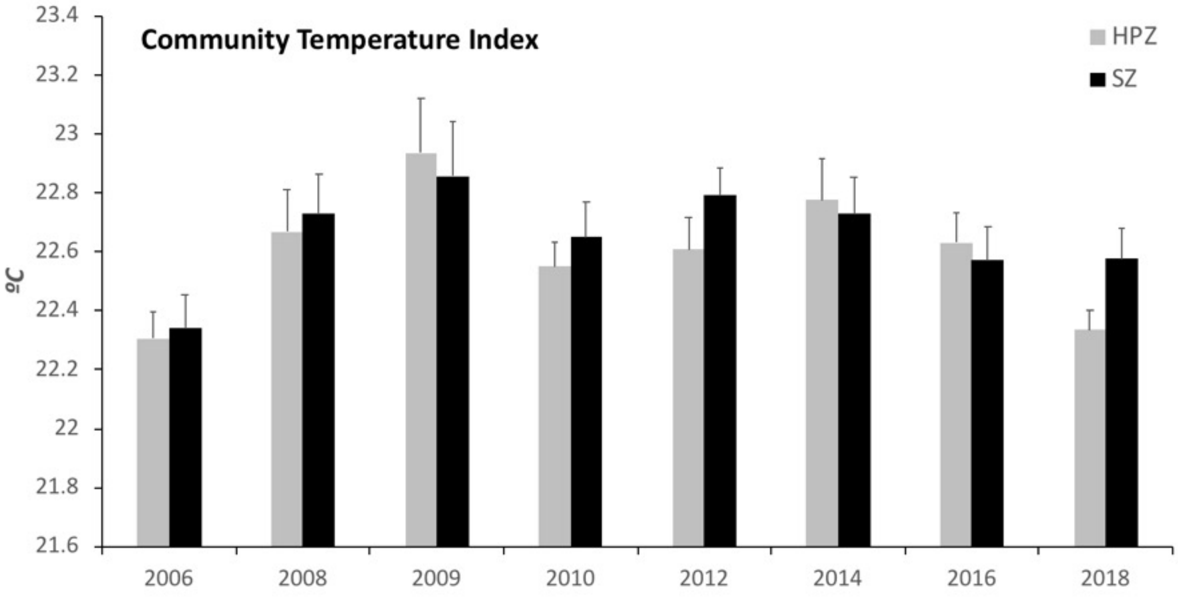

Figure 8. Trends in the Community Temperature Index (CTI) of fishes (+ SE of site means) recorded on surveys in the two major management zones across years.

As in previous years, a number of fish species were recorded in 2016 and 2018 that did not appear in any of the previous checklists of species recorded at LHI (M. Francis, unpub data). New records for 2016-2018 included are shown in Plate 1.

Rhinecanthus lunula (Image: Margo Smith)

Fusigobius duospilus (Image: Andrew Green)

Gobiodon citrinus (Image: Rick Stuart-Smith)

Myripristis murdjan (Image: Rick Stuart-Smith)

Coris dorsomacula (Image: Rick Stuart-Smith)

Paraluteres prionurus (Image: Rick Stuart-Smith)

Plate 1. New fish species records observed during the 2016 and 2018 surveys. Images shown are not necessarily taken from Lord Howe Island but were chosen to clearly show the new species records.

MOBILE INVERTEBRATE COMMUNITIES

As was the case with results for fish communities, PCO of sites in different habitat and zone types showed invertebrate community structure in 2016 and 2018 to be within the range of variation expected from surveys in previous years (Figure 9). No consistent trajectory was evident between years for any of the habitat types, but Algal Holes and lagoon sites differed most between years in general. Relative positions of SZ and HPZ sites within the PCO were generally consistent between years, suggesting no major divergence in invertebrate community structure between zone types. However, HPZ and SZ sites in lagoonal habitats were distinctly different, with HPZ lagoon sites much more similar to Algal Holes sites, and SZ lagoon sites forming a unique group.

Invertebrate species richness dropped slightly in 2014 (Figure 10), and remained similar in 2016 and 2018, and not significantly different from 2006 or between zone types (Table 3).

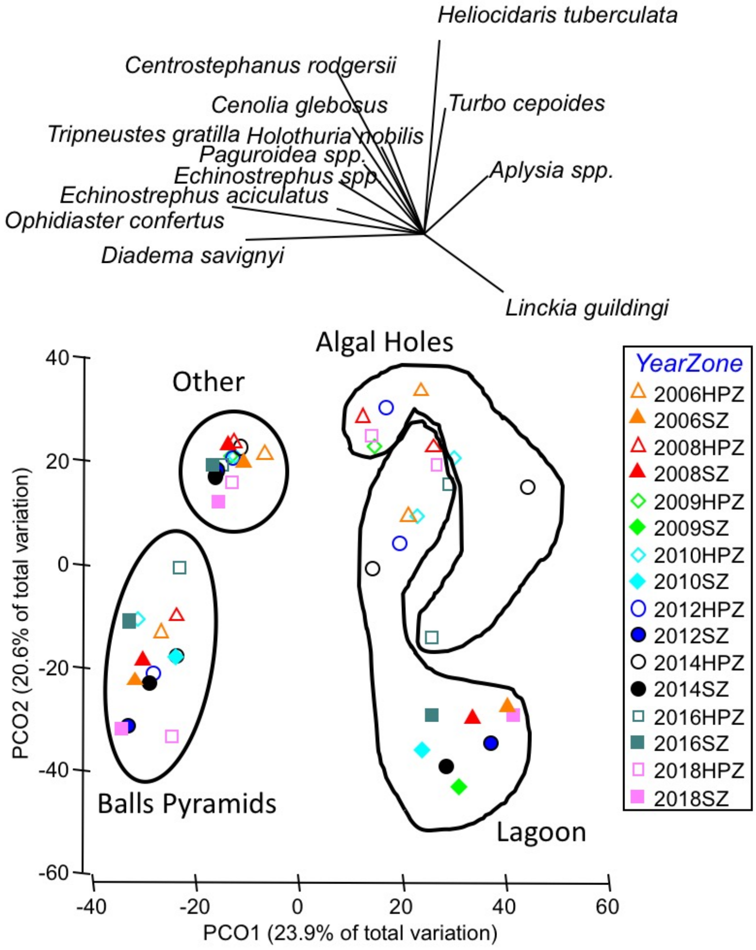

Figure 9. PCO showing relationships in mobile invertebrate community structure based on mean density (per $100m^2$) across sites within zones and habitat types. Symbol colour differs among years, and SZ symbols are filled, while HPZ symbols are open. Vectors are for species with correlation to PCO axes >0.4.

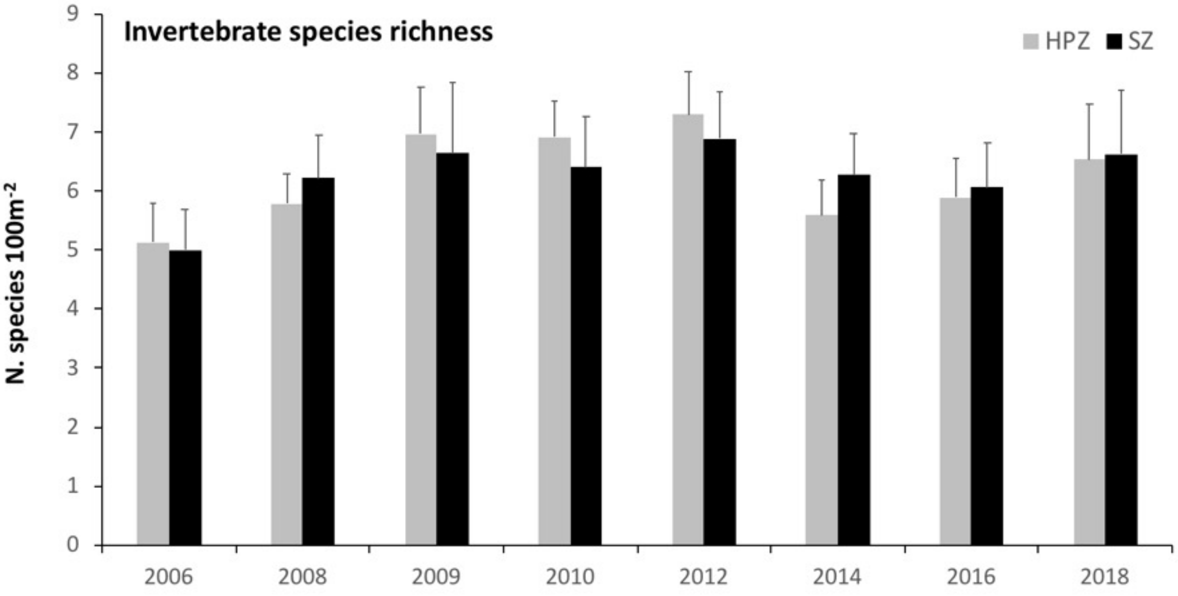

Figure 10. Trends in invertebrate species richness (+ SE of site means) at sites in the two major management zones across survey years. Only sites used in previous analyses have been included for consistency in comparisons between years.

Sea urchin densities generally peaked between 2009 and 2012, but then declined again in 2014 and 2016. An upturn in sea urchin densities appeared again in 2018, bringing most species back up to densities equivalent to their highest observed previously (Figure 9, Table 3). *Tripneustes gratilla* was the exception, after the boom in the population in 2008 and steep decline to 2014, this species has not been recorded again at these sites in 2016 and 2018. There was high variability between sites for all species, masking any potential differences between zones and between years; zone differences appeared consistent only for *Echinometra mathaei* (higher densities in SZs) and *Heliocidaris tuberculata* (higher densities in HPZs). Temporal trends in *C. rodgersii* and *H. tuberculata* were remarkably similar to each other, when comparing between the sites in the same zones (i.e. SZ trends were the similar between species, and HPZ trends were similar between species).

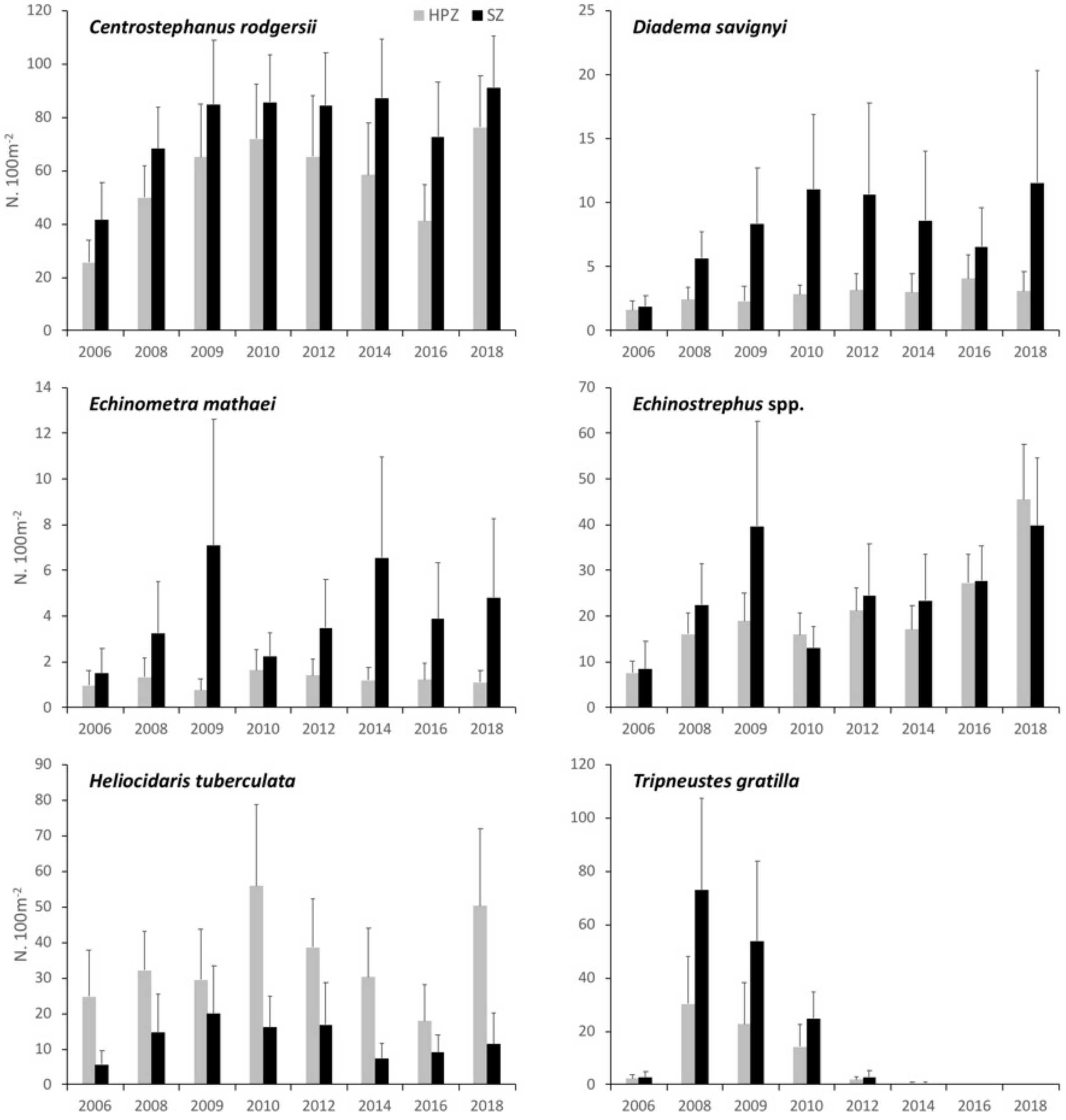

Figure 11. Trends in density of particular urchin species (+ SE of site means) from surveys in the two major management zones across years. Only sites used in previous analyses have been included for consistency in comparisons between years.

Table 3. Results of PERMANOVAs using data from mobile invertebrate surveys at each of the core sites surveyed from 2006 to 2018, with the fixed factors ‘zone’ (2 levels; sanctuary zone, habitat protection zone) and ‘year’ (2 levels; 2006, 2018). Degrees of freedom for F-tests are 1/49. ***, p<0.001; ** 0.001<p<0.01; *, 0.01<p<0.05.

Variable	Zone		Year		Zone*Year		Error
	MS	F	MS	F	MS	F	MS
Community							
Community structure (Multivariate)	2991	1.35	18105	8.20***	388.31	0.18	2208.3
Species richness	290.63	0.82	289.58	0.81	233.93	0.66	355.86
Species							
Centrostephanus rodgersii	133.6	0.19	1281.7	1.81	44.76	0.06	708.07
Diadema savignyi	533.18	1.12	384.39	0.81	164.07	0.35	474.15
Echinometra mathaei	170.91	0.43	405.5	1.02	77.65	0.20	397.74
Echinostrephus spp.	193.8	0.66	12846	43.79***	193.8	0.66	293.37
Heliocidaris tuberculata	3102	3.44	114.95	0.13	61.95	0.07	900.64
Tripneustes gratilla	9.71	0.04	1827.4	6.97*	7.30	0.03	262.16

SESSILE COMMUNITIES

Similar groupings among sites existed based on sessile community data as for those based on fishes and invertebrates, with greater variation among reef types than other groups (Figure 10). Some divergences occurred through time; with significant changes between 2006 and 2018 (Table 4), distinctive community structure in the years 2006 and 2008, a further shift in 2010 (potentially associated with bleaching), and generally similar assemblages in 2012-2018. In the early years, the sessile communities were dominated by *Acropora* and *Isopora* spp. and a combination of green and brown algae; in later years there appears to have been a shift towards foliose and encrusting corals and algal turf. The Algal Hole sites stood out as dominated by foliose red algae throughout the survey period (Figure 10). There was a small but significant difference between management zones (Table 4), largely driven by higher coral cover in SZs and higher macroalgal cover in HPZs.

