COMMUNITY-ASSISTED SCIENTIFIC ASSESSMENT AND MANAGEMENT OF WESTERN AUSTRALIAN MARINE PROTECTED AREAS

NINGALOO MARINE PARK

Project by the Reef Life Survey Foundation Incorporated

Report by Paul Day, Rick Stuart-Smith, Graham Edgar, Kim Friedman, Tom Holmes, Lynda Bellchambers

February 2013

Supported by:

Citation

Day, PB, Stuart-Smith RD, Edgar GJ, Friedman KJ, Holmes, T, and Bellchambers LM (2013) Community-assisted scientific assessment and management of Western Australian Marine Protected Areas. Ningaloo Marine Park report for Coastwest and Caring for our Country. Reef Life Survey Foundation Incorporated, Hobart.

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Contents

List of acronyms

ACRONYM	EXPANDED
RLS	Reef Life Survey
RLSF	Reef Life Survey Foundation Incorporated
GPS	Global Positioning System
DPaW	Department of Parks and Wildlife
NMP	Ningaloo Marine Park
NRM	Natural Resource Management
UTas	University of Tasmania

Executive summary

This report outlines key results of the Reef Life Survey Project *Community-assisted scientific assessment and monitoring of Western Australian Marine Protected Areas,* funded by a Coastwest grant, and run from February 2012 to February 2013 in partnership with the Department of Parks and Wildlife, Rottnest Island Authority and the Department of Fisheries, and with the support of the Perth Region NRM and Rangelands NRM.

The project goals were to provide additional, complementary quantitative data on reef biodiversity to project partners to assist meeting of monitoring, assessment and research objectives under the management plans for Rottnest Island and Ningaloo Marine Park, and to directly engage committed members of the recreational SCUBA diving community in this process.

Surveys at Ningaloo Marine Park were carried out between 22nd July and 2nd August 2012. Seven volunteer divers surveyed 53 transects at 22 sites, 10 of which were Department of Parks and Wildlife long-term fish monitoring sites. Fish diversity across the 22 sites was relatively high, with 236 species of fish recorded. The most common species recorded included *Thalassoma lunare* (Moon wrasse), *Thalassoma lutescens* (Green moon wrasse), *Labroides dimidiatus* (Common cleaner fish), *Chlorurus sordidus* (Greenfin parrotfish) and *Scolopsis bilineata* (Two-line monocle bream).

Mobile macroinvertebrate fauna was dominated by echinoderms and molluscs. *Echinometra mathaei* (Mathae's sea urchin), the sea star *Nardoa variolata*, *Drupella cornus* (Horn drupe) and *Turbo argyrostomus* were the most commonly sighted species.

Comparison of macroinvertebrate data from a previous RLS survey of Ningaloo in 2010 revealed a significant increase in the mean density of the corallivorous gastropod *Drupella cornus* from 3.15 to 22.9 per 100 m². Ongoing monitoring of the population density and spatial distribution of this species is a priority of the Marine Park Management Plan. Temporal data for fishes also indicated the mean biomass per 500 m² of the commercially and recreationally important *Lethrinus nebulosus* declined steeply from 1162.3g per 500 m² in 2010, to 230g per 500 m² in 2012. Although not statistically significant, this decline warrants further investigation and monitoring.

1 Introduction

1.1 Ningaloo Marine Park

Ningaloo Marine Park (NMP) is listed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as being an area of outstanding universal value. It is listed alongside areas such as Rapa Nui national park on Easter Island, Grand Canyon National Park in Arizona and the Galápagos Islands.

The Ningaloo Marine Park is the largest fringing coral reef in Australia, covering an area of approximately 28,616 ha along the North West Cape of Western Australia, approximately 1,200 km north of Perth. It supports a high diversity of marine life, including many species of conservation significance, such as turtles, whales, dugongs, whale sharks and dolphins. Both temperate and tropical species occur at Ningaloo with some at the limit of their distribution. The mixing of the cooler, northern flow of the West Australian Current and the warm, southward flowing Leeuwin Current makes Ningaloo Marine Park an exceptional transition zone of temperate and tropical marine fauna and flora (IUCN 2011).

The 290 km long reef system sustains approximately 300 species of coral, 500 species of reef fishes and 600 species of molluscs (Commonwealth of Australia 2002). In addition, recent research on benthic communities has identified many species previously unrecorded in Australia and some new to science, including 25 new species of Echinoderms (IUCN 2011).

1.2 Threats to NMP

Some of the major potential and current pressures to the biodiversity of NMP identified in this report are listed in table 1.

The NMP has significant social value, an abundance of Aboriginal history, and is accessible to visitors due to its close proximity to shore. In 2004, approximately 200,000 people visited Ningaloo to enjoy a range of nature based activities such as fishing, wildlife watching, diving, snorkelling and boating. These activities are managed, along with the parks natural environment, under the NMP and Muiron Islands management plan (Department of Environment and Conservation 2005).

Table 1. Potential and current major pressures affecting the ecological values of Ningaloo Marine Park. Adapted from Management Plan for The Ningaloo Marine Park and Muiron Islands Marine Management Area 2005-2015.

Ecological value	Pressures
Geomorphology The reserves contain a diverse range of sea bed and coastal geomorphology located within Australia's largest fringing coral reef.	Recreational and commercial use of landforms. Commercial fishing (trawling) and coastal infrastructure.
Sediment and water quality Generally undisturbed, calcareous sands in shallow lagoons, finer sands and silt in offshore water. Low terrestrial runoff and limited coastal development has maintained high water quality essential for healthy ecosystem function.	Contamination from drilling activities, toxic inputs and nutrient inputs. Antifouling paints, oil spills, sewage discharge and litter.
Coral reef communities Ningaloo marine park contains around 300 species of coral with all 15 families of hermatypic corals represented.	Vessels colliding with shallow coral communities, anchor damage, trophic effects due to fishing, litter, pollution and direct impacts by recreation (trampling and diving), coral bleaching, cyclone damage
Macroalgal and seagrass communities These communities have a patchy distribution within the park but remain important primary producers. Seagrass meadows form the primary food source for Dugongs (*Dugong dugon*).	Boating activities (anchoring, moorings and propeller scour). Pollution and nutrient inputs.
Finfish Species rich finfish fauna with a diversity of tropical, sub-tropical and warm temperate species occur throughout the reserve.	Commercial and recreational fishing of target species. Fishing of non-target species, habitat disturbance and trophic interactions.
Invertebrates High species diversity is poorly described but is characterised by tropical, sub-tropical and temperate species.	Commercial and recreational fishing of target species, introduced marine pests from ballast and biofouling.
Sharks and rays Diverse and abundant shark and ray populations that are important apex predators in the reserve's food webs.	Recreational fishing, commercial fishing by-catch and habitat disturbance.