It is likely that minor differences in classification may have contributed to the observed temporal signal in the PCO (see plots of individual categories below). Thus, to remove the possibilities of different classification interfering with interpretation of trends, a second PCO (Figure 11) was undertaken using similarity of sites based on cover data aggregated into the six higher level categories that points are scored under: algae, soft corals, all other corals (including bleached), other sessile invertebrates (e.g. sponges, zoanthids), crustose coralline algae and other non-living or non-structural substrates (including filamentous slime, dead corals). This increased similarity among the majority of sites, leaving only the Algal Holes sites as most unique with a dominance of algae and crustose coralline algae, and lacking a consistent temporal trajectory. The separation between sites dominated by algae and all other sites accounted for 50% of the variability in the data. Within the larger group of all other sites, data from the bleached lagoon sites in 2010 are separate from the remainder, before returning close to pre-bleaching structure in 2012. By 2018 these sites had moved back towards the original 2006-2008 points, indicating potential recovery.

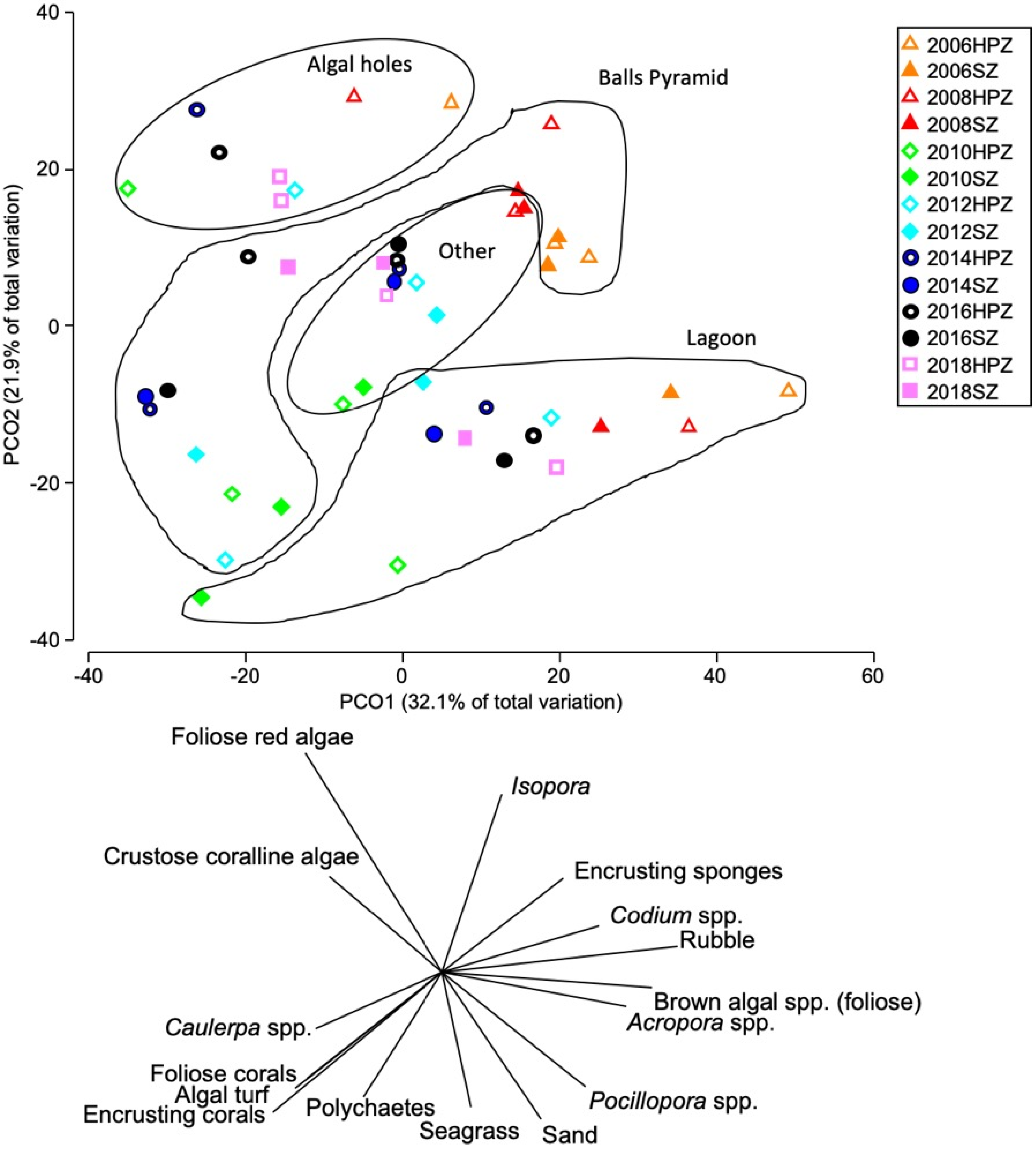

Figure 12. PCO showing relationships in sessile community structure based on mean cover of sessile organisms to the highest taxonomic resolution possible, across sites within zone and habitat types. Symbol colour differs among years, and SZ symbols are filled, while HPZ symbols are open. Vectors are for species with correlation to PCO axes >0.5.

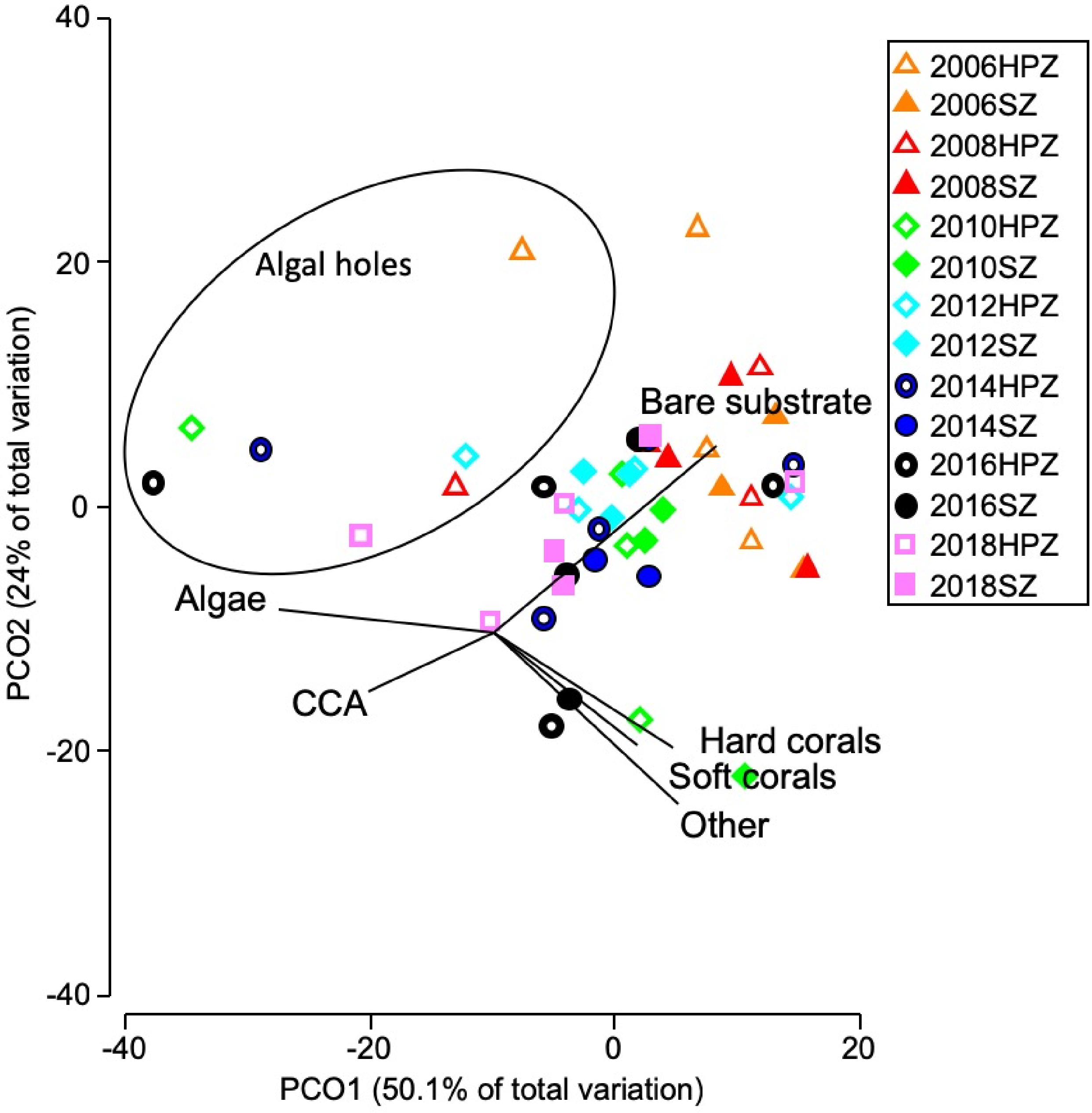

Figure 13. PCO showing relationships in sessile community structure based on mean cover of sessile organisms aggregated into six key categories, across sites within zone and habitat types. Groups are algae, soft corals, all other corals (including bleached), other sessile invertebrates (e.g. sponges, zoanthids), crustose coralline algae and other non-living or non-structural substrates (including filamentous slime and dead corals). Symbol colour differs among years, and SZ symbols are filled, while HPZ symbols are open.

Table 4. Results of PERMANOVA of data from photoquadrats of the sessile community at each of the core sites surveyed from 2006 to 2018, with the fixed factors ‘zone’ (2 levels; sanctuary zone, habitat protection zone) and ‘year’ (2 levels; 2006, 2018). Degrees of freedom for F-tests are 1/48. ***, p<0.001; ** 0.001<p<0.01; *, 0.01<p<0.05.

Variable	Zone		Year		Zone*Year		Error
	MS	F	MS	F	MS	F	MS
Community structure (Multivariate)	1546.2	2.20*	12959	18.47***	302.66	0.43	701.70
Corals	1023.7	5.85*	561.79	3.21	106.98	0.61	174.96
Macroalgae	415.6	6.66*	609.77	9.77**	13.50	0.22	62.39
Soft corals	385.47	1.12	85.94	0.25	44.73	0.13	344.69
Turf	285.44	1.28	16836	75.64***	196.21	0.88	222.57
Other sessile inverts	544.06	1.34	1072.2	2.65	101.4	0.25	404.54
Bare substratum	29.23	0.61	533,76	11.21***	141.4	2.97	47.61

Coral cover has remained stable since 2010, with an increasing trend in 2016 and 2018, although 2018 cover was not significantly higher than in 2006 (Table 4; Figure 12). Macroalgal cover has declined significantly, and, after being mostly lower in SZ sites compared to HPZ sites throughout the survey period (due to higher macroalgal cover at the Algal Holes sites in the HPZ group), was relatively even between zones in 2018. Macroalgal cover was signifcantly lower than when monitoring began in 2006. The cover of soft corals showed a declining trend in 2016 and 2018; dead coral and non-structural substrate types (‘Bare substratum and CCA’) has remained stable after an initial decline between 2008 and 2010, although this was likely due to a different characterisation of turf during photoquadrat annotation in those years, and inclusion of turf within values of cover. As a result, turf cover appeared to increase after 2008, and has remained stable since. Thus, the combination of bare substrate/CCA/turf cover has remained relatively stable at ~30-40% over the entire monitoring period. The fluctuating patterns in the relatively low cover of other sessile invertebrates showed no specific trend. Bare substratum declined in cover between 2008 and 2010 and has been stable in representing lower cover since (Table 4).

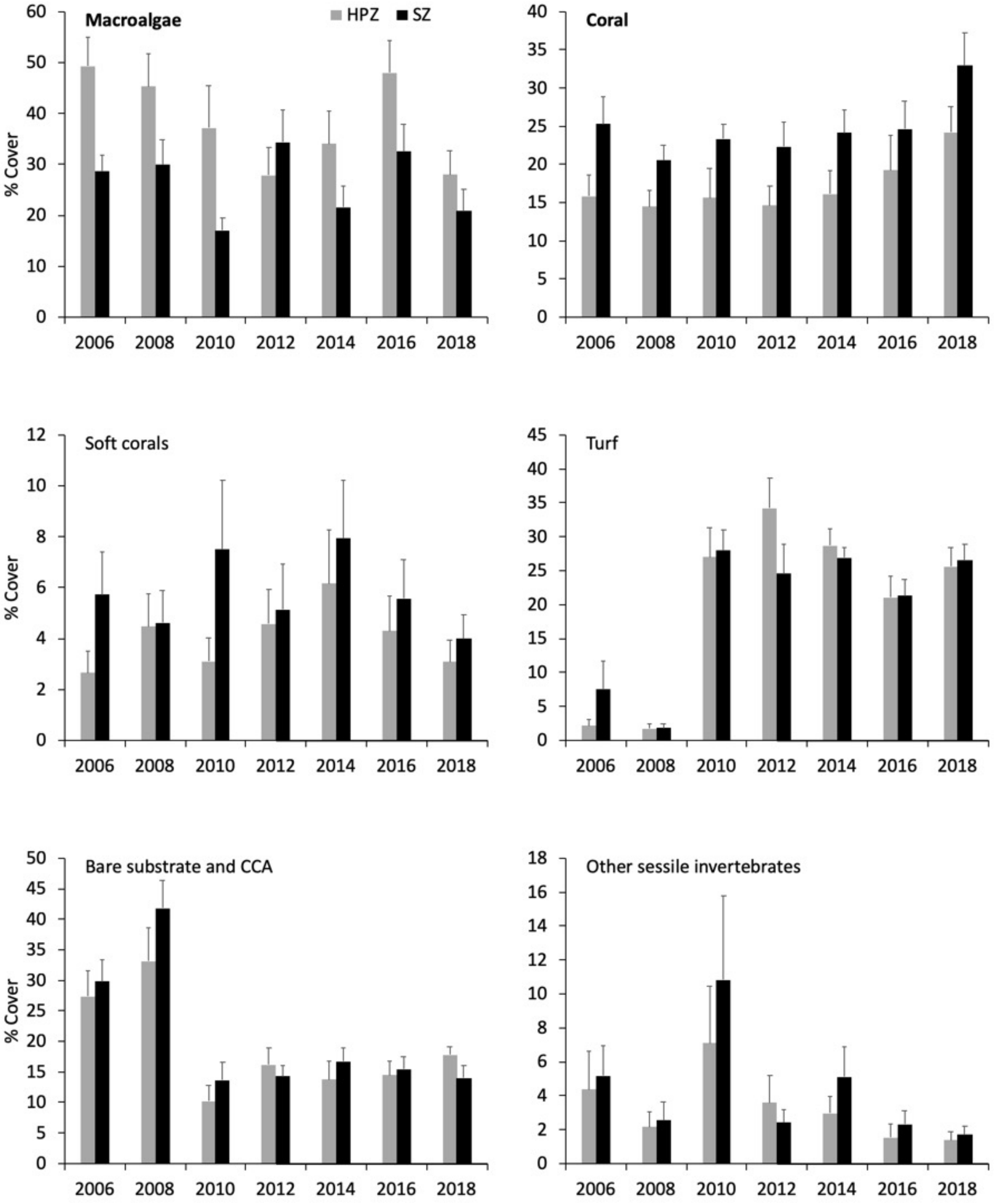

Figure 14. Mean cover of sessile categories from photoquadrat data (+ SE of site means) at sites in the two major management zones across survey years. Only sites used in previous 2006-2014 analyses have been included for consistency in comparisons between years.

Three of four species of *Caulerpa* (excluding *C. cupressoides*) increased during the 2010-2014 period; of these, two persisted in 2016 but disappeared in 2018 (Figure 13). Plots in Figure 13 are only based on sites surveyed across all years to allow for fair assessment of the temporal trend without being biased by the addition of new sites in later years, with different substrate composition. If all the more recently established sites are included, the cover of all three species still declines considerably in 2018, but does not disappear entirely. Mean cover of *C. taxifolia* at Neds beach doubled from 14% in 2012 to 29% in 2014, but declined to 5% by 2018. At Le Merthe Hole it declined from 24% to 6% , at Horseshoe it disappeared, and at Stephens Hole it declined from 27% to less than 1%.