The key strategies outlined within the NMP management plan are:

- Implementation of a zoning scheme for the park that includes sanctuary zones that are representative of the park's marine habitats, flora and fauna, comprising 34% of the park. This will provide a high degree of protection for representative areas throughout the park.
- Implementation of a zoning scheme for the marine management area that includes conservation areas that provide a high level of protection to representative marine habitats in the marine management area.
- Implementation of comprehensive research and monitoring programs to improve the understanding of the marine environment and to assess the impacts of human activities.
- Implementation of comprehensive education and information programs to support the management of the reserves.
- Development of detailed recreational management plans and implementation of management strategies throughout the park to facilitate the sustainable management of recreational activities.
- Close integration of management of the adjoining coastal lands and the park.
- Close cooperation with other agencies, particularly the Department of Fisheries, in achieving integrated management of the marine environment in this area.

Strategies quoted directly from Department of Environment and Conservation 2005.

The biodiversity surveys conducted by Reef Life Survey volunteers and production of a public presentation as part of the Coastwest grant provide valuable components to implementation of the management plan, specifically in the areas of sanctuary zone monitoring, research and education.

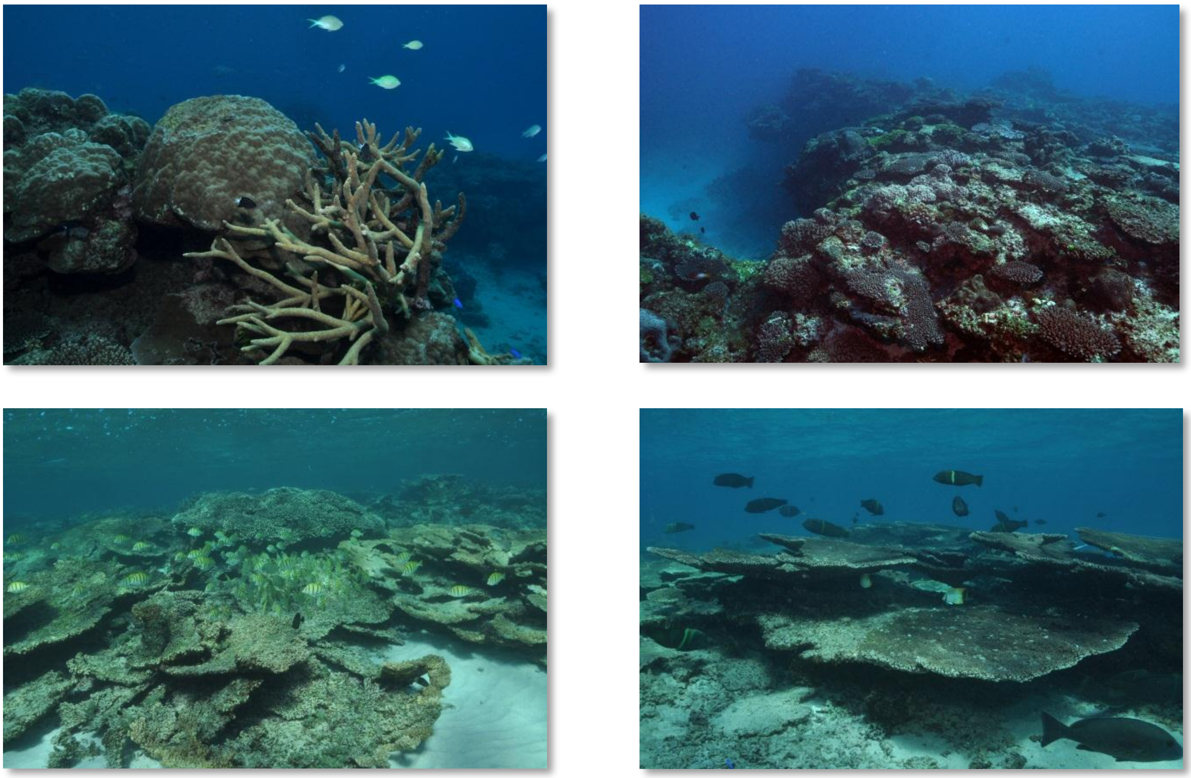

Plate 1. Typical reef habitats within the Ningaloo Marine Park

1.3 Rationale

Threats to the health of the world's oceans—pollution, overfishing, habitat destruction, climate change, introduced pests—are now universally recognized to be serious, pervasive and diverse (Jackson 2001; Edgar *et. al.* 2005). In order to allocate resources to where conservation actions are most needed and most likely to be successful, coastal managers need detailed information on the distribution and structure of marine floral and faunal communities. Unfortunately, the out-of-sight nature and size of the marine realm, a shortfall of available relevant information, and high field survey costs, add enormous challenges to effective management. The Reef Life Survey program (RLS) was developed in 2007 to provide a means for collecting detailed biodiversity information using standardized methods over broad scales, in order to help address these challenges.

Key to the success of RLS are the skills and enthusiasm of recreational divers trained to a scientific level of data-gathering, as this allows quantitative data to be gathered across temporal and spatial scales impossible for professional scientific teams to cover. The RLS dataset currently contains detailed information on marine biodiversity from more than 5,200 surveys in 40 countries and provides the best opportunity to address, at scales relevant to management, the most critical ecological questions associated with persistence of marine biodiversity and ecosystem function. In addition to the broad-scale, management-related scientific value of RLS data gathering efforts, RLS works with state management agencies to collect data that are complimentary to local monitoring efforts, expanding the monitoring reach of these agencies in time and space.

This project was specifically designed to provide data for WA Marine Protected Areas (MPAs) that are complimentary to existing monitoring data and of sufficient detail and quality to contribute to management of these MPAs. The project also aimed to involve community members, generating and maintaining community monitoring capacity through RLS, while improving public appreciation of the biodiversity values of the MPAs studied.

1.4 Objectives

The project objectives were to:

1. Develop and greatly extend comprehensive and rigorous scientific datasets on the condition and trends in biodiversity through support of the recreational SCUBA diving community,
2. Build capacity in the WA diving community to increase the pool of skilled divers able to contribute to scientifically-rigorous biodiversity research and monitoring,

And through these, ultimately to:

3. Protect and enhance biodiversity values, including populations of threatened species, within key WA MPA's by assisting management with critical information needs and increasing community awareness of major threats and values.

These objectives closely align with the priorities in Australia's Biodiversity Conservation Strategy 2010-2030 (Natural Resource Management Ministerial Council 2010), and include increasing the number of Australians participating in biodiversity conservation activities, contributing to building ecosystem resilience through the input of biodiversity data to management plans, and extending a standardized, robust national dataset.

2 Methods

All fieldwork involved the use of standardized RLS underwater visual census protocols. These surveys were based around 50 m transects, and comprise three main components.

2.1 Fish Surveys

Fish census protocols involve 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 are recorded on waterproof paper as divers swim slowly along the line. Size-classes of total fish length (from snout to tip of tail) used are 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 400, 500 and above. Lengths of fish larger than 500 mm are estimated to the nearest 12.5 cm and individually recorded.