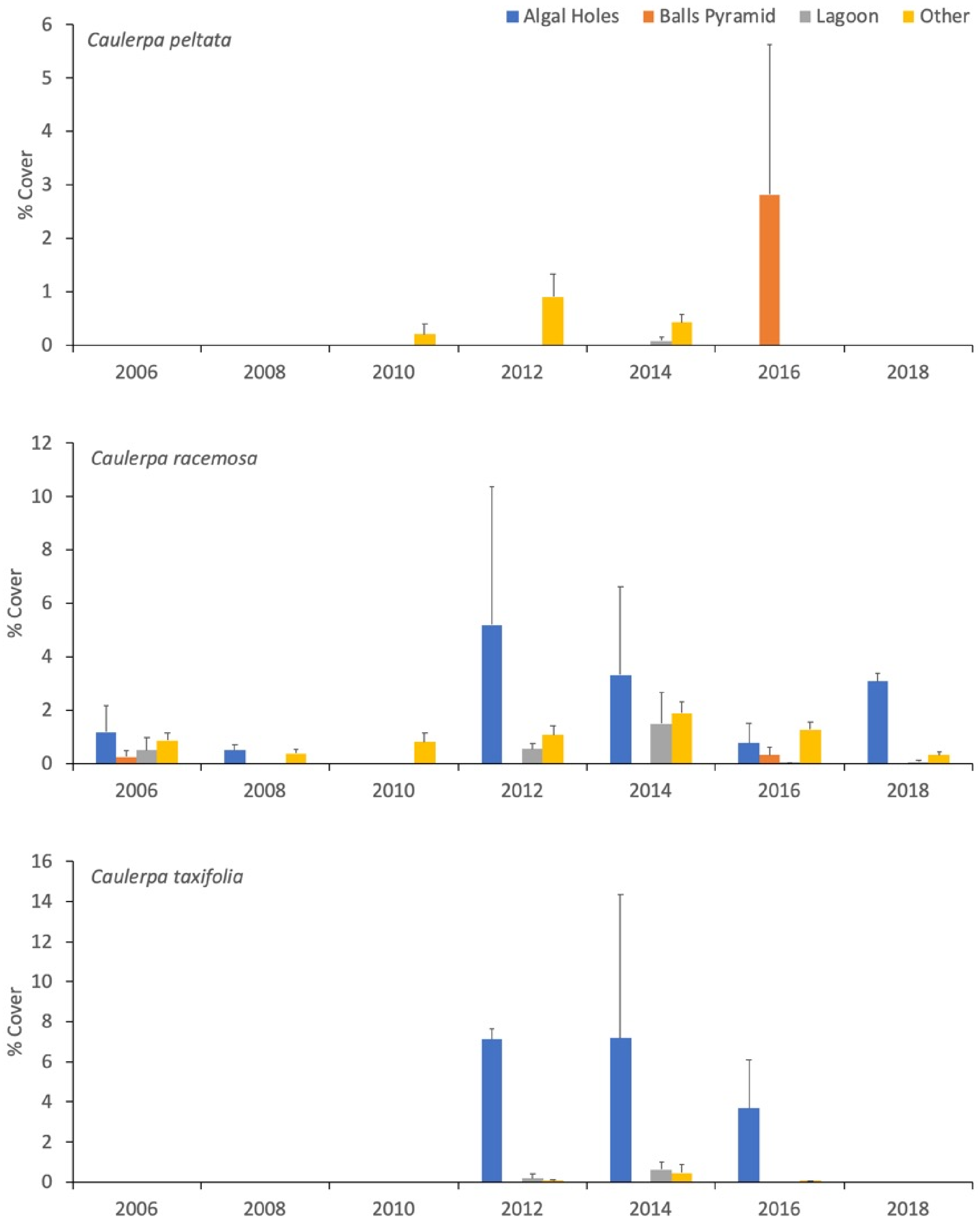

Figure 15. Mean cover of *Caulerpa* species from photoquadrat data (+ SE of site means) at sites in the different habitat types across survey years. Only sites used in previous 2006-2010 analyses have been included for consistency in comparisons between years. Note that y-axis values differ between plots.

CORAL BLEACHING

Data collected in 2016 and 2018 at sites affected by the 2010 bleaching were assessed to identify whether any further changes in coral cover have occurred, and whether the trajectory of recovery (decrease or increase in total coral cover) has resulted in long-term changes in other groups (e.g. fishes and invertebrates) at these sites.

Only one of the sites (Erscotts Passage South) that experienced bleaching in 2010 showed some minor bleaching (0.9%) in 2016, and no bleaching was seen in 2018 (Table 5). Six of 17 sites that were bleached in 2010 experienced loss in coral cover between 2010 and 2018, with a mean loss of 14.4% (±19% SD) total cover (Table 5). The remaining 11 sites experienced a gain in total coral cover, however, with a mean increase of 14.3% (±9.9% SD) in total cover. Overall, there was no significant correlation between the percentage of coral bleached in 2010 and the change in coral cover from 2010 to 2018 (pearson correlation coefficient = 0.01, p=0.69).

Table 5. Coral bleaching at sites bleached in 2010. Live = % cover of live, unbleached corals; Bl = % cover of recently bleached (white) corals; %Bl = % of total coral cover consisting of bleached corals (i.e. Bl divided by the sum of Live & Bl, multiplied by 100); ΔCC = change in total % cover of corals (the sum of live and bleached corals) from 2010 to 2018. Percent cover data from the two Comet's Hole sites have been averaged in all years. Sites that were merged with other sites in the latest surveys were omitted.

		2010			2016			2018			2010-2018
Site		Live	Bl	**% Bl**	Live	Bl	**% Bl**	Live	Bl	**% Bl**	ΔCC
LHI26	Sylphs Hole N	1.7	11.1	**86.5**	29.3	0.0	**0.0**	43.3	0.0	**0.0**	30.5
LHI38	North Bay	10.8	56.5	**83.9**	30.5	0.0	**0.0**	15.1	0.0	**0.0**	-52.2
LHI40	Horseshoe	11.3	40.3	**78.1**	32.0	0.0	**0.0**	43.5	0.0	**0.0**	-8.1
LHI5/6	Comets Holes	10.5	27.3	**72.3**	56.8	0.0	**0.0**	64.7	0.0	**0.0**	26.9
LHI33	Signal Point	4.9	6.0	**55.0**	15.4	0.0	**0.0**	36.3	0.0	**0.0**	25.4
LHI7	Erscotts Passage South	29.6	8.7	**22.6**	31.9	0.3	**0.9**	24.3	0.0	**0.0**	-14.0
LHI41	Stephens Hole NE	12.3	2.3	**15.9**	19.3	0.0	**0.0**	15.5	0.0	**0.0**	0.8
LHI3	Erscotts Blind Passage	17.3	3.1	**15.2**	13.2	0.0	**0.0**	16.3	0.0	**0.0**	-4.1
LHI11	Little Slope	13.1	0.8	**5.8**	33.3	0.0	**0.0**	24.0	0.0	**0.0**	10.1
LHI13	Little Island	9.6	0.6	**5.5**	12.1	0.0	**0.0**	31.4	0.0	**0.0**	21.3
LHI30	Malabar	19.9	0.9	**4.3**	13.5	0.0	**0.0**	14.1	0.0	**0.0**	-6.7
LHI23	Boat Harbour	12.1	0.5	**4.0**	n	0.0	**n**	21.8	0.0	**0.0**	9.2
LHI34	Neds Beach	18.2	0.5	**2.7**	11.8	0.0	**0.0**	17.5	0.0	**0.0**	-1.2
LHI16	Rabbit Island offshore	24.0	0.6	**2.6**	18.6	0.0	**0.0**	31.6	0.0	**0.0**	7.0
LHI1	North Channel	5.4	0.1	**2.4**	5.3	0.0	**0.0**	17.1	0.0	**0.0**	11.6
LHI48	Malabar West	23.3	0.4	**1.7**	30.2	0.0	**0.0**	32.9	0.0	**0.0**	9.2
LHI10	Noddy Island	23.4	0.2	**0.8**	15.4	0.0	**0.0**	29.0	0.0	**0.0**	5.4

Sites were divided into those which were bleached in 2010 and had lost more than 5% total coral cover by 2014, those which were bleached in 2010 but had little change or greater coral cover in 2014, and those that were unaffected by the bleaching in 2010.

Trends in two of the dominant sea urchins found in the coral-dominated lagoon sites appeared to be related to whether sites experienced loss of coral cover following bleaching (Figure 14). The boom in *Heliocidaris* numbers in 2010 and 2012 was apparently greatest among sites at which coral cover declined following bleaching (Horseshoe, Erscotts Passage South, Erscotts Blind Passage, Malabar, Neds Beach). However, there was no correlation between the magnitude of coral cover change between 2010 and 2018 with the mean density of *Heliocidaris* over 2010-2018 (pearson correlation coefficient = 0.05, p=0.2), with some of the highest densities of *Heliocidaris* occurring at sites which experienced only minor coral loss. *Heliocidaris* densities declined again by 2016, reducing the magnitude of differences among sites with differing coral recovery trajectories (Table 6). Trends in *Diadema* densities were similar. Increased *Diadema* densities in 2018 were largely restricted to sites which experienced increases in coral cover following the 2010 bleaching event, and densities have been stable since.

Densities and richness of cryptic fishes recorded during the Method 2 invertebrate searches increased through time, possibly as a result of greater emphasis on this component of surveys in recent years. No trend in cryptic fishes has been related to coral recovery vs loss following the bleaching (Table 6). Likewise, there were no apparent effects of changes in coral cover from bleaching on the species richness of fishes recorded with Method 1, and although fish biomass was initially significantly higher at sites where coral cover decreased following bleaching, this did not persist after 2014 (Figure 14).

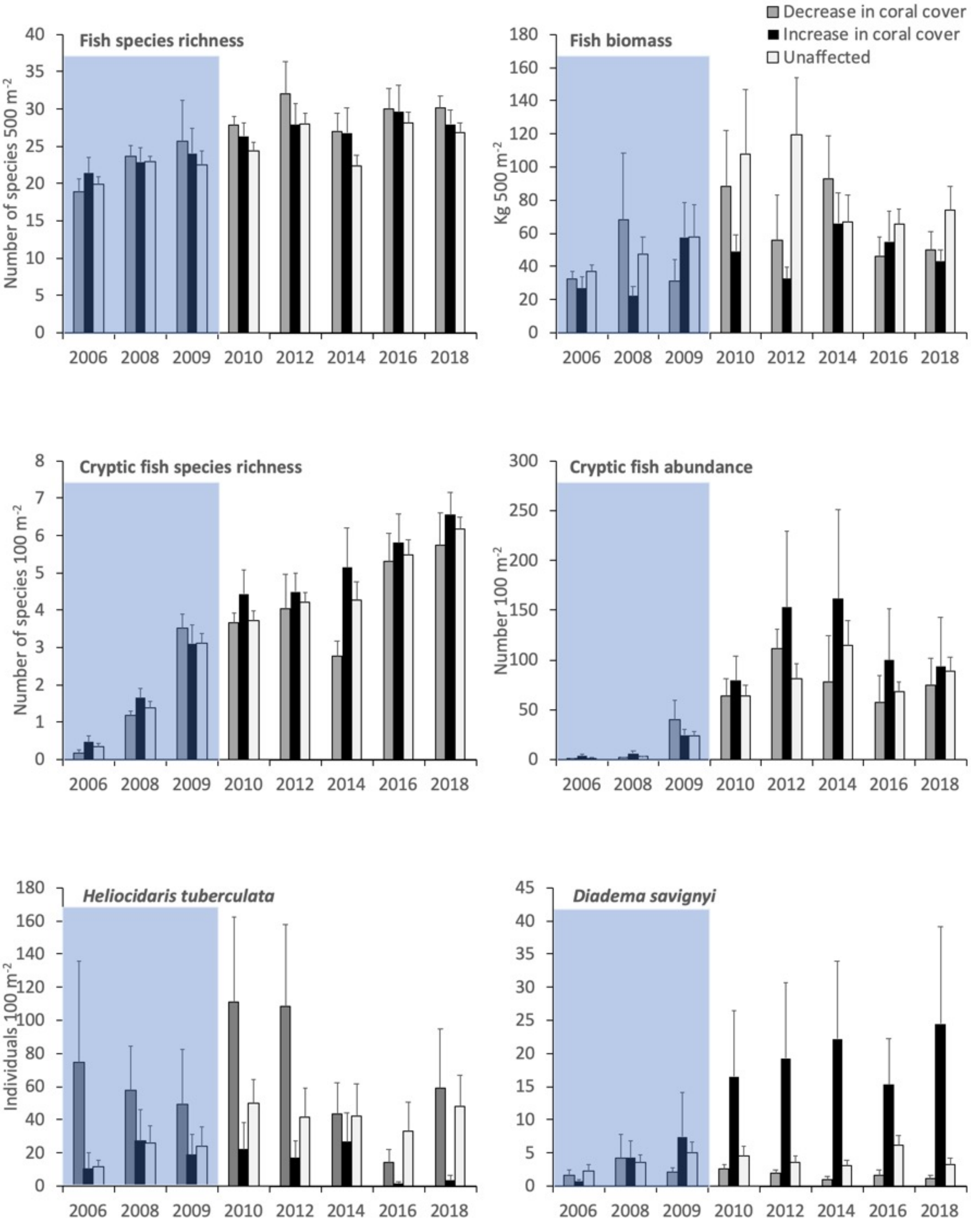

Figure 16. Trends in fish and invertebrate community metrics among sites which have experienced decreases in total coral cover since 2010 bleaching compared to those at which coral cover has remained stable or increased. Site groupings are based on data in Table 5, as sites that experienced a decrease in overall coral cover of more than 5% since 2010 (black bars, n=4-8), those which have experienced little loss or a gain in coral cover since 2010 (grey bars, n=8-10) and those which were unaffected by bleaching in 2010 (light grey; not listed in Table 5. n>16). Trends prior to the 2010 bleaching are shown (in blue shaded parts of the plots) for context.

Table 6. Results of PERMANOVAs testing for change in univariate fish and invertebrate community metrics at sites bleached in 2010, with the fixed factors 'coral recovery' (2 levels; decreased cover, increased cover) and 'year' (2 levels; 2009, 2018). Degrees of freedom for F-tests are 1/18. ***, p<0.001; ** 0.001<p<0.01; *, 0.01<p<0.05.

Variable	Coral recovery (CR)		Year		CR*Year		Error
	MS	F	MS	F	MS	F	MS
Community							
Fish species richness	5.37	0.43	39.09	3.15	0.21	0.02	12.40
Total fish biomass	12.15	0.13	76.99	0.82	49.22	0.53	93.55
Community Temperature Index	0.28	2.20	0.01	0.05	0.03	0.21	0.13
Cryptic fish density	54.31	0.45	376.15	3.09	15.80	0.13	121.79
Cryptic fish species richness	10.12	0.14	1025.8	14.23**	87.21	1.21	72.10
Invertebrate species richness	461.02	0.83	80.40	0.14	184.39	0.33	555.95
Species							
Diadema savignyi	649.12	0.93	55.30	0.08	442.97	0.63	697.97
Echinometra mathaei	1023.8	2.70	113.98	0.30	892.17	2.35	379.35
Heliocidaris tuberculata	5110.8	6.07*	171.8	0.20	69.99	0.08	841.47

SESSILE COMMUNITIES IN RELATION TO URCHIN TRENDS

Tripneustes at offshore sites

Sessile communities were analysed at sites that experienced the boom in *Tripneustes* sea urchins and associated destructive grazing reported in 2010 (Table 7). Plots (Figure 15) may differ slightly from those presented in 2010 report due to slight differences in categorisation of substrate types, but general trends in 2006-2014 are consistent with those previously reported. Data from 2016 and 2018 show an increase in macroalgae cover at sites where *Tripneustes* densities were low or absent, but in 2018 there was a decline at all sites back to 2014 levels. Hard coral cover was also higher at sites where *Tripneustes* were absent, especially in 2018. Bare substratum, which had almost disappeared by 2016, increased dramatically in cover in 2018.

Table 7. Sites and site categories used for the analysis of sessile communities in relation to different *Tripneustes* densities.

Site Code	Site Name	*Tripneustes* density $100m^{-2}$	Category
LHI10	Noddy Island	433	High
LHI18	Keyhole North	267.5	High
LHI19	Sugarloaf West	328.5	High
LHI28	Old Gulch N	69	High
LHI30	Malabar	25.5	Low
LHI31	Wheatsheaf	2	Absent
LHI37	Malabar 2	88	High
LHI9	Ruperts Reef	148	High
LHI24	Phillip Rock North	0	Absent
LHI32	Observatory	1	Absent

Heliocidaris tuberculata at Algal Holes

A key concern relates to urchin densities in the Algal Holes area, which contains endemic flora at risk of extinction through overgrazing (Edgar et al. 2010). The two dominant urchin species at the Algal Holes sites, *Centrostephanus rodgersii* and *Heliocidaris tuberculata*, peaked in density at Algal Holes sites in 2010 (Figure 16), the latter at 87 urchins per 100 m^2. While densities in 2014 and 2016 were much reduced, they rose again to 13 and 50 per 100 m^2, respectively, in 2018. Only four transects are surveyed at two sites in this location, however, and mean densities are therefore more sensitive to transect placement than for other zones which have many more transects surveyed.

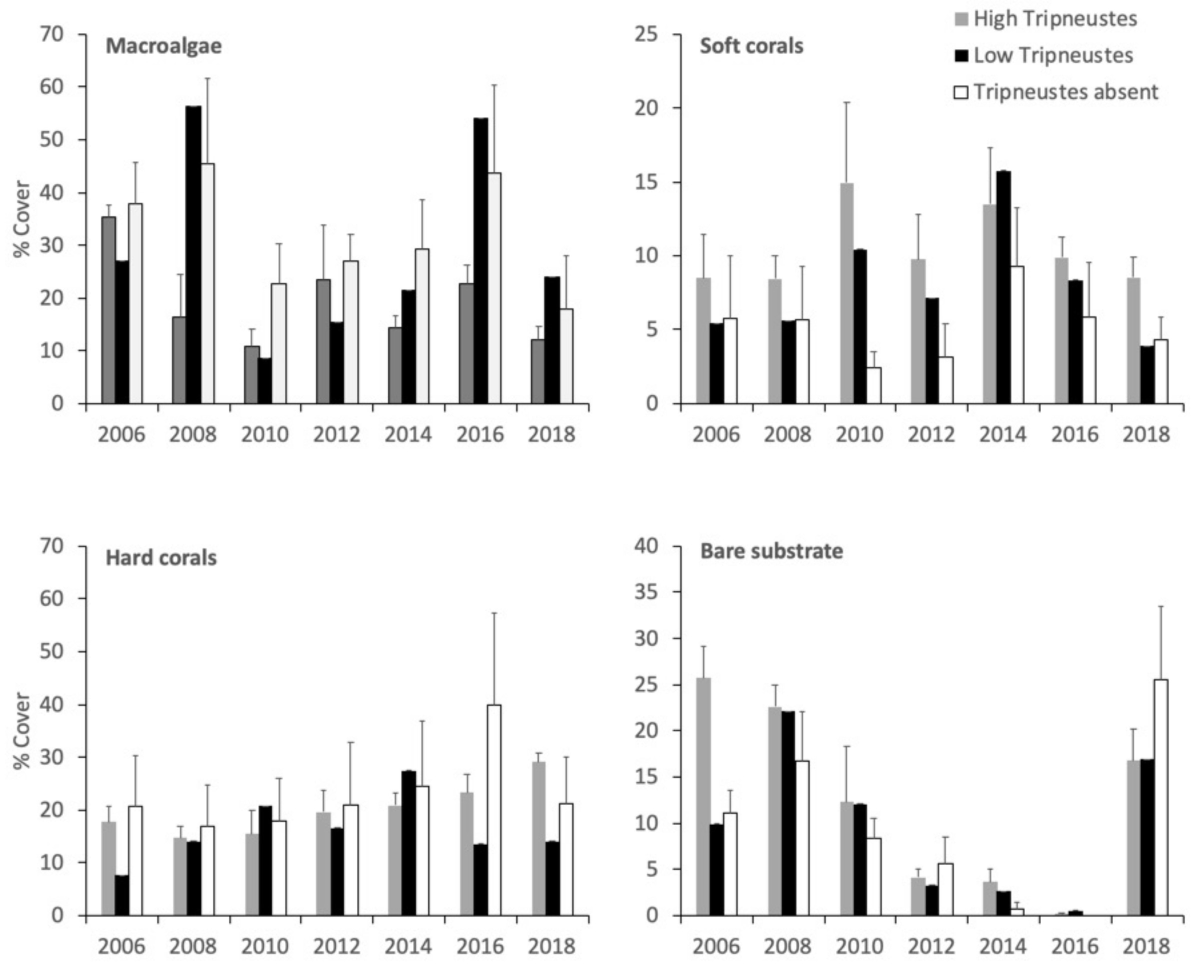

Figure 17. Changes between years in mean cover (+ SE) of four major benthic groups at sites within each of three categories of *Tripneustes* outbreak.

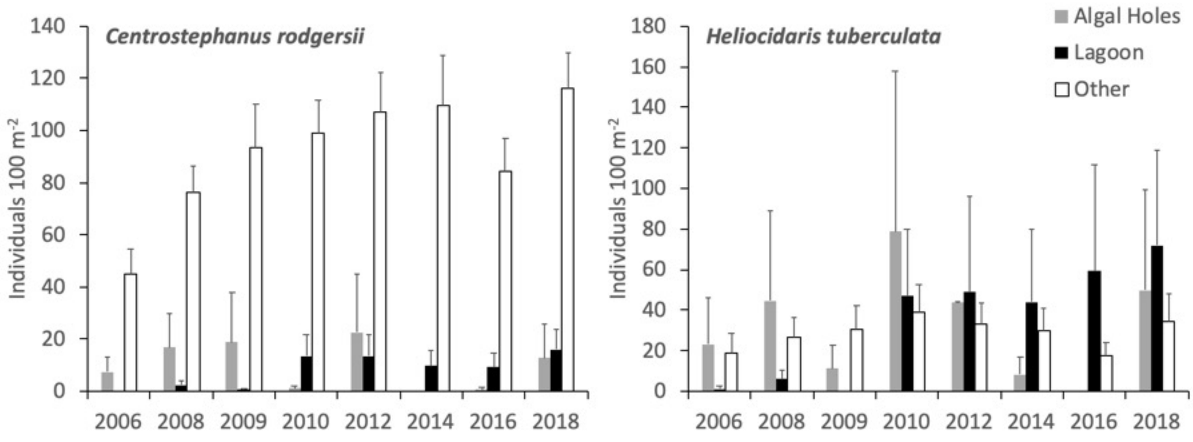

Figure 18. Trends in density *Centrostephanus* and *Heliocidaris* urchins (+ SE of site means) at the Algal Holes sites compared with other locations.

Assessment of the macroalgal cover at the Algal Holes sites indicated a decline between 2014 and 2018, from ~84% to 60% (Figure 17). With the current grouping of taxa, there was no evidence of a decline in richness of taxa scored in photoquadrats at the Algal holes over this period, and while there were significant declines in the Lagoon and outer reef habitats, 2018 values were no lower than at the start of monitoring in 2006 (Figure 18).

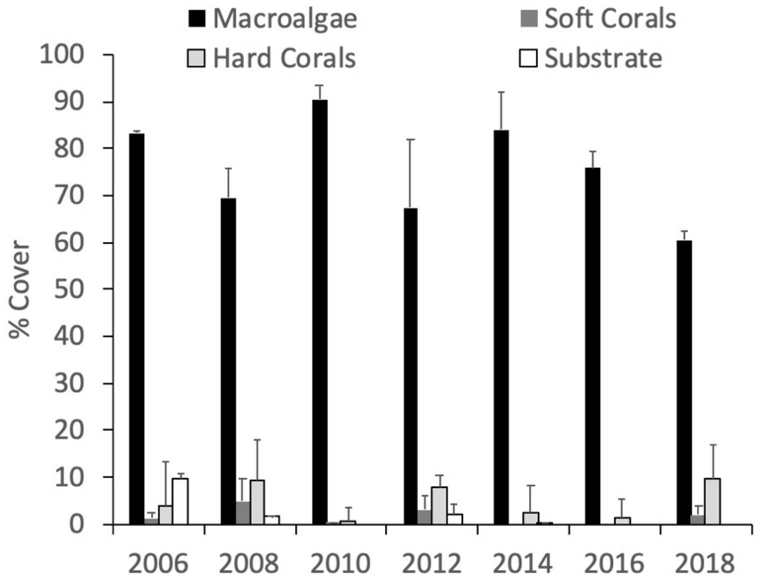

Figure 19. Changes in cover and (+ SE) of major substrate categories at the Algal Holes sites.

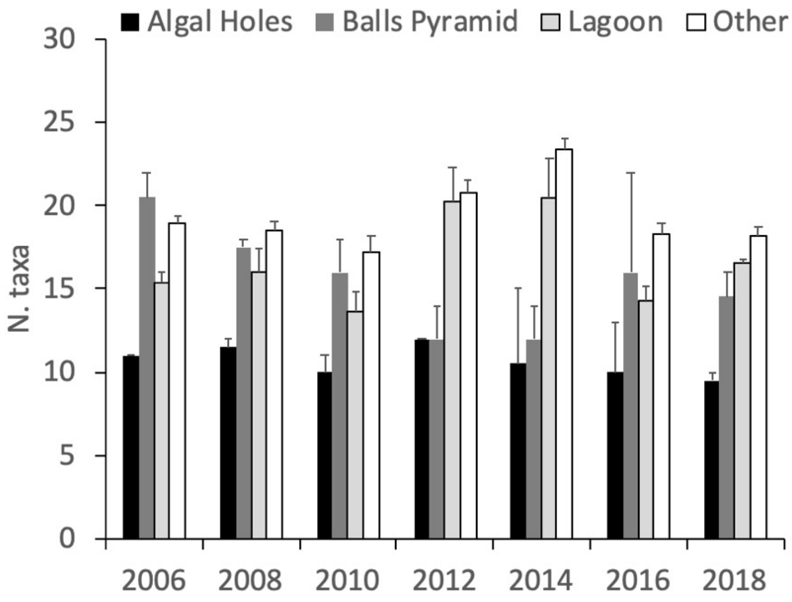

Figure 20. Trends in mean richness of taxa (+SE) recorded in photoquadrats (among taxa occurring in algae, corals and soft coral groupings only) in different habitat types. Differences between the groups of sites in different habitats ($F_{3,138}$=32.34, P<0.001) and the effect of site (nested within habitat; $F_{24,138}$=2.28, P<0.01) were significant, as was the interaction between year and habitat type ($F_{18,138}$=2.63, P<0.01) (F values are Pseudo-F values from PERMANOVA).

4 Discussion

The objectives of this report were to continue to monitor coral reef communities of the Lord Howe Island Marine Park, particularly organisms that give an indication of reef condition. This includes ongoing trends in sea urchin and bluefish densities, macroalgae cover, and a continued assessment of sites that suffered bleaching in 2010. A summary of results relating to these is provided here:

- The outbreak of the sea urchin *Tripneustes gratilla* at the Admiralty Islands and wave-exposed sites subsided in 2014, and this species has remained largely absent in 2016 and 2018. However, the macroalgal cover at sites affected by the outbreak remains low.

- Sea urchin densities in the Algal Holes area (mostly *Heliocidaris tuberculata*) declined from 2010 to 2014, but began to increase again in 2018.

- Macroalgae appear to be declining at the Algal Holes sites; between 2014 and 2018, macroalgal cover was reduced from ~84% to 60%. This may be linked to recent increases in sea urchin densities and/or environmental factors. The risk of extinction of endemic macroalgae is of concern.

- Bluefish (*Girella cyanea*) densities remain as low in 2018 as they were in 2010 and 2014. Doubleheader wrasse (*Coris bulbifrons*) were higher in HPZs than SZs in 2018, but populations show no clear trends. Both species remain a potential concern, even within SZs.

- Coral cover at sites affected by the substantial bleaching event in 2010 appears to be recovering at most sites; the ca. 15% loss of live corals at Horseshoe Reef (site LHI40) is now a 8.1% loss (51.6% total coral cover in 2010, 36.3% in 2014, 43.5% in 2018). North Bay, however, has shown continued decline in live hard corals. No large changes in invertebrate and fish communities have been observed at coral loss sites.

Other important results identified in these analyses include:

- The decline in fish biomass in sanctuary zones (SZs) between 2012 and 2014 indicated a loss of a substantial ‘reserve effect’ that had built up to 2012. This decline has not continued, and biomass has remained stable in 2016 and 2018, suggesting a return of effective compliance and recovering populations; it is likely to take time for biomass to build again. Fish community structure was generally very stable.

- The cyclical trend in planktivores has become clearer with two additional surveys; this trend mirrors the overall trends in fish biomass. Planktivores contribute at least one-third of the total fish biomass, and these temporal dynamics suggest that cycles in plankton delivery to the island may be important in shaping overall fish productivity.

- A sharp decline in Galapagos sharks (*Carcharhinus galapagensis*) was evident inside and outside SZs from 2014 to 2018.

- Kingfish (*Seriola lalandi*) declined in frequency between 2014 and 2018, from being oserved in 9.4% of transect blocks to 6.5% of transect blocks. Black cod (*Epinephelus daemelii*) frequency did not change (1.9%) between 2014 and 2018.

- There was evidence of a return of drummer biomass (*Kyphosus* species) in both HPZ and SZ sites. This trend was less clear for other important herbivorous fishes in SZs, including sawtail surgeonfish (*Prionurus maculatus*) and bluefish.

- There was a general decline in *Caulerpa* cover in all habitats, back to the sparse cover originally recorded in earliest survey years.

SEA URCHINS AND MACROALGAE

Lord Howe Island is a refuge for key species of macroalgae, some of which (47 species) are endemic, and which provide critical habitat for fishes and invertebrates during parts of their life cycle (Edgar et al. 2010). The Algal Holes are particularly rich in macroalgae, and support a unique reef community which can be vulnerable to overgrazing by sea urchins or to increases in temperature associated with climate change (Edgar et al. 2010). The general loss of macroalgae cover from the Algal Holes during 2016 and 2018 is of concern, and cannot be attributed entirely to sea urchins. The general decline in *Caulerpa* cover in all habitats suggests that environmental factors were also responsible for the declines in the Algal Holes.

Sea urchins are important and natural components of the LHI reef systems, but their populations are easily affected by changes in abundance of their key predators, which are in turn affected by fishing pressure (Shears and Babcock 2002, Barrett et al. 2009, Ling et al. 2009). Under reduced predation, they have the potential to reach high densities and overgraze the unique macroalgal communities found only on reefs around the island (Edgar et al. 2010).

Tripneustes, *Heliocidaris* and *Centrostephanus* have maintained low densities in wave-exposed and Algal Hole sites, but the macroalgal component of the sessile communities at *Tripneustes* affected sites has not returned to pre-outbreak cover, and the potential for *Heliocidaris* overgrazing in the Algal Holes remains, despite low urchin densities in the 2014-2018 period.

The declines in doubleheader biomass and of benthic carnivores in general imply a reduction in the potential for predatory control of urchins, and a corresponding increase in potential for future urchin density increases (or behavioural 'release') that could result in destructive grazing. The brief increase in the biomass of these species in 2016 appears not to have persisted to 2018. Recovery of species which may contribute to ecological control of urchins could be assisted through establishment of a sanctuary zone around the Algal Holes area and/or tightened fishing controls on important species such as doubleheader. Such management action is not guaranteed to prevent urchin overgrazing, but, regardless, the likelihood of ecological gains in some form make this proactive approach worth considering.

FISH AND FISHING ACTIVITIES

In 2016 and 2018 the abundance and biomass of large fishes in SZs stabilised, after a large decline in 2014. Protection from fishing apparently resulted in an increase in large fish biomass and total fish biomass between 2006 and 2012 within SZs, but this gain was eroded between 2012 and 2014. The large difference between zones of 60 kg per 500 m^2 in 2012 was reduced to no difference between zones by 2014. This loss was partly driven by the the substantial reduction in biomass of drummer (*Kyphosus* spp.); the subsequent increase to 2018 also appeared to be driven in large part by this species. The trend in drummer biomass is unlikely to relate to fishing pressure, however, as drummers are not targeted by fishers in LHI. The effectiveness of no-take reserves such as the SZs at LHI is easily compromised by illegal fishing, and populations can take a long time to recover due to limited connectivity to external sources of larvae (van der Meer et al. 2015, Steinberg et al. 2016), and limited potential for population establishment in marginal environmental conditions (Keith et al. 2015).