2.2 Macroinvertebrate and cryptic fish surveys

Large macro-invertebrates (molluscs, echinoderms and crustaceans > 2.5 cm) and cryptic fishes* are censused along the same transect lines set for fish surveys. Divers swim just above the seabed, up then down the two sides of the transect line, recording all mobile macroinvertebrates and cryptic fishes on exposed surfaces of the reef within 1 m of the line. Giant clams in the genus *Tridacna*, although not mobile, are also counted within the 1 m wide bands for this component of the survey. Cryptic fishes are those from families that are inconspicuous and closely associated with the seabed, and thus likely to be overlooked during general fish surveys. The global list of families considered cryptic for RLS surveys is provided in Appendix 1.

2.3 Photoquadrats of benthic cover

Information on the percentage cover of sessile animals and seaweeds along the transect lines set for fish and invertebrate censuses is recorded using photo-quadrats taken every 2.5 m along the 50 m transect. Digital photo-quadrats are taken vertically-downward from a height sufficient to encompass an area of approximately 0.3 m x 0.3 m. The percentage cover of different macroalgal, coral, sponge and other attached invertebrate species have not been obtained from photo-quadrats as part of this study, but can later be extracted using Coral Point Count with Excel extensions (CPCe) software (Kohler and Gill, 2006). Standard protocol for processing photo-quadrats includes recording the taxon under each point of a 56 point grid overlaid on each image.

A manual detailing the RLS methodology can be downloaded at:
http://reeflifesurvey.com/information

 

Plate 2. RLS divers carrying out surveys at Ningaloo Marine Park

2.4 Data analysis

Data collected in this project were analysed in conjunction with other data collected in NMP by RLS teams in 2010. While some differences exist between years with regard to the sites surveyed, a reasonable number of sites were surveyed on both occasions. The same methodology and some of the same divers were involved in the repeat surveys which were undertaken at a similar time of year. All multivariate tests were based on log(x+1) transformed biomass data and Bray-Curtis dissimilarity (Clarke & Gorley 2006), while univariate tests involved transformations as appropriate to the metric, and Euclidean distances when analysed in PERMANOVA.

3 Results

3.1 Fish surveys

Surveys at Ningaloo Marine Park were carried out between 22nd July and 2nd August 2012. A total of 53 transects were surveyed at 22 sites by seven RLS divers. The survey effort and site details for these 2012 surveys and previous surveys by RLS in 2010 are shown in Table 2 and Figure 1.

Fish diversity across the 22 sites surveyed in 2012 was relatively high, with 236 species of fish recorded at an average of 45.6 species per 500m^2, taking the total number of fish species recorded over both years to 336 (including genus or higher level records). The most common species recorded on RLS transects in 2012 are listed in table 3.

General summaries of fish surveys in 2012 by site are presented in table 4 indicating the survey effort at each site (number of 50m transects), the mean number of fish species per 500m², mean density and biomass per 500m².

Table 2 Details of RLS surveys and sites at Ningaloo Marine Park. The number of 50 m transects surveyed is indicated for each site under each year.

SiteCode	Site	Latitude	Longitude	Zone	2010	2012
NMP1	Point Maud Outer	-23.11234	113.75042	Sanctuary Zone	1	2
NMP10	Maud RZ1	-23.21313	113.76296	Open to fishing	2	
NMP11	Maud RZ2	-23.20838	113.76328	Open to fishing	2	2
NMP12	Pelican Nth	-23.32164	113.78224	Sanctuary Zone	1	
NMP13	Monck Head Inner	-23.17989	113.76169	Open to fishing	1	
NMP14	Monck Head North	-23.17758	113.76397	Open to fishing	1	
NMP15	A & D s Dilemma	-21.90414	113.94328	Open to fishing	1	
NMP18	Rick s Folly	-21.91842	113.95551	Open to fishing	1	
NMP19	Maud SZ Nth	-23.09197	113.73966	Sanctuary Zone	2	2
NMP2	Point Maud Inner	-23.12142	113.75562	Sanctuary Zone	1	2
NMP20	Oyster rocks buoy	-23.04473	113.81843	Open to fishing	2	2
NMP21	Coral Bay	-23.14221	113.76709	Sanctuary Zone		
NMP22	Turquoise Bay	-22.09786	113.88472	Sanctuary Zone		
NMP23	Kate s Corner	-21.97653	113.91861	Open to fishing	2	
NMP24	Yalobia Bommie	-23.20194	113.76248	Open to fishing		2
NMP25	Outside Yalobia North	-23.19459	113.75209	Open to fishing		2
NMP26	Outside Yalobia South	-23.2175	113.75466	Open to fishing		2
NMP27	Coral Bay Offshore	-23.13496	113.7404	Open to fishing		2
NMP6	Monck Head Outer	-23.16108	113.75875	Sanctuary Zone	2	2

Table 2 cont. Details of RLS surveys and sites at Ningaloo Marine Park. The number of 50 m transects surveyed is indicated for each site under each year.

SiteCode	Site	Latitude	Longitude	Zone	2010	2012
NMP7	Monck Head Sth	-23.16489	113.76611	Sanctuary Zone	1	
NMP8	Maud SZ external	-23.17642	113.76097	Open to fishing	1	
NMP9	Bills Bay 1	-23.12627	113.76158	Sanctuary Zone	1	1
NMP-B3	Bundegi	-21.82729	114.1801	Open to fishing	1	
NMP-B4	Nth Bundegi	-21.8559	114.16763	Sanctuary Zone	1	
NMP-B5	Sth Bundegi	-21.86971	114.15813	Sanctuary Zone	1	
NMP-BF1	Bundegi	-21.83921	114.17564	Open to fishing		3
NMP-BF2	Bundegi SZ North	-21.85245	114.16954	Open to fishing		3
NMP-BF3	Bundegi SZ South	-21.86648	114.15926	Sanctuary Zone		3
NMP-BF4	Bundegi RZ	-21.83633	114.17777	Open to fishing		3
NMP-C1	Monck Head	-23.17701	113.75987	Open to fishing		3
NMP-C3	Coral Bay Central	-23.14152	113.75364	Sanctuary Zone		3
NMP-C4	Yalobia Passage	-23.19995	113.76354	Open to fishing		3
NMP-P2	Pelican Nth	-23.31925	113.7807	Sanctuary Zone		3
NMP-S1	Dugong	-22.86905	113.76443	Sanctuary Zone	2	3
NMP-S2	Bruboodjoo	-22.92875	113.77937	Open to fishing	2	3
NMP-S3	Coral Bay DEC1	-23.12872	113.75232	Sanctuary Zone	2	2
NMP-S4	Pelican	-23.33246	113.77923	Sanctuary Zone	1	

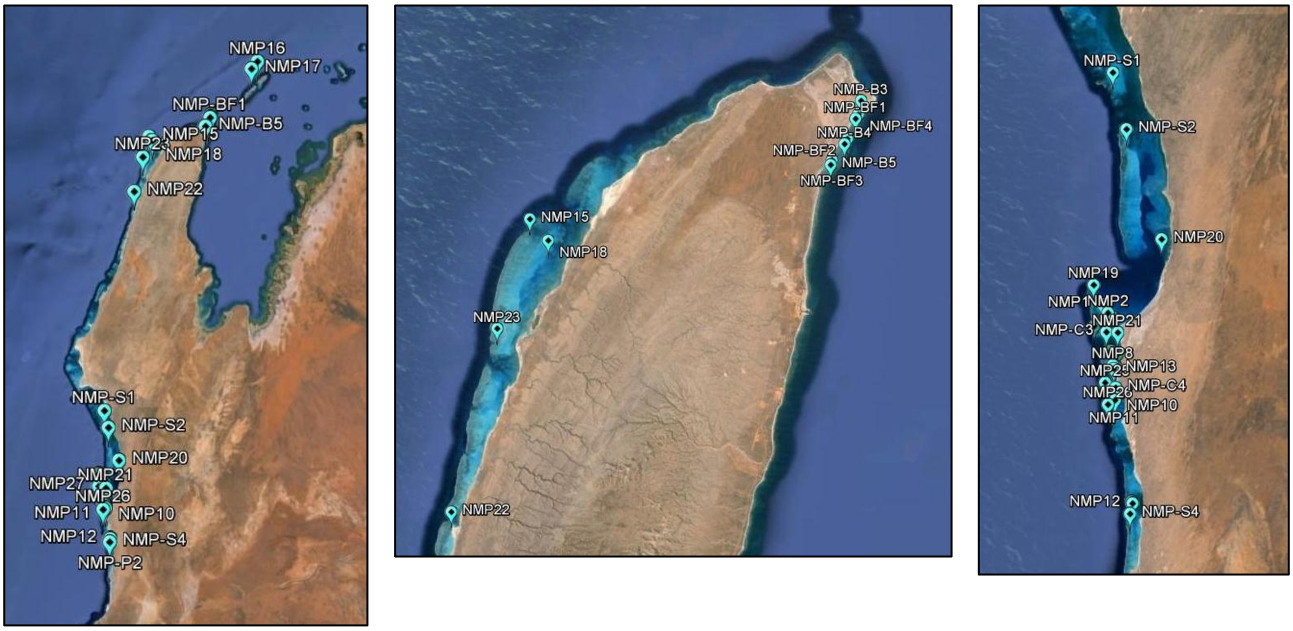

Figure 1. RLS sites surveyed in Ningaloo Marine Park (left panel). Sites at Bundegi and Cape Range National Park are shown in the middle panel, and sites in the Coral bay region in the right panel.

Principle Coordinates Analysis (PCO) of fish community data for all sites surveyed in 2012 revealed three distinct fish community types (Figure 2), representing sites characterised by different reef habitats, and differentiated by the presence or higher biomass of species listed in Appendix 2. Sites with high PCO1 values (NMP25, NMP26 and NMP27) were outside of the reef and were characterized most by higher biomass of *Acanthurus dussumieri, Epinephelus fasciatus, Lethrinus nebulosus, Sufflamen chrysopterum* and *Thalassoma lutescens.*

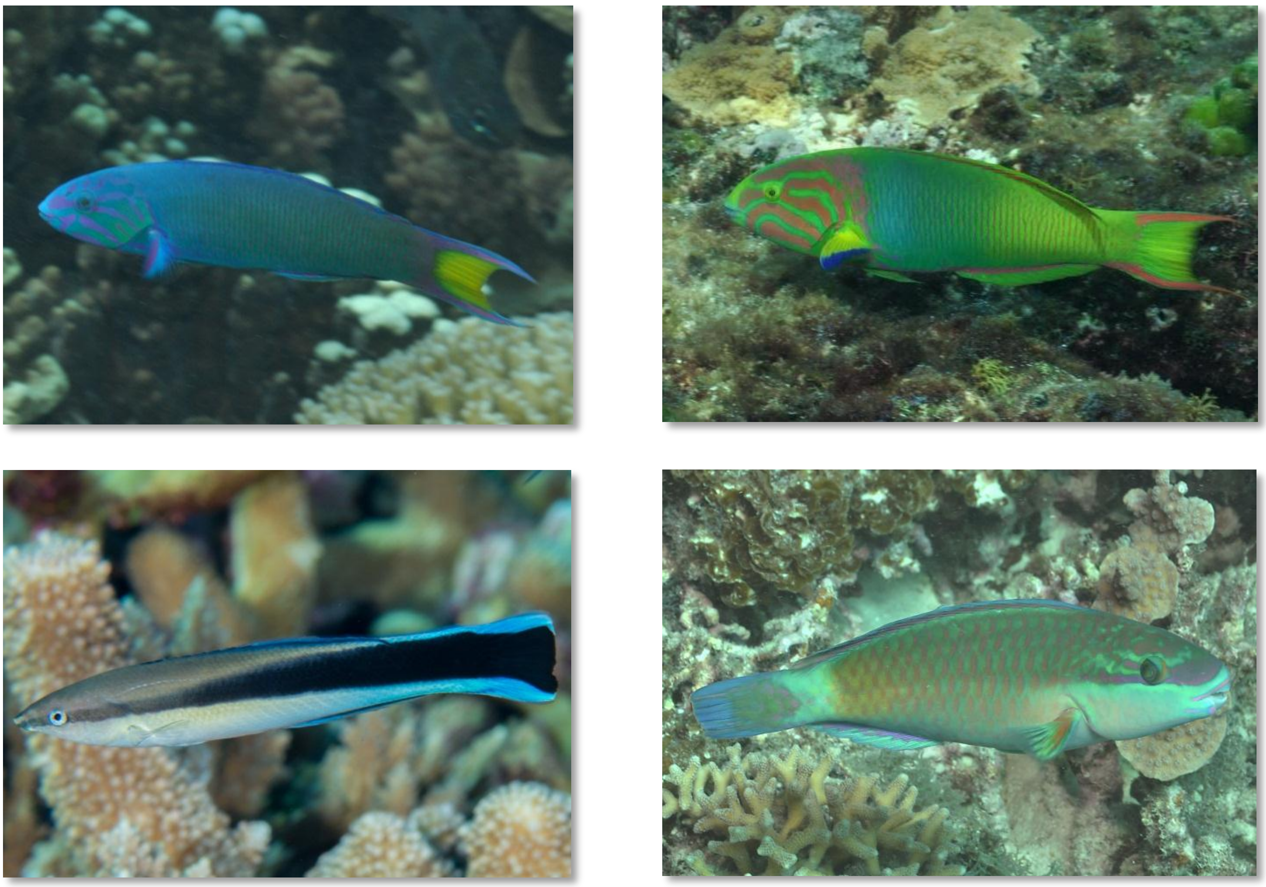

Plate 3. Common fish species recorded at Ningaloo. *Thalassoma lunare*, *Thalassoma lutescens*, *Labroides dimidiatus* and *Chlorurus sordidus*.