The trend in total fish biomass was also partly a result of increasing planktivore biomass, which appears to be showing an upward trend as part of a long-term cycle. Thus, total fish biomass at LHI likely partly reflects oceanographic patterns that result in changes in plankton delivery and secondary productivity (with a lag in biomass increases on higher carnivores). This would not be expected to differ between management zones, however. Habitat complexity was shown to interact with SZ protection within LHIMP to influence target fish biomass (Rees et al. 2018); while changes in benthic composition may have affected reef structure in this study, structural complexity was not measured specifically. Interestingly, Galapagos sharks increased in biomass in the years to 2014; this biomass was largely lost by 2018, declining 5-fold in HPZs by 2016, and then in 2018 also in SZs. The cycles in Galapagos shark abundance appear to lag approximately two years behind those in planktivore biomass; this shows a possibility that Galapagos shark may be dependent on planktivores as prey, and that their populations are therefore as vulnerable to oceanographic cycles as to fishing pressure. Anecdotal recent increases in the frequency of interactions between Galapagos sharks and fishing activities may also represent shifting habitat use by the sharks, moving between reef and open water food sources.

The biomass of bluefish, one of the primary target species, showed a significant reserve effect in 2016, but in 2018 the biomass was similar to that in 2014 in both HPZs and SZs. Given the long-lived nature of many species of large fishes targeted by fisheries, visible and consistent recovery from the dramatic reduction in 2014 is likely to take longer than four years. It is possible that trends in Galapagos shark populations may have contributed to fluctuating biomass of other species, either directly, through increased predation, or indirectly through inducing increased hiding behaviour in prey.

CLIMATE CHANGE

Indirect effects of coral loss through bleaching, and direct effects of warm water events on recruitment or population dynamics of reef species, may both contribute to important ecological change on reefs within the LHIMP. Coral growth rates have already been found to be declining on Lord Howe Island reefs in response to decreasing aragonite saturation and warming seas (Anderson et al. 2015). The increases in *Caulerpa* cover and subsequent declines as corals began to recover offers a strong suggestion for competition between corals and these algae in particular. However, as warm events fuel the growth of *C. taxifolia*, a warm water species, corals can be disadvantaged.

An alternative explanation is that trends in *Caulerpa* are associated with changes in herbivorous fish populations, particularly drummer, bluefish and sawtails. Herbivorous fish biomass in SZs in 2014 was the lowest recorded in any zone in any monitoring year; the 2014 survey also recorded high cover of *Caulerpa*. Possibly partly associated with a return of active management, but also likley a consequence of unknown environmental factors, herbivorous fishes increased on surveys again in 2018. It is possible that this, along with changes in sea urchin densities, were responsible for the concomitant decline in *Caulerpa*. Targeted research is needed to help inform whether these important changes in the benthic community are more likely linked to trends in herbivorous fishes or environmental change, particularly as the former offers potential for management intervention. Such research may require transplantation and cage experiments and might be most cost-effective if undertaken as part of a university postgraduate research project.

The Community Temperature Index (CTI) was examined for the fish community to better identify if the abundance or relative abundance of warm affinity species was increasing or cool affinity species were disappearing. The former appears to be the major contributor to a long-term warming signal in reef fishes in Tasmania (Bates et al. 2014), and for seasonal and inter-annual variation in CTI at mainland locations such as Port Stephens and Sydney (RLS, unpublished data). The magnitude of CTI change at LHI between 2006 and 2018 has been very low (0.26^{o}C) and is probably of little ecological significance, being far less than short-term variation at locations investigated on the mainland. However, the geographical isolation of LHI means that there is very limited opportunity for adult immigration for the majority of reef species, or recruitment of new species with short larval stages. Only long-distance larval dispersal and recruitment events may add new species to the community, or replenish a depleted community (Ayre and Hughes 2004). The observed stability in CTI at LHI is probably in large part due to these effects of isolation, and may possibly also reflect less dynamic community structure (that is, relatively small changes in composition of species in the fish community), compared to mainland locations, although this remains to be tested.

Although low variation to the present suggests application of the CTI at LHI is of limited value, this index is easily calculated using transect data for the fish community (and the invertebrate community), and offers potential to highlight important ecological changes. It is unknown how local endemic species will respond to warming, and it is difficult to make predictions on the basis of contemporary geographic distributions (e.g. as in (Stuart-Smith et al. 2015b)), given these species are limited in geographic range by factors other than temperature. Future changes in the CTI (of larger magnitude than that noted here) would highlight a need for more detailed investigation of underlying causes of changes in species composition, regardless of whether in the direction expected due to warming or not.

5 Recommendations

Management recommendations arising from the Reef Life Survey monitoring program, including confirmation of some previous recommendations, are as follows:

- The previous recommendation of creating a sanctuary zone that includes the unique Algal Holes community type is affirmed. A preliminary suggested zone is shown in Fig 19, as an extension of the current Lagoon Sanctuary Zone to include the Algal Holes and the complex structures associated with coral reefs outside the lagoon in the vicinity of Little Island. No fishing of any species is the recommended zoning option, given uncertainties over which species may assist in keeping urchin densities under control and the unknown roles of herbivorous fishes in either facilitating or grazing endemic seaweeds. Regarding ongoing monitoring, additional transects should be added to the two monitoring sites at the Algal Holes to more closely track urchin densities at this location. Two additional transects would be most feasible initially, running in the opposite direction to the two parallel transects historically surveyed at each site. In the event that ongoing monitoring identifies further substantial increases in urchin densities, then it may be necessary to consider urchin removal as a management option.
- Additional research should investigate other (not urchin-related) potential causes of macroalgae loss, especially environmental factors associated with nutrient input to the region, and with climate change.
- Targeted research should be considered to better understand the population dynamics of bluefish and doubleheader wrasse.
- Population dynamics of Galapagos sharks, including identification of prey and patterns of habitat use, should be investigated.
- Monitoring should be continued through the long-term on a two-yearly basis, or more frequently.
- Additional surveys of impacted and reference sites should be undertaken following exceptional events (e.g. oil spills, extreme bleaching).
- With the exception of suggested modification of boundaries associated with the Algal Holes, the boundaries of sanctuary zones should remain stable through the long term.
- Potential illegal fishing activities should be investigated, and consideration given to an education campaign to raise awareness in the local community of ecological and conservation importance of bluefish and doubleheader, in particular. Populations of these species appear to have declined to ~1/3 of their 2006 biomass and, regardless of the ultimate cause of declines, the local fishing community has an important role to play in bringing these species back to densities needed to play their natural roles in the ecosystem.

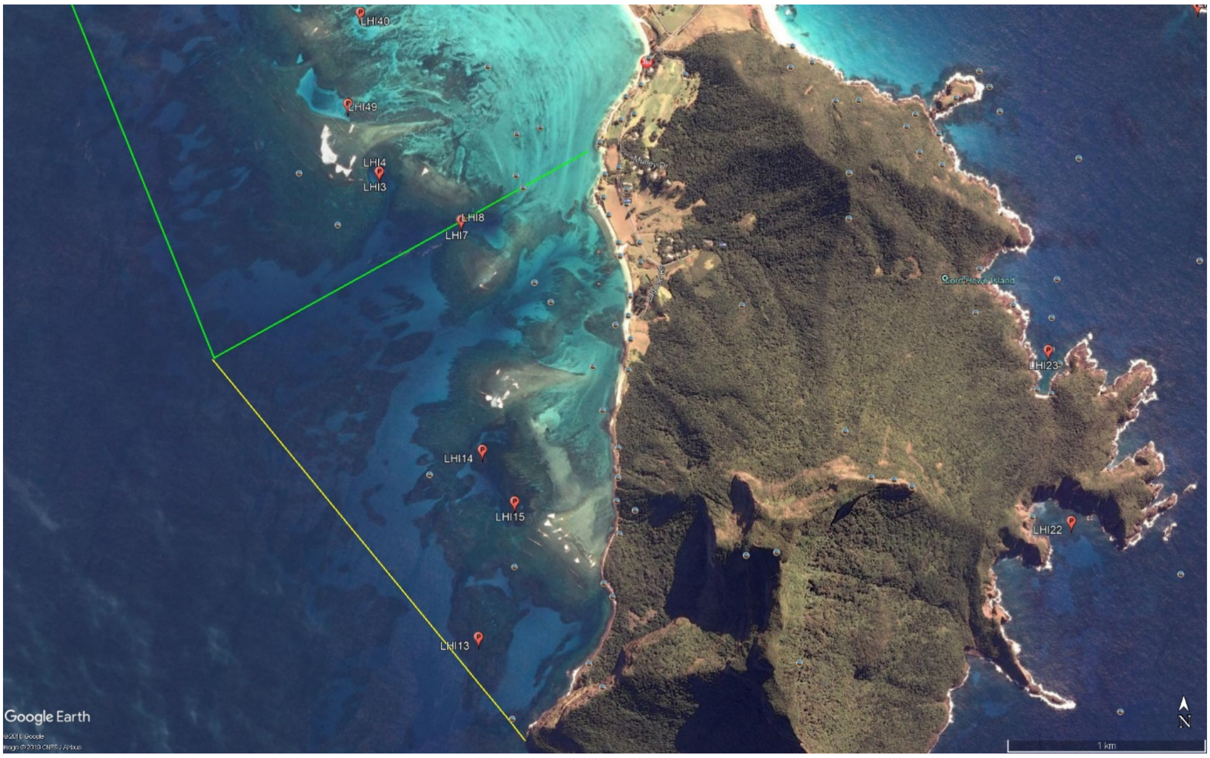

Figure 21. Map of sanctuary zone suggested for Algal Holes. Green lines represent approximate location of the Lord How Island Lagoon Sanctuary Zone. The Yellow represents a recommended extension to this to encompass the Algal Holes area, and complex coral formations offshore from Little Island.

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Appendices

APPENDIX 1 –Fish species recorded on M1 transects in each year, and their frequency of occurrence (numbers represent the % of transect blocks surveyed in that year on which each species was recorded, with the total number of transect blocks surveyed in that year at the top of the column).

Family	**Species**	**2006**	**2008**	**2009**	**2010**	**2012**	**2014**	**2016**	**2018**
	Numer of $250m^2$ blocks	132	152	162	232	222	212	242	216
Acanthuridae	Acanthurid spp.		4.6	1.2	0.9	1.4	0.9		
	Acanthurus albipectoralis						1.4		
	Acanthurus blochii	0.8						2.1	
	Acanthurus dussumieri	3.0	3.9	0.6	0.4	0.5	1.4	0.4	0.5
	Acanthurus nigrofuscus					5.9	1.4	5.8	5.6
	Acanthurus olivaceus	0.8							0.5
	Acanthurus spp.						0.5		0.5
	Acanthurus triostegus							0.4	
	Ctenochaetus striatus			0.6		0.9	0.9	0.4	
	Naso brevirostris			1.9			1.9	3.7	0.9
	Naso lituratus			0.6				0.4	
	Naso spp.		1.3		0.9	0.5			
	Naso unicornis	3.0	2.0	2.5	5.2	4.1	0.9	9.1	3.7
	Naso vlamingii						0.5	0.8	
	Prionurus maculatus	12.9	25.0	21.6	24.6	25.7	20.8	28.1	23.1
	Prionurus microlepidotus	0.8			2.6	0.5	0.5	2.1	1.4
	Zebrasoma scopas	3.0	2.6	2.5	3.9	5.4	4.7	5.8	5.6
	Zebrasoma velifer	0.8	0.7	1.2	0.4	0.9	0.9	3.3	
Aplodactylidae	*Aplodactylus etheridgii*	9.1	9.9	4.9	8.2	9.5	3.3	7.4	4.6
Apogonidae	*Apogon doederleini*	6.8	6.6	1.9	7.8	7.2	6.6	8.7	7.9
	Apogon flavus	10.6	16.4	18.5	17.2	20.7	21.2	16.9	16.7
	Apogonid spp.			0.6					
	Cheilodipterus macrodon						0.5		
	Cheilodipterus quinquelineatus	1.5	2.6	2.5	5.2	8.6	2.8	3.3	6.9
	Ostorhinchus aureus						0.5		
	Ostorhinchus norfolcensis	37.1	55.3	43.8	50.9	45.0	42.5	52.1	54.6
Arripidae	*Arripis trutta*								0.9
Atherinidae	Atherinid spp.					0.5			
	Atherinomorus vaigiensis							0.4	

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
Aulostomidae	*Aulostomus chinensis*	1.5	0.7	1.2	0.4	1.8	1.9	1.2	2.3
Balistidae	*Balistoides conspicillum*		0.7		0.4	0.5	0.5		
	Rhinecanthus lunula							0.4	
	Sufflamen chrysopterum	1.5	2.0	1.2	0.9	4.1	1.4	3.3	3.2
	Sufflamen fraenatum	12.1	21.1	8.6	19.0	14.0	7.1	9.5	6.5
Belonidae	Belonid spp.								0.5
	Strongylura incisa							0.4	
	Tylosurus crocodilus							1.2	
Blenniidae	*Aspidontus taeniatus*		0.7						0.5
	Blenniid spp.			2.5		0.9		1.7	0.9
	Cirripectes alboapicalis	0.8	7.9	8.0	0.4	2.3	6.6	0.4	14.8
	Cirripectes chelomatus	3.8			2.2		2.8	5.8	6.9
	Cirripectes filamentosus				0.9				
	Cirripectes spp.					5.0	7.1	2.1	8.8
	Cirripectes stigmaticus					1.4			0.9
	Exallias brevis				0.4		0.9	0.4	0.5
	Meiacanthus atrodorsalis						0.5		
	Plagiotremus rhinorhynchos	1.5	1.3	2.5	3.0	0.9	0.9	6.2	1.9
	Plagiotremus tapeinosoma	21.2	38.8	38.9	17.7	20.3	40.1	40.1	49.5
	Stanulus talboti		2.0			4.1	6.6	4.5	11.6
Bothidae	*Bothus mancus*					0.9			
Caesionidae	*Pterocaesio digramma*		1.3						0.5
Carangidae	Carangid spp.				0.4				
	Carangoides orthogrammus					0.9		1.2	2.3
	Caranx lugubris		0.7		0.4	3.6	0.5	0.4	
	Caranx melampygus			0.6	0.9				
	Caranx sexfasciatus					0.5			
	Elagatis bipinnulata				0.9				0.5
	Pseudocaranx georgianus	2.3	2.6	1.9	2.6	6.3	3.8	1.2	
	Pseudocaranx sp. *[dentex]*							3.3	3.2
	Seriola dumerili								0.5
	Seriola lalandi		2.6		4.3	3.6	4.7	3.7	3.2
	Seriola rivoliana	0.8			1.7	0.5	0.9	0.4	
	Trachinotus baillonii				0.4				
	Trachurus novaezelandiae		0.7						
Carcharhinidae	*Carcharhinus galapagensis*	0.8	5.9	6.8	2.6	17.1	17.9	18.6	6.9
Chaetodontidae	*Amphichaetodon howensis*	8.3	7.2	4.9	4.7	7.2	6.1	6.6	4.2
	Chaetodon auriga	11.4	10.5	13.0	4.7	4.5	11.8	8.7	7.9
	Chaetodon bennetti		0.7	1.2	0.9	0.5	0.5		
	Chaetodon citrinellus	7.6	3.3	3.7	7.3	6.8	6.6	9.5	3.7