Table 3. Most commonly recorded fishes on RLS transects at Ningaloo Marine Park in 2012. Mean density and biomass are per 500m² transect at each site. Of the 22 sites surveyed, *Thalassoma lunare* and *Thalassoma lutescens* were equally most common, with records at every site and on every transect.

Species	Mean density	Mean Biomass (g)	Frequency (% of transects)
Thalassoma lunare	31.7	301.9	100
Thalassoma lutescens	26.1	439.3	100
Labroides dimidiatus	5.6	19.9	98
Chlorurus sordidus	119.9	8224.1	92
Scolopsis bilineata	10.8	834	92
Chaetodon plebeius	8.4	355.5	83
Plectroglyphidodon lacrymatus	47.7	692	90
Pomacentrus moluccensis	90.8	576.7	88
Pomacentrus vaiuli	40	225	88
Acanthurus grammoptilus	4.3	882.7	85

Table 4. Results of fish surveys for RLS monitoring sites at Ningaloo Marine Park in 2012. Values represent the mean per 500m² transect at each site.

Site code	Number of transects	Number of fish species	Total fish density	Total fish biomass (kg)
NMP1	2	57	773.5	42.874
NMP11	2	50	1341.0	93.307
NMP19	2	47	789.5	65.539
NMP2	2	52	726.5	30.399
NMP20	2	57	847.0	52.176
NMP24	2	40	1205.0	86.239
NMP25	2	28	424.0	25.894
NMP26	2	43	637.0	72.653
NMP27	2	43	492.5	33.510
NMP6	2	43	1212.0	42.933
NMP9	1	37	895.0	41.454
NMP-BF1	3	37	1328.7	49.223
NMP-BF2	3	41	977.3	31.968
NMP-BF3	3	46	808.3	34.047
NMP-BF4	3	41	839.3	77.873
NMP-C1	3	44	867.0	12.117
NMP-C3	3	37	859.3	18.395
NMP-C4	3	59	1555.3	106.814
NMP-P2	3	49	1121.0	24.399
NMP-S1	3	47	687.3	58.098
NMP-S2	3	57	997.3	32.850
NMP-S3	2	44	1072.5	36.816

a)

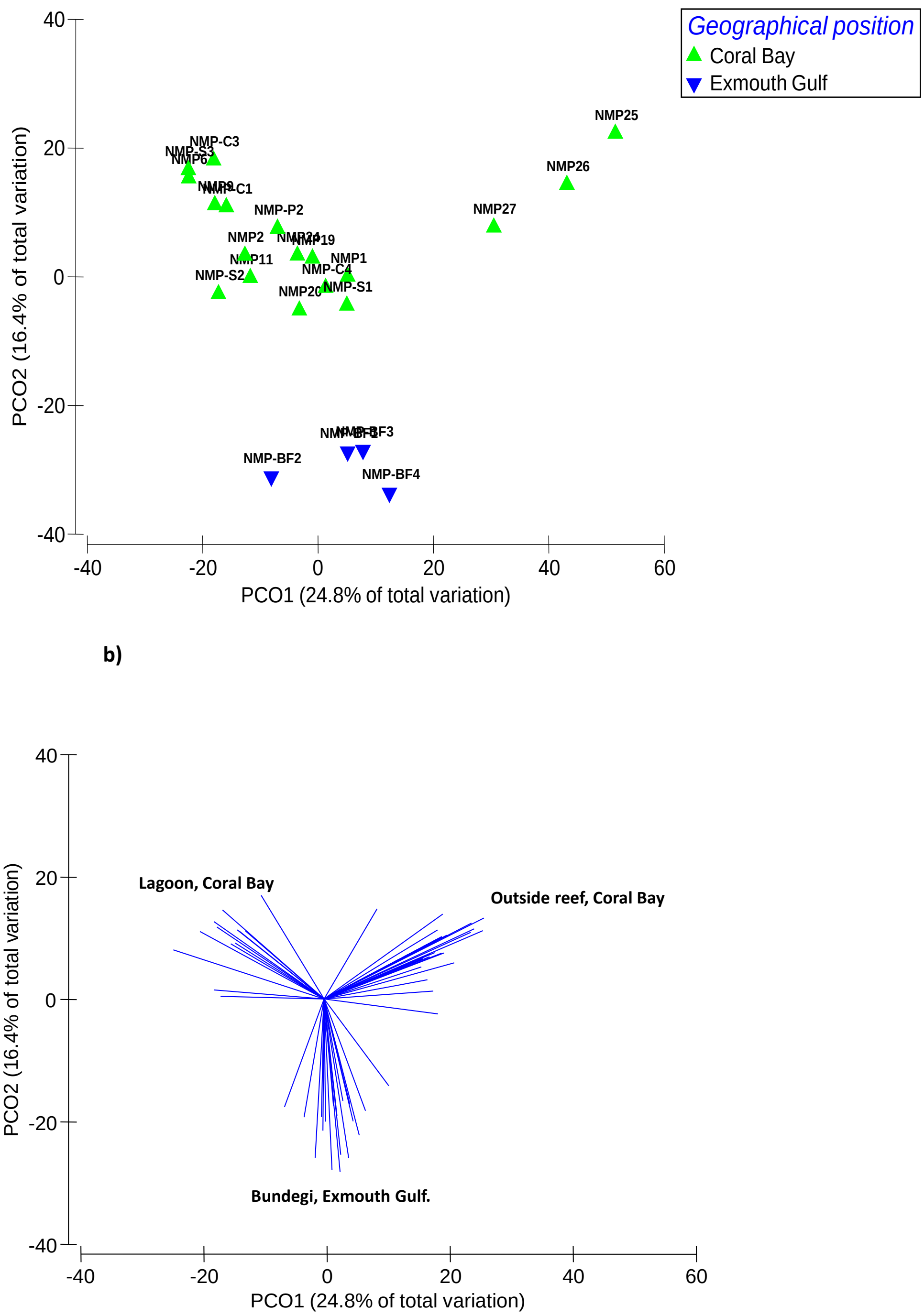

Figure 2 PCO of fish community data collected at Ningaloo Marine Park in 2012 reveals three main clusters of sites (a) characterized by species identified by vector overlay (b) (r>0.5) and listed in Appendix 2.

Sites with low PCO2 values (NMP-BF1, NMP-BF2, NMP-BF3, NMP-BF4) relate to surveys at Bundegi Reef, located in the Exmouth Gulf. These sites were characterized by a suite of species not recorded at Coral Bay (Lagoon and outside the reef). Those species include *Choerodon cyanodus, Choerodon schoenleinii, Choerodon cauteroma* and *Pomacentrus milleri*. Sites clustered to the left of the plot (Figure 2a) with low PCO1 values are those located inside the reef in Coral Bay and were characterized most by *Chlorurus sordidus, Scolopsis bilineata, Pomacentrus moluccensis* and *Chaetodon plebeius.*

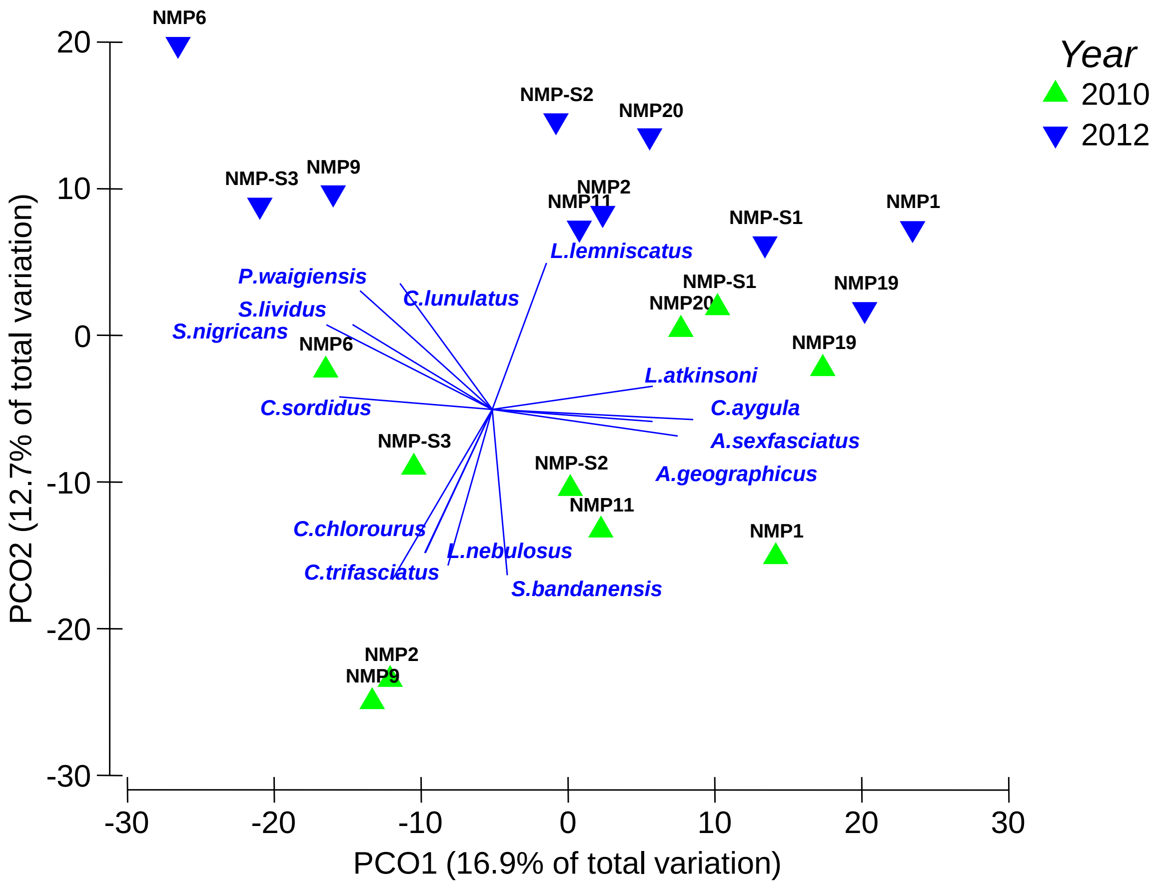

Figure 3. PCO of fish community structure for sites surveyed in both 2010 and 2012 at Ningaloo Marine Park, characterized by a slight shift to higher PCO2 values and slightly higher PCO1 values. Vectors (r>0.6) indicate which species characterize those sites in the same area of the plot. For example, sites NMP2 and NMP9, surveyed in 2010 are characterized by a higher biomass of *Stethojulis bandanensis, Chaetodon trifasciatus, Lethrinus nebulosus* and *Cheilinus chlorourus.*

PCO of fish community biomass data for sites surveyed in both years (Figure 3) revealed slight differences in community structure between 2010 and 2012, characterized by a movement towards higher PCO2 values and slightly higher PCO1 values. This was not statistically significant, however (results of PERMANOVA factor year presented in section 3.4 Sanctuary zone analysis).

Although differences between years were not significant overall, sites NMP2 and NMP9 were relatively more dissimilar between years compared to other sites. From the PCO, *Lethrinus nebulosus* (Spangled emperor) was identified as an important species related to that shift with low PCO1 values. Biomass of this commercially and recreationally important species declined from 1162.3 g per 500 m² to 230 g per 500 m², but this was also not statistically significant because of high variability between sites and times (see 3.4 Sanctuary zone analysis for more detail).

3.2 Invertebrate and cryptic fish surveys

The macroinvertebrate fauna surveyed at Ningaloo Marine Park in 2012 was dominated by echinoderms; *Echinometra mathaei, Echinostrephus* spp. and Comasterid spp. and the molluscs *Drupella cornus* and *Tridacna maxima*. The most common of the cryptic fishes were *Ecsenius yaeyamaensis, Eviota* sp. [*cf. guttata*] and *Fusigobius neophytus.* In total, 53 species of macroinvertebrates were recorded with a mean of 6.6 species per transect (100 m²) and 54 species of cryptic fishes were recorded, with a mean of 4.6 species per transect (100 m²). A summary of the key results from mobile invertebrate and cryptic fish surveys are provided in Table 5, and the most frequently recorded invertebrates are listed in Table 6.

Table 5. Summary of invertebrate and cryptic fish surveys at Ningaloo Marine Park in 2012. Values represent the mean per 100 m² at each site.

SiteCode	Invertebrate abundance	Number of invertebrate species	Sea urchin abundance	Number of sea urchin species	Cryptic fish abundance	Number of cryptic fish species	Giant clam abundance	*Drupella* abundance
NMP1	154	8	33.5	1.5	8	4	6	107.5
NMP11	25.5	4	4.5	1	13.5	4	5.5	13
NMP19	59.5	9.5	10.5	1	7.5	4	6	22.5
NMP2	59.5	7	40.5	2	7	4	4	11
NMP20	34.5	9	0.5	0.5	14	5	1.5	12.5
NMP24	57	11	19	1	8	3	1.5	12.5
NMP25	1108.5	13	1089	2	2	2	2.5	0
NMP26	1099	14	1069.5	2	2.5	2	4	0.5
NMP27	300.5	9	276.5	2	3	1	0	2
NMP6	38	2	0	0	2	2	1	37
NMP9	10	5	4	1	3	2	3	0
NMP-BF1	3.6	3	0	0	5.6	3	0.3	0
NMP-BF2	3	2	0	0	66.6	4	0	0
NMP-BF3	28	4	0	0	92.6	5	0	14.6
NMP-BF4	3.6	3	0.3	0.3	2.6	2	0	0
NMP-C1	88	9	33.3	1	36.3	9	12.6	28
NMP-C3	29.6	5	4	0.6	18	4	1	19.3
NMP-C4	278	16	135.6	1.6	11	3	8	16
NMP-P2	51.6	7	11.3	1	17	5	4.6	25.6
NMP-S1	58.3	7	41	0.6	3	2	0.3	6.6
NMP-S2	28	6	1.3	0.6	74.3	7	1.3	12
NMP-S3	11.5	4	0.5	0.5	3.5	2	0.5	7

Table 6.The most commonly recorded mobile invertebrate species at Ningaloo Marine Park 2012.