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
	Chaetodon ephippium				1.3				2.8
	Chaetodon flavirostris	21.2	20.4	16.0	19.8	14.9	14.6	21.5	12.0
	Chaetodon guentheri	1.5	4.6	4.3	2.2	6.8	4.2	8.7	8.8
	Chaetodon kleinii	4.5			1.3				0.5
	Chaetodon lineolatus	3.8	0.7	1.2	1.3		0.5	1.7	1.4
	Chaetodon lunula							0.4	
	Chaetodon lunulatus	4.5	4.6	6.2	1.3	2.3	2.8	3.7	2.3
	Chaetodon melannotus	12.9	9.9	16.7	22.0	16.2	18.4	28.9	20.4
	Chaetodon mertensii	2.3	1.3	3.7	3.4	1.4	2.4	3.3	5.6
	Chaetodon ornatissimus			0.6	3.0		0.9	1.2	0.9
	Chaetodon pelewensis	4.5	6.6	4.3	5.6	9.9	3.3	10.7	8.8
	Chaetodon plebeius	7.6	9.2	10.5	15.9	7.2	9.0	14.0	9.3
	Chaetodon rainfordi		1.3		0.4	1.4		0.4	
	Chaetodon speculum	2.3	2.6	1.9	0.4	1.4	1.4	2.1	0.9
	Chaetodon spp.			0.6	0.9				
	Chaetodon tricinctus	44.7	56.6	58.6	64.7	59.9	50.9	69.8	55.6
	Chaetodon trifascialis	1.5	9.9	1.9	12.5	7.7	4.7	4.1	6.5
	Chaetodon ulietensis		2.0	1.2					
	Chaetodon unimaculatus		0.7	1.9	1.7		0.5		
	Chaetodon vagabundus		1.3		0.9	1.4	0.5	0.8	
	Forcipiger flavissimus	2.3	1.3	0.6	0.9	2.7	0.9	2.1	1.9
	Heniochus acuminatus		2.0	0.6	0.4	3.6	2.4		0.5
	Heniochus chrysostomus			0.6	0.4	1.4			
	Heniochus monoceros			0.6					
	Heniochus varius					1.4	0.5		
Cheilodactylidae	*Cheilodactylus ephippium*	18.2	24.3	24.1	30.2	32.0	30.7	26.0	25.5
	Cheilodactylus francisi	0.8	0.7		1.7	0.5	3.3		1.4
	Cheilodactylus vestitus	2.3	4.6	1.9	0.9			1.7	0.5
Cheloniidae	*Chelonia mydas*				2.2	1.4	0.5	1.2	
	Eretmochelys imbricata					0.5			
Chironemidae	*Chironemus marmoratus*			0.6					
	Threpterius maculosus							0.4	
Cirrhitidae	*Cirrhitichthys aprinus*				0.4				
	Cyprinocirrhites polyactis				0.4				
	Notocirrhitus splendens	26.5	17.8	18.5	18.1	27.5	11.3	12.4	21.3
	Paracirrhites forsteri					0.5		0.8	0.5
Clupeidae	Clupeoid spp.						0.5		0.5
Creediidae	*Limnichthys fasciatus*					0.9		0.8	3.7
Dasyatidae	*Bathytoshia brevicaudata*							0.4	0.9
	Dasyatis thetidis	0.8		0.6		0.5		0.8	0.5

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
	Taeniura meyeni				0.4		0.5	0.8	1.4
Diodontidae	*Chilomycterus reticulatus*							0.4	
	Diodon holocanthus			0.6		0.5		0.4	
	Diodon hystrix	1.5	0.7		0.9		0.9	2.5	0.9
Echeneidae	*Echeneis naucrates*					0.5			
Fistulariidae	*Fistularia commersonii*	2.3	1.3	1.2	6.5	11.3	5.7	4.5	2.3
Gobiesocidae	Gobiesocid spp.				0.4				
Gobiidae	*Amblygobius nocturnus*				1.7	0.5	0.5		0.5
	Amblygobius phalaena	3.8	3.3	5.6	9.5	5.4	3.3	2.9	3.2
	Asterropteryx semipunctata							0.4	
	Eviota hoesei			0.6	0.4		1.9	6.6	16.2
	Eviota readerae						0.5	0.8	0.5
	Eviota spp.					13.5	3.8	0.4	3.7
	Exyrias spp.							0.4	
	Favonigobius spp.				0.4				
	Fusigobius duospilus								0.5
	Fusigobius neophytus					2.3	1.9	2.1	0.5
	Gnatholepis anjerensis			1.9	2.6	1.8		0.8	
	Gnatholepis cauerensis	0.8	0.7				1.9	0.8	2.3
	Gobiid spp.			1.2	0.4	1.4	0.5	2.1	
	Gobiodon citrinus								0.5
	Gobiodon spp.								0.5
	Istigobius rigilius					0.5	1.4		0.9
	Macrodontogobius wilburi				0.4			0.8	0.9
	Valenciennea strigata				0.9				
Haemulidae	*Diagramma labiosum*					0.9	0.5	1.2	
	Plectorhinchus flavomaculatus						0.5		
	Plectorhinchus picus	6.1	3.9	4.9	6.9	5.0	6.1	4.1	5.1
Hemiramphidae	*Hyporhamphus* spp.								0.9
Holocentridae	*Myripristis berndti*						0.5		
	Myripristis murdjan								0.5
	Neoniphon sammara			0.6			0.5	0.4	
	Sargocentron rubrum		0.7	0.6	0.4				
	Sargocentron spp.				0.4				
Kuhliidae	*Kuhlia mugil*							0.4	
Kyphosidae	*Atypichthys latus*	7.6	12.5	8.0	9.5	8.6	8.0	8.3	8.8
	Bathystethus cultratus		1.3	0.6	0.4		0.5		0.9
	Girella cyanea	15.9	25.0	17.9	12.5	21.2	17.5	24.8	25.0
	Kyphosus bigibbus	15.9	30.3		21.6	14.9	25.0	30.2	14.4
	Kyphosus cinerascens	1.5							0.5

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
	Kyphosus sectatrix	12.1	8.6		12.9	29.3	20.8	18.2	28.7
	Kyphosus spp.			14.2		3.6			0.5
	Kyphosus sydneyanus			16.7		5.0			
	Kyphosus vaigiensis			1.9	1.3	0.9	0.5	0.4	5.1
	Labracoglossa nitida				3.0		8.0	5.4	2.8
	Microcanthus strigatus	4.5	3.3	5.6	3.4	0.9	3.8	1.2	1.9
	Scorpis violacea		0.7	0.6	2.2	4.1	0.9		0.9
Labridae	*Anampses caeruleopunctatus*		1.3		6.5	4.5	2.4	3.7	2.3
	Anampses elegans	31.8	50.0	45.7	40.1	35.6	28.8	43.0	43.5
	Anampses femininus	6.1	1.3	6.2	3.4	6.8	7.1	5.4	6.0
	Anampses geographicus			0.6	3.9	1.8	0.5	2.5	0.5
	Anampses neoguinaicus	4.5	7.9	6.8	17.7	17.1	10.8	6.6	6.9
	Anampses spp.	0.8			0.4				
	Bodianus axillaris			0.6	0.9	0.9			
	Bodianus perditio	0.8	0.7				0.5	1.2	
	Cheilinus chlorourus					0.9		0.4	1.4
	Cheilinus spp.					0.9			
	Cheilinus trilobatus				0.9				
	Cheilio inermis	0.8	0.7	2.5	5.6	4.1	3.8	6.6	5.1
	Cirrhilabrus punctatus			0.6	0.9	5.0	1.4	3.3	1.4
	Coris aygula				0.0	0.9		1.2	0.5
	Coris bulbifrons	37.9	55.3	45.1	48.7	45.5	44.3	60.7	48.6
	Coris dorsomacula							0.4	
	Coris picta	15.2	6.6	15.4	9.1	11.3	13.2	16.9	11.6
	Coris sandeyeri				0.9			1.7	1.4
	Coris spp.					0.9			
	Epibulus insidiator					0.5	0.5		
	Gomphosus varius	13.6	19.1	17.9	27.2	28.8	26.9	25.6	25.9
	Halichoeres biocellatus			0.6					
	Halichoeres hortulanus				1.3	0.9			
	Halichoeres margaritaceus				1.3			0.4	
	Halichoeres marginatus					1.4	0.5		
	Halichoeres melanurus					0.5		0.8	
	Halichoeres nebulosus				0.9	0.5		0.8	
	Halichoeres spp.	1.5	2.6						
	Halichoeres trimaculatus		1.3	1.2	6.0	5.0	5.7	2.1	3.2
	Hemigymnus fasciatus			0.6	0.9	0.9	2.8	2.1	1.4
	Hemigymnus melapterus	0.8	2.0	5.6	4.7	9.9	9.9	8.7	6.9
	Hologymnosus annulatus			0.6	0.4	0.5		0.8	0.5
	Hologymnosus doliatus							0.4	

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
	Hologymnosus sp. *[dark]*	0.8							
	Labrichthys unilineatus		2.6	2.5	6.9	15.8	4.7	3.3	2.8
	Labrid spp.	10.6	1.3	5.6	6.9	0.9	0.9		
	Labroides bicolor			4.9	1.7	5.0	2.8	8.7	0.9
	Labroides dimidiatus	33.3	34.2	48.1	58.2	54.5	38.7	47.5	44.9
	Macropharyngodon meleagris	0.8	3.3	1.2	5.2	9.9	3.3	5.4	4.2
	Macropharyngodon negrosensis			0.6					
	Macropharyngodon spp.	0.8							
	Notolabrus gymnogenis			0.6				0.4	0.5
	Notolabrus inscriptus	29.5	34.9	29.0	20.3	27.9	20.3	30.6	18.5
	Novaculichthys taeniourus				0.4				
	Novaculoides macrolepidotus	2.3							
	Oxycheilinus digrammus			1.2					
	Oxycheilinus spp.					0.5			
	Pseudocheilinus hexataenia		2.6	4.9	6.5	10.8	6.6	9.1	12.0
	Pseudocoris yamashiroi						0.5		
	Pseudojuloides elongatus					0.5			0.9
	Pseudolabrus luculentus	89.4	99.3	97.5	96.1	96.8	99.1	97.5	98.1
	Stethojulis bandanensis	12.1	18.4	17.3	28.0	26.6	24.5	16.5	21.8
	Stethojulis interrupta			3.1	4.3	3.2	0.5	3.3	1.4
	Stethojulis spp.	1.5				0.5			
	Stethojulis strigiventer					5.4	0.9	1.7	
	Suezichthys arquatus			0.6					
	Thalassoma amblycephalum	0.8	5.9	14.2	22.0	26.1	18.9	20.7	24.1
	Thalassoma hardwicke	6.8	9.2	8.0	19.8	21.2	20.8	17.4	19.0
	Thalassoma jansenii			3.1					
	Thalassoma lunare	10.6	13.8	27.2	32.8	37.8	38.2	28.1	31.9
	Thalassoma lutescens	50.0	70.4	51.9	59.9	61.3	54.2	55.8	52.3
	Thalassoma nigrofasciatum	5.3	4.6		3.9	13.1	9.0	5.8	2.8
	Thalassoma purpureum	11.4	22.4	11.7	21.1	20.7	11.3	17.8	18.5
	Thalassoma quinquevittatum		1.3	2.5	1.7	1.8	0.5		0.9
	Thalassoma spp.	0.8							
	Thalassoma trilobatum		3.3		0.9	0.9	1.4	4.1	1.9
Lethrinidae	*Lethrinus atkinsoni*							0.4	
	Lethrinus nebulosus	2.3	3.3	5.6	4.7	2.7	0.5	5.4	2.8
	Lethrinus spp.	0.8							
	Monotaxis grandoculis	0.8	0.7						
Lutjanidae	*Lutjanus bohar*				1.3	0.5			
	Lutjanus fulviflamma	1.5	1.3				0.5	0.4	
	Lutjanus kasmira			0.6	0.9		0.5		0.5

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
	Lutjanus spp.		0.7						
	Paracaesio xanthura	6.1	1.3	3.1	5.2	6.8		1.2	4.6
Malacanthidae	*Malacanthus brevirostris*				0.4				
Microdesmidae	*Ptereleotris evides*	3.0	0.7	1.9	2.6	2.7	2.8	2.9	1.9
	Ptereleotris monoptera					0.5	0.5		
	Ptereleotris zebra			0.6		0.5			
Monacanthidae	*Aluterus scriptus*	0.8							
	Cantherhines dumerilii		2.0	1.9	1.3	5.0	3.3	8.7	7.9
	Cantherhines fronticinctus					1.4	0.5	0.8	0.9
	Cantherhines pardalis	7.6			3.4	5.9	0.9	1.7	4.6
	Monacanthid spp.		1.3	0.6					0.5
	Oxymonacanthus longirostris	0.8			1.7	1.4	0.9	1.2	1.9
	Paraluteres prionurus								0.5
	Pervagor alternans				1.7	1.8	0.5	1.2	0.9
	Pervagor janthinosoma						0.5	0.4	0.9
	Thamnaconus analis	5.3	2.6	0.6	4.7	1.4	1.4	5.4	4.2
Moridae	Morid spp.				0.4				
Mullidae	*Mulloidichthys flavolineatus*	1.5	0.7	1.9	3.0	5.9	2.8	5.8	2.8
	Mulloidichthys vanicolensis					1.4	0.5	2.1	1.4
	Parupeneus barberinus				0.4	0.5		0.4	0.5
	Parupeneus ciliatus	0.8	3.9	1.2	0.9	4.5	4.7	5.8	2.3
	Parupeneus cyclostomus				0.4				
	Parupeneus multifasciatus			0.6	1.3	0.5		1.7	
	Parupeneus pleurostigma	1.5	0.7					0.4	0.9
	Parupeneus spilurus	18.9	29.6	21.0	32.3	18.9	12.7	24.4	21.8
	Parupeneus spp.			0.6					
Muraenidae	*Echidna nebulosa*					0.5			
	Enchelycore ramosa	0.8	0.7	1.9		0.9	0.9	0.4	0.9
	Gymnothorax annasona	2.3	4.6	0.6	1.7	2.3	0.5	1.7	1.9
	Gymnothorax eurostus	2.3	0.7	3.1	2.2	4.5	2.4	1.7	6.9
	Gymnothorax favagineus			0.6			0.5		
	Gymnothorax meleagris				0.9		0.5	0.8	0.9
	Gymnothorax nubilus								0.5
	Gymnothorax prionodon			0.6	0.4				
	Gymnothorax spp.				0.4				
	Gymnothorax thyrsoideus	0.8							
Nemipteridae	*Pentapodus* spp.							0.4	
	Scolopsis bilineata	0.8			0.9	1.4			0.5
Octopodidae	*Octopus* spp.			0.6					
Ophichthidae	*Leiuranus versicolor*				0.4				

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
Ostraciidae	*Ostracion cubicus*	5.3	6.6	3.7	6.5	5.4	6.1	10.3	9.3
	Ostracion meleagris		1.3			0.9	0.5	0.4	0.9
Pempheridae	*Pempheris analis*	3.0	6.6	11.7	9.9	10.8	6.1	12.8	8.8
	Pempheris oualensis			0.6			1.9		
Pempherididae	*Parapriacanthus elongatus*								0.5
	Parapriacanthus ransonneti						0.5		
Pinguipedidae	*Parapercis australis*		1.3	0.6	1.3	1.4	1.4	0.4	0.9
	Parapercis queenslandica						0.9	0.4	0.5
	Parapercis spp.					0.5		0.4	
Plesiopidae	*Plesiops insularis*							0.4	
Plotosidae	*Plotosus lineatus*		2.6	0.6			1.9	1.2	6.0
Pomacanthidae	*Centropyge bispinosa*						0.5		
	Centropyge spp.				0.4				
	Centropyge tibicen	12.1	9.2	15.4	15.1	10.8	17.0	16.1	10.6
	Centropyge vrolikii					0.5	0.5		0.5
	Chaetodontoplus conspicillatus	3.8	2.6	3.7	1.3	4.1	3.3	5.0	3.7
	Chaetodontoplus meredithi				0.4	0.0			
	Genicanthus semicinctus	1.5	1.3	1.2	2.2	1.8	0.9		1.9
	Pomacanthid spp.				0.4				
	Pomacanthus imperator				0.9	0.5			
	Pomacanthus semicirculatus		0.7				0.5	0.4	
Pomacentridae	*Abudefduf bengalensis*	0.8		0.6	0.4	1.4	1.4	2.1	
	Abudefduf sexfasciatus	9.8	3.3	9.3	6.5	8.6	13.7	8.7	13.4
	Abudefduf sordidus	0.8							
	Abudefduf vaigiensis		6.6	3.7	1.7	0.5	3.3	3.7	3.2
	Amphiprion latezonatus	0.8		0.6		0.5		3.7	0.5
	Amphiprion mccullochi	20.5	22.4	17.3	37.1	23.4	22.6	26.0	26.9
	Chromis agilis		0.7						
	Chromis amboinensis								0.5
	Chromis atripectoralis		5.9	2.5	10.3	9.5	13.7	13.6	10.6
	Chromis chrysura						0.5		
	Chromis flavomaculata	3.8	7.2	9.9	7.3	6.3	7.1	4.1	10.6
	Chromis hypsilepis	66.7	67.1	62.3	60.8	65.8	63.2	69.8	70.4
	Chromis iomelas							0.8	
	Chromis margaritifer	0.8			0.9			1.2	2.3
	Chromis vanderbilti			1.2	0.4	0.5			1.9
	Chromis viridis	6.1	0.7	0.6	0.9	1.8			
	Chrysiptera flavipinnis	0.8							
	Chrysiptera notialis	55.3	65.1	72.8	51.3	55.9	56.6	67.8	63.4
	Dascyllus aruanus	4.5	5.3	4.9	6.5	6.8	6.1	5.0	5.1