Species	Mean density (per 100m²)	Frequency (% of transects)
Drupella cornus	15.8	77.4
Nardoa variolata	3.0	77.4
Echinometra mathaei	113.4	69.8
Turbo argyrostomus	1.1	64.2
Tridacna maxima	1.8	52.8
Tridacna spp.	1.1	52.8
Comasterid spp.	5.0	35.8
Cerithium spp.	0.8	32.1
Echinostrephus spp.	12.7	30.2
Stichopus chloronotus	1.1	24.5

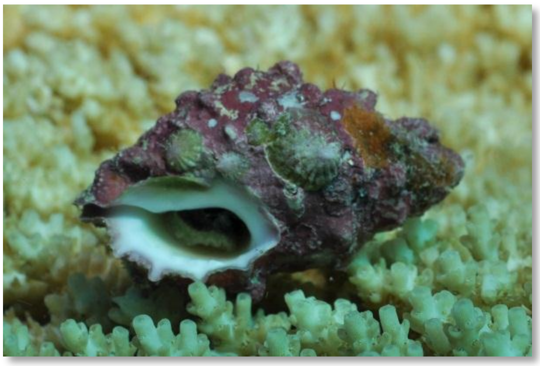

Plate 4. Most common mobile invertebrates recorded at Ningaloo Marine Park: *Drupella cornus*, *Nardoa variolata*, *Echinometra mathaei* and *Turbo argyrostomus.*

Data for mobile invertebrates and cryptic fishes from sites surveyed in both years were considered together as two mobile benthic faunal assemblages for multivariate analysis using PCO. The overall structure of mobile benthic fauna appeared quite similar between years (Figure 4), but important differences were evident at the species level. Most notably, the mean density and frequency of the drupe shell *Drupella cornus* increased significantly from 3.15 on 71% of transects to 22.9 per 100 m^2 on 95.25% of transects in 2010 and 2012 respectively. More details on changes in community structure and Drupella densities are provided in 3.4 Sanctuary zone analysis.

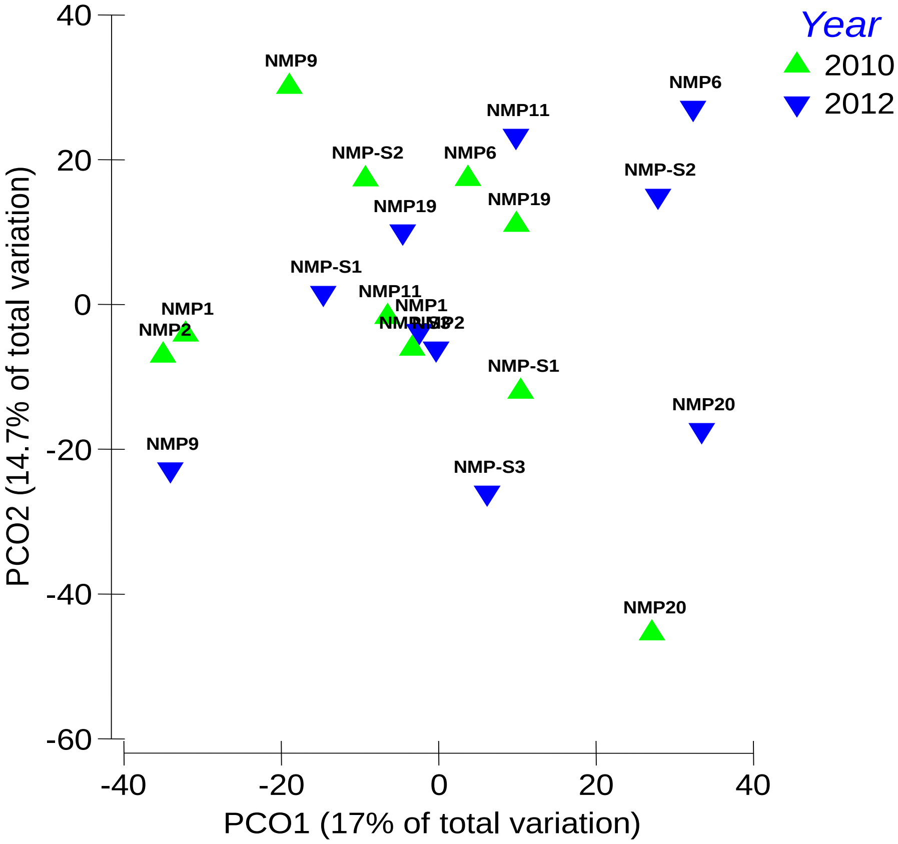

Figure 4. PCO of macro invertebrate and cryptic fish fauna at RLS monitoring sites in 2012. No significant difference in overall community structure was evident between 2010 and 2012. Only sites surveyed in both years were included.

3.3 Benthic cover

Mass mortality of hard corals was clearly evident in both *in situ* observations and photo-quadrats at Bundegi Reef. Photo-quadrats have not yet been processed, however, and so no quantitative data are presented here on the percentage of recently dead corals, but some example images are included here to highlight the current condition of the reef. Much of the dead coral was covered with epiphytic algae with little evidence of foliose macrophyte species.