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
	Dascyllus reticulatus	3.0		0.6	3.0	4.1	5.2	5.0	3.2
	Dascyllus trimaculatus	0.8	0.7	1.2	1.7	1.8	0.5	2.1	0.9
	Neoglyphidodon polyacanthus	48.5	63.2	71.0	69.0	70.3	67.5	63.2	70.4
	Parma alboscapularis			8.0	3.0	0.9	0.5	2.5	1.9
	Parma microlepis							0.8	
	Parma polylepis	83.3	84.9	87.0	83.6	86.5	89.6	90.1	89.4
	Parma spp.			0.6					
	Plectroglyphidodon dickii	12.1	15.1	3.1	10.3	6.8	6.1	3.3	8.3
	Plectroglyphidodon johnstonianus			12.3	15.5	17.1	11.8	16.1	23.6
	Plectroglyphidodon lacrymatus					0.5			
	Pomacentrid spp.			1.2			0.5		
	Pomacentrus australis				0.9			0.8	
	Pomacentrus bankanensis				0.4				
	Pomacentrus coelestis	6.8		11.7	40.1	5.9	1.9	0.8	2.3
	Pomacentrus moluccensis		2.0	1.9		1.4	1.9	1.2	0.5
	Stegastes apicalis			0.6					
	Stegastes fasciolatus	48.5	67.1	67.9	62.1	72.1	67.9	66.9	74.1
	Stegastes gascoynei	70.5	73.0	74.7	73.7	76.1	91.0	83.5	85.2
	Teixeirichthys jordani								1.4
Priacanthidae	*Heteropriacanthus cruentatus*			0.6	0.4	0.5		0.4	1.4
	Priacanthus hamrur						0.9	0.4	
Ptereleotridae	*Aioliops* spp.								0.5
Scarinae	*Chlorurus frontalis*					1.4		0.4	0.5
	Chlorurus microrhinos	0.8	5.3			0.5	1.4	2.1	0.9
	Chlorurus sordidus		0.7	17.3	27.6	27.0	22.6	31.0	35.6
	Scarid spp.	18.2	7.9			15.3	0.9	0.4	1.4
	Scarus altipinnis		11.8	3.7	0.4	3.6	5.2	5.0	6.0
	Scarus chameleon		5.3			0.5	6.1	0.4	2.8
	Scarus dimidiatus					0.5			
	Scarus flavipectoralis					1.4		1.7	0.5
	Scarus frenatus	6.8	4.6		3.9	6.3	4.7	7.0	5.1
	Scarus ghobban	6.1	9.9	2.5	8.6	7.7	6.6	12.0	10.6
	Scarus globiceps					3.6	2.8	1.2	2.8
	Scarus longipinnis	0.8							
	Scarus niger		0.7	0.6	0.4			0.8	0.5
	Scarus oviceps						0.5	0.4	1.4
	Scarus psittacus				3.0	1.4	2.4	2.5	0.9
	Scarus rivulatus				1.3		6.1	9.1	7.9
	Scarus schlegeli						0.9	2.5	3.2
	Scarus spp.			13.0	3.4		3.3	0.4	

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
Scombridae	*Scombrid* spp.					0.5			
Scorpaenidae	*Dendrochirus zebra*					0.9	0.5		
	Pterois volitans	5.3	5.3	4.3	2.6	3.6	3.8	4.1	
	Scorpaena cardinalis	2.3	1.3				4.2	5.4	3.7
	Scorpaena cookii			6.2	3.0	7.7		1.2	
	Scorpaenodes spp.						0.5		
	Scorpaenopsis oxycephala								0.5
	Scorpaenopsis spp.								0.5
Serranidae	*Acanthistius cinctus*	4.5	6.6	2.5	3.9	5.4	1.4	6.6	6.0
	Cephalopholis argus				0.4			0.4	0.9
	Cephalopholis miniata	1.5			0.9	1.4	1.9	1.7	1.4
	Cephalopholis spp.					0.5			
	Epinephelus cyanopodus		2.6		0.4		0.9	0.4	
	Epinephelus daemelii	0.8	2.0	1.9	0.4	2.7	0.9	1.2	0.9
	Epinephelus fasciatus	1.5		0.6	0.4	0.5	0.5	1.2	0.5
	Epinephelus maculatus							0.8	
	Epinephelus merra			0.6	0.4				
	Epinephelus polyphekadion		0.7		0.9	0.5			0.5
	Epinephelus rivulatus							0.4	
	Epinephelus spp.		1.3		0.4				
	Epinephelus tauvina						0.5	0.4	
	Grammistes sexlineatus	0.8				0.5		0.4	0.5
	Hypoplectrodes annulatus							0.4	
	Hypoplectrodes sp. *[Lord Howe]*			0.6	0.4				0.9
	Hypoplectrodes spp.		0.7						
	Pseudanthias pictilis	3.8		0.6	0.4				
	Pseudanthias squamipinnis	13.6	14.5	0.6	12.5	12.2	9.4	11.2	13.0
	Trachypoma macracanthus	13.6	19.1	17.3	12.5	15.8	3.8	12.4	20.8
Siganidae	*Siganus fuscescens*							0.4	
Sillaginidae	*Sillago ciliata*								0.5
Soleidae	*Aseraggodes* spp.						0.5		
Sphyraenidae	*Sphyraena barracuda*	0.8							
	Sphyraena spp.					0.5			
Syngnathidae	*Halicampus boothae*			0.6					
Synodontidae	*Saurida gracilis*	0.8	0.7	0.6		0.5	0.9		
	Saurida nebulosa							0.4	
	Synodus binotatus					0.5			0.5
	Synodus dermatogenys				0.4		0.5	0.4	0.9
	Synodus doaki								0.5
	Synodus jaculum					1.4			

Family	Species	2006	2008	2009	2010	2012	2014	2016	2018
	Synodus similis							0.4	
	Synodus variegatus	3.0	1.3	0.6	3.4	8.1	6.1	2.9	7.9
Tetraodontidae	*Arothron hispidus*	0.8		0.6	0.4		0.5	1.2	
	Arothron nigropunctatus								0.5
	Canthigaster bennetti								0.5
	Canthigaster callisterna	3.8	0.7	1.2	0.9	5.0	0.5	1.2	1.9
	Canthigaster janthinoptera					0.9			
	Canthigaster spp.					0.5			
	Canthigaster valentini	5.3	2.0	3.1	5.6	14.0	9.9	10.7	11.6
Tripterygiidae	*Enneapterygius howensis*							7.0	22.2
	Enneapterygius howensis[?]						1.9		
	Enneapterygius rufopileus		5.9	3.1	9.9	18.0	7.1	10.7	15.7
	Enneapterygius spp.					0.5			2.3
	Tripterygiid spp.	2.3				0.5			
Zanclidae	*Zanclus cornutus*	8.3	9.2	4.3	11.6	18.5	8.0	9.5	4.2

APPENDIX 2. - Mobile invertebrate and cryptic fish species recorded on transects in each year, and their frequency of occurrence (numbers represent the % of transect blocks surveyed in that year on which each species was recorded, with the total number of transect blocks surveyed in that year at the top of the column).

		Year	**06**	**08**	**09**	**10**	**12**	**14**	**16**	**18**
Class	**Family**	***N. 100m^2 blocks***	**132**	**152**	**156**	**232**	**222**	**212**	**242**	**216**
Actinopterygii	Apogonidae	*Apogon doederleini*	0.0	0.0	3.2	5.6	5.9	6.6	9.5	7.4
		Apogon flavus	0.0	0.0	7.1	7.3	9.9	11.8	10.7	12.0
		Cheilodipterus macrodon	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.0
		Cheilodipterus quinquelineatus	0.0	0.0	1.9	9.5	3.6	3.3	5.4	5.1
		Ostorhinchus norfolcensis	0.0	0.0	10.3	15.1	28.4	31.1	38.0	43.5
	Blenniidae	Blenniid spp.	0.0	0.0	4.5	0.4	1.8	0.0	4.1	5.6
		Cirripectes alboapicalis	0.0	0.7	9.6	0.0	5.4	11.8	1.7	15.3
		Cirripectes chelomatus	0.0	0.0	0.0	6.0	0.0	2.8	12.8	6.0
		Cirripectes filamentosus	0.0	0.0	0.0	0.9	0.0	0.0	0.4	0.0
		Cirripectes spp.	0.0	0.0	0.6	0.4	5.0	16.5	4.5	8.3
		Cirripectes stigmaticus	0.0	0.0	0.0	0.4	2.3	0.0	0.0	1.9
		Ecsenius bicolor	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Ecsenius fourmanoiri	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0
		Ecsenius spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Exallias brevis	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5
		Meiacanthus atrodorsalis	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Plagiotremus rhinorhynchos	0.0	0.0	0.0	0.4	0.0	0.0	0.8	0.9
		Plagiotremus tapeinosoma	0.0	0.0	0.0	0.9	0.5	9.4	12.8	19.4
		Stanulus talboti	0.0	0.0	0.0	4.3	8.1	13.2	14.9	21.8
	Bothidae	*Bothus mancus*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Bothus pantherinus	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Callionymidae	*Diplogrammus goramensis*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	Cirrhitidae	*Cirrhitichthys falco*	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.5
		Notocirrhitus splendens	0.0	3.9	12.8	15.9	14.4	9.9	10.7	18.5
		Paracirrhites arcatus	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Paracirrhites forsteri	0.0	0.0	0.6	0.4	0.0	0.0	0.0	0.0
	Creediidae	Creediid spp.	0.0	0.0	0.0	6.0	0.0	0.0	3.3	0.0
		Limnichthys fasciatus	0.0	0.0	0.0	0.4	3.6	3.3	2.1	5.1
	Gobiesocidae	*Lepadichthys frenatus*	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.0
		Pherallodus indicus	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5
	Gobiidae	*Amblygobius nocturnus*	0.0	0.0	0.0	1.7	0.0	0.5	0.0	0.9
		Amblygobius phalaena	9.1	5.9	2.6	12.9	2.3	3.8	3.7	3.2
		Asterropteryx semipunctata	0.0	0.0	0.0	0.4	2.3	0.0	0.4	0.0
		Asterropteryx spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Bryaninops spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Coryphopterus spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0

		Year	**06**	**08**	**09**	**10**	**12**	**14**	**16**	**18**
Class	**Family**	***N. 100m^2 blocks***	**132**	**152**	**156**	**232**	**222**	**212**	**242**	**216**
		Eviota fasciola	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
		Eviota hoesei	0.0	0.0	7.7	19.8	0.0	16.5	38.8	44.4
		Eviota readerae	0.0	0.0	0.0	0.0	0.0	0.0	2.9	1.4
		Eviota sp. *[green]*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Eviota spp.	0.0	0.0	0.0	1.3	38.3	15.6	2.1	7.9
		Fusigobius duospilus	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5
		Fusigobius inframaculatus	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Fusigobius neophytus	0.0	0.0	0.0	0.0	1.8	0.9	2.1	0.5
		Gnatholepis anjerensis	0.0	0.0	14.1	8.2	4.1	0.0	2.1	0.0
		Gnatholepis cauerensis	0.8	3.9	0.0	0.0	0.0	5.7	1.7	2.8
		Gobiid spp.	5.3	17.1	14.7	2.6	4.5	7.1	11.6	0.9
		Gobiodon citrinus	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.5
		Istigobius decoratus	0.0	0.0	0.0	0.0	0.5	0.0	0.4	0.0
		Istigobius rigilius	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.9
		Istigobius spp.	0.0	0.0	0.0	1.3	0.0	3.8	0.0	0.0
		Koumansetta rainfordi	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
		Macrodontogobius wilburi	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.2
		Paragobiodon echinocephalus	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
		Priolepis cincta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Trimma spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Holocentridae	*Sargocentron cornutum*	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
	Muraenidae	*Echidna nebulosa*	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0
		Enchelycore ramosa	0.8	0.0	1.9	2.2	1.8	0.5	1.7	2.3
		Gymnothorax annasona	0.0	0.7	2.6	2.2	1.4	1.9	2.9	3.7
		Gymnothorax eurostus	4.5	3.9	7.7	12.1	8.6	10.8	11.2	12.5
		Gymnothorax favagineus	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Gymnothorax meleagris	0.0	0.0	1.3	0.9	1.4	0.9	2.5	1.4
		Gymnothorax nubilus	0.0	0.0	2.6	0.0	0.5	0.5	0.8	0.0
		Gymnothorax porphyreus	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.9
		Gymnothorax prionodon	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
		Gymnothorax spp.	1.5	0.0	0.0	0.0	2.7	0.0	0.0	0.0
		Gymnothorax thrysoideus	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.9
		Gymnothorax undulatus	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Muraenid spp.	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
	Pempheridae	*Pempheris analis*	0.0	0.0	0.0	0.0	5.0	5.7	1.7	6.5
		Pempheris oualensis	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Pinguipedidae	*Parapercis australis*	0.0	0.0	0.6	0.4	0.5	1.4	0.4	0.0
	Plesiopidae	*Plesiops insularis*	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.9
		Plesiops spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	Plotosidae	*Plotosus lineatus*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.9
	Priacanthidae	*Heteropriacanthus cruentatus*	0.0	0.0	0.0	0.4	0.0	0.9	0.4	0.9
		Priacanthus hamrur	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0

Class	Family	*Year* *N. 100m² blocks*	06 132	08 152	09 156	10 232	12 222	14 212	16 242	18 216
	Scorpaenidae	*Dendrochirus zebra*	0.0	0.0	0.0	0.0	0.9	1.4	0.4	0.9
		Parascorpaena aurita	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Pterois volitans	0.0	1.3	0.0	2.6	0.5	2.4	1.2	0.5
		Scorpaena cardinalis	1.5	12.5	1.3	0.0	0.0	7.5	11.2	9.3
		Scorpaena cookii	0.0	0.0	9.6	14.2	15.3	0.0	2.1	0.5
		Scorpaenid spp.	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Scorpaenodes evides	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Scorpaenodes scaber	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Scorpaenopsis cirrosa	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
		Scorpaenopsis diabolus	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.9
		Scorpaenopsis oxycephala	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Sebastapistes tinkhami	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	Serranidae	*Acanthistius cinctus*	0.0	0.0	1.9	3.0	0.9	0.9	2.5	2.3
		Cephalopholis miniata	0.0	0.0	0.0	0.0	0.5	0.0	0.4	0.0
		Epinephelus cyanopodus	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Epinephelus daemelii	0.0	0.0	0.0	0.4	0.5	0.5	0.4	0.0
		Epinephelus fasciatus	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Epinephelus maculatus	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
		Epinephelus polyphekadion	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Epinephelus rivulatus	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Epinephelus spp.	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0
		Epinephelus tauvina	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Grammistes sexlineatus	0.0	0.0	0.0	0.0	0.0	0.9	0.8	0.0
		Hypoplectrodes maccullochi	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Hypoplectrodes sp. *[Lord Howe]*	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.5
		Serranid spp.	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
		Trachypoma macracanthus	0.0	27.0	33.3	27.2	19.8	9.4	24.8	34.7
	Syngnathidae	*Halicampus boothae*	0.0	0.0	0.6	0.0	0.0	0.5	0.0	0.5
		Heraldia nocturna	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
	Synodontidae	*Saurida gracilis*	0.0	0.0	0.0	0.4	0.9	1.4	0.0	0.0
		Saurida nebulosa	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.9
		Synodus binotatus	0.0	0.0	0.0	0.0	1.4	0.0	0.0	2.3
		Synodus dermatogenys	0.0	0.0	0.0	0.0	0.5	1.4	1.7	0.5
		Synodus doaki	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.5
		Synodus jaculum	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Synodus spp.	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0
		Synodus variegatus	0.0	1.3	1.3	4.7	5.4	5.2	2.9	6.0
	Tripterygiidae	*Enneapterygius howensis*	0.0	0.0	0.0	0.0	0.0	0.0	30.2	47.2
		Enneapterygius howensis[?]	0.0	0.0	0.0	0.0	0.0	19.3	0.0	0.0
		Enneapterygius rufopileus	0.0	3.3	51.3	59.9	77.0	43.4	57.0	32.9
		Enneapterygius spp.	0.0	0.0	0.0	0.4	1.4	0.0	0.0	14.8
		Norfolkia squamiceps	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.0

		Year	06	08	09	10	12	14	16	18
Class	**Family**	***N. 100m^2 blocks***	**132**	**152**	**156**	**232**	**222**	**212**	**242**	**216**
		Tripterygiid spp.	0.0	0.7	0.0	0.0	6.3	0.9	0.0	0.0
	(blank)	Actinopterygii spp.	1.5	0.0	0.0	1.7	0.9	0.0	0.0	0.0
Anthozoa	Actiniidae	*Entacmaea quadricolor*	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.0
Asteroidea	Acanthasteridae	*Acanthaster planci*	0.8	0.0	0.6	0.4	0.9	0.5	0.4	0.0
	Asteriidae	*Astrostole rodolphi*	0.8	2.0	2.6	2.6	2.3	4.7	3.7	2.8
		Coscinasterias muricata	0.0	0.7	0.6	0.0	0.0	0.0	0.0	0.0
	Goniasteridae	*Neoferdina cumingi*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Luidiidae	*Luidia australiae*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Mithrodiidae	*Mithrodia clavigera*	0.0	0.0	0.0	0.4	1.8	0.0	0.8	0.0
	Ophidiasteridae	*Leiaster leachi*	0.0	0.7	0.0	0.9	0.5	0.9	1.2	0.5
		Linckia guildingi	4.5	0.7	1.3	0.9	3.6	1.4	1.2	1.9
		Linckia laevigata	0.0	0.0	0.0	0.4	0.0	0.5	0.0	0.0
		Ophidiaster confertus	43.2	50.7	58.3	52.2	47.3	52.4	57.0	53.2
	(blank)	Asteroidea spp.	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Bivalvia	Pectinidae	*Pectinid* spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Tridacnidae	*Tridacna maxima*	0.0	1.3	0.6	0.4	1.8	3.8	0.4	0.9
		Tridacna spp.	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0
Cephalopoda	Octopodidae	*Octopus cyanea*	0.0	0.0	0.0	0.0	0.5	0.5	0.4	0.5
		Octopus spp.	0.0	0.0	0.0	2.6	0.0	0.0	0.8	0.0
		Octopus tetricus	1.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Crinoidea	Colobometridae	*Oligometra serripinna*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
	Comasteridae	*Comanthus* spp.	0.0	0.0	27.6	0.0	16.2	19.8	5.0	18.5
		Comanthus wahlbergi	9.1	13.8	3.8	28.9	0.0	0.0	13.2	0.0
		Oxycomanthus bennetti	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
	Himerometridae	*Amphimetra tessellata*	0.8	5.3	3.2	6.5	5.0	8.0	3.7	0.0
		Himerometra robustipinna	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
	Tropiometridae	*Tropiometra afra*	26.5	27.0	33.3	31.0	25.7	25.5	28.5	24.1
	(blank)	Crinoidea spp.	0.0	0.0	0.0	0.9	0.0	0.5	0.4	0.0
Echinoidea	Brissidae	*Brissid* spp.	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0
	Cidaridae	*Phyllacanthus* spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Prionocidaris callista	3.8	2.0	3.2	2.2	0.0	0.9	1.7	2.3
	Clypeasteridae	*Clypeaster australasiae*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	Diadematidae	*Astropyrga* spp.	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
		Centrostephanus rodgersii	67.4	78.9	81.4	73.7	77.9	74.5	77.3	75.0
		Diadema savignyi	28.8	38.2	49.4	52.2	45.5	42.0	46.3	37.0
		Echinothrix diadema	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
	Echinometridae	*Echinometra mathaei*	21.2	22.4	25.0	30.6	27.0	32.5	27.7	27.8
		Echinostrephus aciculatus	43.2	63.8	65.4	49.1	56.8	52.8	64.5	59.7
		Heliocidaris erythrogramma	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
		Heliocidaris tuberculata	39.4	43.4	47.4	44.4	42.8	45.8	35.1	42.1
		Heterocentrotus mammillatus	0.0	1.3	0.0	0.0	0.0	0.5	0.0	0.0
	Echinoneidae	*Echinoneus cyclostomus*	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0

		Year	**06**	**08**	**09**	**10**	**12**	**14**	**16**	**18**
Class	**Family**	***N. 100m^2 blocks***	**132**	**152**	**156**	**232**	**222**	**212**	**242**	**216**
	Loveniidae	*Breynia australasiae*	0.0	0.0	0.0	0.9	0.5	0.0	0.4	0.0
	Toxopneustidae	*Tripneustes gratilla*	18.9	46.7	46.2	47.8	25.2	8.0	3.7	1.9
Elasmobranchii	Dasyatidae	*Taeniura meyeni*	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Gastropoda	Aglajidae	*Chelidonura hirundinea*	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Chelidonura inornata	0.0	0.0	0.6	0.9	3.6	0.5	0.0	3.2
	Aplustridae	*Micromelo undatus*	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
	Aplysiidae	*Aplysia dactylomela*	0.0	0.7	0.0	0.4	0.5	0.9	0.0	0.0
		Aplysia juliana	0.0	0.0	0.0	0.0	1.8	0.0	0.0	1.4
		Aplysia parvula	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Aplysia spp.	1.5	0.7	0.0	1.7	0.0	0.9	0.0	0.5
	Bursidae	*Bursa verrucosa*	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
	Chromodorididae	*Ardeadoris rubroannulata*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
		Ceratosoma amoenum	0.0	0.7	0.0	0.4	0.0	0.5	0.0	0.0
		Chromodoris elisabethina	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
		Chromodoris sp. *[reticulata]*	0.0	0.0	0.0	0.0	0.9	0.5	0.0	0.0
		Chromodoris spp.	0.0	0.0	1.3	0.0	0.5	0.0	0.0	0.0
		Goniobranchus collingwoodi	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Goniobranchus decorus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Goniobranchus geometricus	0.0	0.0	0.0	1.3	0.9	0.5	0.0	1.4
		Goniobranchus kuniei	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Goniobranchus roboi	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.0
		Goniobranchus tinctorius	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.9
		Hypselodoris jacksoni	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.4
		Hypselodoris spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Miamira sinuata	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Columbellidae	*Columbellid* spp.	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0
	Conidae	*Conus anemone*	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Conus coronatus	0.0	0.0	0.0	0.0	0.9	0.0	0.8	0.0
		Conus figulinus	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Conus miles	0.0	0.0	0.6	0.0	0.0	0.0	0.8	0.0
		Conus rattus	0.0	0.0	0.6	0.0	0.0	0.5	0.0	0.5
		Conus sanguinolentus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
		Conus spp.	0.0	2.0	2.6	0.0	0.9	0.9	0.8	6.0
		Conus ventricosus	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
	Cypraeidae	*Cypraea* spp.	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
		Cypraea tigris	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0
		Naria helvola	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
		Ovatipsa chinensis	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
	Dendrodorididae	*Dendrodoris krusensternii*	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Dendrodoris spp.	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
	Discodorididae	*Atagema intecta*	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Halgerda aurantiomaculata	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0

		Year	**06**	**08**	**09**	**10**	**12**	**14**	**16**	**18**
Class	**Family**	***N. 100m^2 blocks***	**132**	**152**	**156**	**232**	**222**	**212**	**242**	**216**
		Halgerda tessellata	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Halgerda willeyi	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.5
		Platydoris formosa	0.0	0.0	0.0	0.0	0.5	0.0	0.4	1.4
		Platydoris spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	Elysiidae	*Thuridilla* spp.	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
	Facelinidae	*Phidiana* spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Phyllodesmium serratum	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Gastropteridae	*Sagaminopteron ornatum*	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
	Gymnodorididae	*Gymnodoris* spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
	Hexabranchidae	*Hexabranchus sanguineus*	0.0	0.0	1.3	0.9	1.8	1.4	2.1	0.9
	Lamellariidae	*Coriocella nigra*	4.5	0.0	0.0	2.2	8.1	3.8	4.1	9.3
	Muricidae	*Coralliophila neritoidea*	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Drupa ricinus	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
		Drupella cornus	0.0	0.0	6.4	0.9	4.1	0.0	3.3	1.4
		Drupella rugosa	0.0	0.0	0.6	0.0	0.0	0.0	0.0	3.2
		Drupella spp.	0.0	0.0	3.8	0.4	3.6	0.9	0.8	0.9
		Morula marginalba	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
		Morula nodulifera	5.3	0.0	0.0	0.9	0.0	0.0	0.0	0.5
		Morula spp.	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
		Muricid spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Phyllidiidae	*Phyllidia ocellata*	0.0	0.7	0.0	1.3	0.5	0.0	0.0	0.0
		Phyllidia spp.	0.8	0.0	1.9	0.0	0.5	0.0	0.0	0.0
		Phyllidiella pustulosa	0.0	1.3	3.8	0.9	3.2	1.4	2.5	0.9
	Plakobranchidae	*Elysia* spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.5
		Plakobranchus ocellatus	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Thuridilla neona	0.0	0.0	0.0	0.0	1.8	0.0	0.8	0.9
		Thuridilla splendens	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
		Thuridilla vataae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	Pleurobranchidae	*Pleurobranchus forskalii*	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Polyceridae	*Kaloplocamus acutus*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
		Roboastra luteolineata	0.0	0.7	2.6	0.4	1.4	0.5	1.7	0.5
		Tambja morosa	0.0	0.0	0.0	0.0	3.2	0.5	0.0	0.0
		Tambja tenuilineata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Tambja verconis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	Ranellidae	*Charonia tritonis*	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
		Ranella australasia	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Strombidae	*Strombus luhuanus*	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0
	Triphoridae	Triphorid spp.	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Trochidae	*Tectus pyramis*	0.0	0.0	2.6	0.9	0.0	0.0	0.4	0.9
		Trochid spp.	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
	Turbinidae	*Astralium* spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
		Turbo cepoides	19.7	19.1	22.4	22.8	36.0	35.4	19.8	25.0

		Year	**06**	**08**	**09**	**10**	**12**	**14**	**16**	**18**
Class	**Family**	***N. $100m^2$ blocks***	**132**	**152**	**156**	**232**	**222**	**212**	**242**	**216**
		Turbo spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Tylodinidae	*Tylodina corticalis*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
	Velutinidae	Velutinid spp.	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(blank)	Gastropoda spp.	0.0	0.7	1.9	0.9	0.0	0.0	0.8	0.0
		Nudibranchia spp.	0.0	2.6	1.3	2.6	0.9	1.4	0.0	0.9
		Opisthobranch sp.	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	(blank)	Mollusca spp.	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Holothuroidea	Holothuriidae	*Actinopyga miliaris*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
		Bohadschia spp.	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Holothuria atra	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
		Holothuria fuscocinerea	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Holothuria impatiens	0.0	0.0	0.0	0.9	0.9	0.0	0.4	0.9
		Holothuria leucospilota	0.0	0.0	0.6	1.7	0.5	1.4	0.4	3.7
		Holothuria nobilis	2.3	2.6	1.9	2.2	4.1	1.9	2.9	2.3
		Holothuria spp.	0.0	0.0	0.0	0.0	0.0	1.9	1.2	0.0
		Holothuriid spp.	0.0	0.0	2.6	1.3	0.0	0.0	0.0	0.0
	Sclerodactylidae	*Cladolabes* spp.	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
	Stichopodidae	*Stichopus chloronotus*	0.0	0.0	0.0	0.9	0.0	0.0	0.8	0.0
		Stichopus sp. *[colemans]*	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5
		Stichopus spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.4	1.4
	Synaptidae	*Euapta godeffroyi*	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
	(blank)	*Holothuroidea* spp.	0.0	0.7	0.0	0.0	2.3	0.0	0.0	0.0
Malacostraca	Dairidae	*Daira perlata*	0.0	0.0	1.9	0.4	1.4	0.0	0.0	0.0
	Diogenidae	*Aniculus maximus*	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.9
		Aniculus spp.	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
		Calcinus imperialis	0.8	2.6	4.5	5.2	1.4	0.0	0.4	0.0
		Calcinus latens	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Calcinus spicatus	1.5	0.7	0.6	0.0	0.0	0.0	0.0	0.0
		Calcinus spp.	0.0	0.0	0.6	0.0	0.0	0.5	1.7	0.0
		Dardanus lagopodes	0.8	0.0	0.0	2.6	0.5	0.0	1.2	1.9
		Dardanus megistos	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0
		Dardanus spp.	0.0	0.0	0.0	0.4	0.0	2.4	0.8	1.9
	Galatheidae	*Galathea* spp.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
	Grapsidae	Grapsid spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Leptograpsus variegatus	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
	Hippolytidae	*Lysmata amboinensis*	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Saron marmoratus	0.0	1.3	0.0	0.0	2.3	0.0	0.0	0.0
		Thor amboinensis	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0
	Majidae	*Majid* spp.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Schizophrys aspera	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
	Paguridae	*Pagurid* spp.	0.0	0.0	0.0	2.2	0.0	0.0	0.8	0.0
	Palaemonidae	*Ancylomenes venustus*	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0

		Year	**06**	**08**	**09**	**10**	**12**	**14**	**16**	**18**
Class	**Family**	***N. 100m^2 blocks***	**132**	**152**	**156**	**232**	**222**	**212**	**242**	**216**
	Palinuridae	*Panulirus longipes*	4.5	1.3	3.8	3.9	3.2	2.4	6.2	6.9
		Panulirus versicolor	0.0	0.0	0.6	0.4	0.0	0.0	0.0	0.5
		Sagmariasus verreauxi	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
	Percnidae	*Percnon planissimum*	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0
	Porcellanidae	*Petrolisthes* spp.	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Portunidae	*Charybdis* spp.	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Thalamita spp.	0.0	0.0	2.6	1.7	1.4	0.0	0.8	0.9
	Scyllaridae	*Arctides antipodarum*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Scyllarides haanii	0.0	0.0	0.0	0.9	0.0	0.0	0.8	0.0
	Stenopodidae	*Stenopus hispidus*	2.3	0.7	1.9	2.2	1.4	4.2	1.7	0.9
	Trapeziidae	*Trapezia septata*	0.0	0.0	1.3	0.0	0.5	0.0	0.0	1.4
		Trapezia spp.	0.0	0.0	0.0	0.0	0.0	1.4	2.5	4.6
	Xanthidae	*Neoliomera* spp.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
		Pseudoliomera spp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
		Xanthid spp.	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
	(blank)	Brachyura spp.	0.0	2.0	3.2	2.6	6.8	0.0	0.0	0.0
		Paguroidea spp.	4.5	11.8	14.7	1.3	14.0	5.7	11.2	9.3
		Unidentified crab	0.0	0.0	0.0	0.0	0.0	2.8	1.2	2.3
Ophiuroidea	Gorgonocephalidae	*Astroboa ernae*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
		Astroboa granulatus	0.0	0.0	0.0	2.2	0.0	0.0	0.8	0.5
		Astroboa spp.	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rhabditophora	Pseudocerotidae	*Pseudobiceros fulgor*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Turbellaria	Pseudocerotidae	*Pseudobiceros* spp.	0.0	0.0	0.0	0.0	0.5	0.9	0.4	0.0
		Pseudobiceros stellae	0.0	2.0	0.6	0.4	0.0	0.0	0.0	0.9
		Pseudoceros imitatus	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0