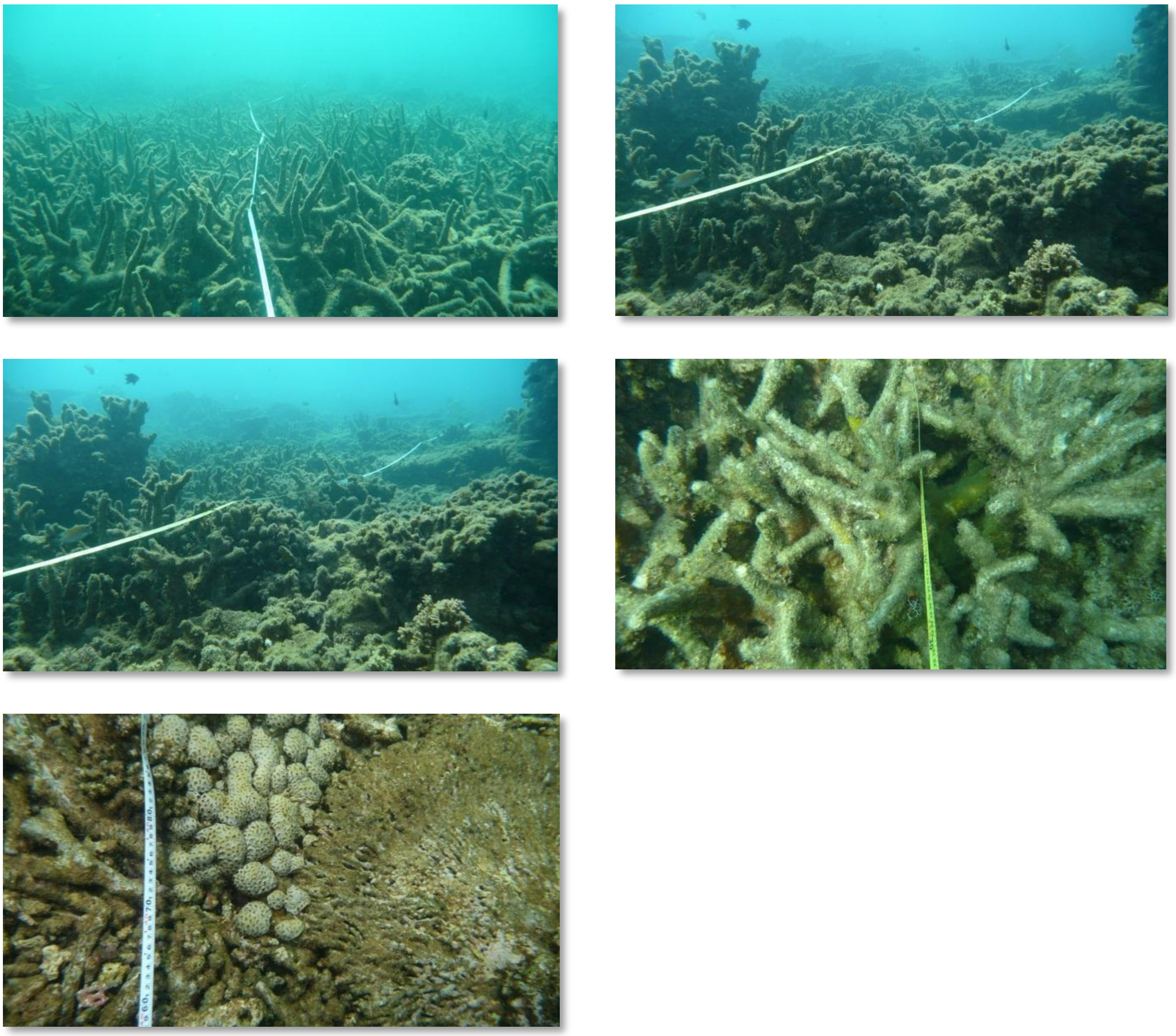

Plate 5. Examples of coral cover at Bundegi.

3.4 Sanctuary zone analysis

Assessment of fish and invertebrate communities in relation to the reserve zoning scheme were undertaken in relation to differences between years. Fish biomass averaged 48.0kg per 500 m^2 across all sites, and was not related to whether sites were in sanctuary zones or areas open to fishing (Figure 5, Table 7).

Although there was a general trend for greater biomass of target species overall, and *Lethrinus nebolusus*, other *Lethrinus* spp. (including *L. atkinsoni*) and *Choerodon rubescens* in sanctuary zones in both years surveyed (Figures 5 & 6), none of these were statistically significant due to large amounts of variation between sites within zones and many sites with zeros (for the individuals species analyses). Similarly, higher biomass of *Plectropomus* spp. (mostly *P. leopardus* and *P. maculatus*), *Epinephelus rivulatus*, *Epinephelus fasciatus* and total invertebrate abundance outside of sanctuary zones were not significant (Figure 6 & 7, Table 7).

Table 7. Results of PERMANOVAs testing for differences between years (2010 v 2012, df = 1) and protection status (sanctuary zone vs open access, df = 1) for fish and mobile benthic faunal communities and species of interest in Ningaloo Marine Park (error df = 42).

Variable	Year			Protection status			Year*Protection			Error
	MS	*F*	*P*	*MS*	*F*	*P*	*MS*	*F*	*P*	*MS*
Multivariate										
Fish community	4716.1	3.147	*0.070*	2507.7	1.707	*0.100*	1468.7	0.949	*0.526*	1547.4
Mobile benthic fauna	8070.1	2.928	*0.082*	4136.1	1.499	*0.299*	2758.7	1.002	*0.446*	2753.0
Univariate										
Fish biomass	0.8	2.300	*0.116*	<0.1	0.034	*0.831*	0.5	1.624	*0.207*	0.3
Fish density	0.1	0.937	*0.388*	<0.1	0.016	*0.932*	<0.1	0.025	*0.870*	0.1
Fish species richness	50.2	0.642	*0.536*	8.2	0.247	*0.635*	33.2	0.426	*0.512*	78.2
Exploited fish species biomass	6.0	0.969	*0.374*	9.1	3.718	*0.232*	2.4	0.395	*0.545*	6.2
Lethrinus nebulosus (biomass)	3.3	0.313	*0.819*	33.2	1.590	*0.468*	20.9	1.954	*0.168*	10.7
Lethrinus nebulosus (density)	<0.1	0.052	*0.963*	1.6	0.888	*0.590*	1.8	1.708	*0.198*	1.1
Lethrinus spp. (other) (biomass)	**22.0**	**3.332**	***0.038***	47.5	37.361	*0.133*	1.3	0.193	*0.655*	6.6
Lethrinus spp. (density)	9.0	2.720	*0.085*	23.2	4.090	*0.328*	5.7	1.706	*0.201*	3.3
Plectropomus spp. (biomass)	6.6	1.129	*0.311*	28.8	17.380	*0.068*	1.7	0.282	*0.592*	5.9
Plectropomus spp. (density)	0.6	1.806	*0.170*	0.8	6.022	*0.336*	0.1	0.437	*0.527*	0.3
Choerodon rubescens (biomass)	4.4	0.622	*0.554*	14.4	1.862	*0.431*	7.7	1.080	*0.303*	7.1
Choerodon rubescens (density)	0.1	0.767	*0.434*	0.3	1.335	*0.401*	0.2	1.631	*0.217*	0.2
Epinephelus fasciatus (biomass)	5.3	0.649	*0.570*	1.5	2.714	*0.103*	0.6	0.069	*0.787*	8.1
Epinephelus fasciatus (density)	0.5	0.890	*0.406*	0.5	10.717	*0.136*	4.2	0.008	*0.782*	0.5
Epinephelus rivulatus (biomass)	**15.5**	**3.505**	***0.046***	5.1	48.623	*0.169*	0.1	0.024	*0.891*	4.4
Epinephelus rivulatus (density)	0.9	3.079	*0.068*	0.6	3.061	*0.338*	0.2	0.704	*0.410*	0.3
Invertebrate density	4.5	3.034	*0.064*	1.8	512.19	*0.067*	<0.1	0.024	*0.962*	1.5
Invertebrate species richness	8.3	0.914	*0.401*	31.3	5.609	*0.228*	5.6	0.611	*0.441*	9.1
Sea urchin density	2.7	0.817	*0.450*	4.8	7.037	*0.233*	0.7	0.202	*0.653*	3.4
Drupella spp. density	**10.7**	**7.725**	***0.001***	6.3	2.802	*0.359*	2.3	1.634	*0.200*	1.4

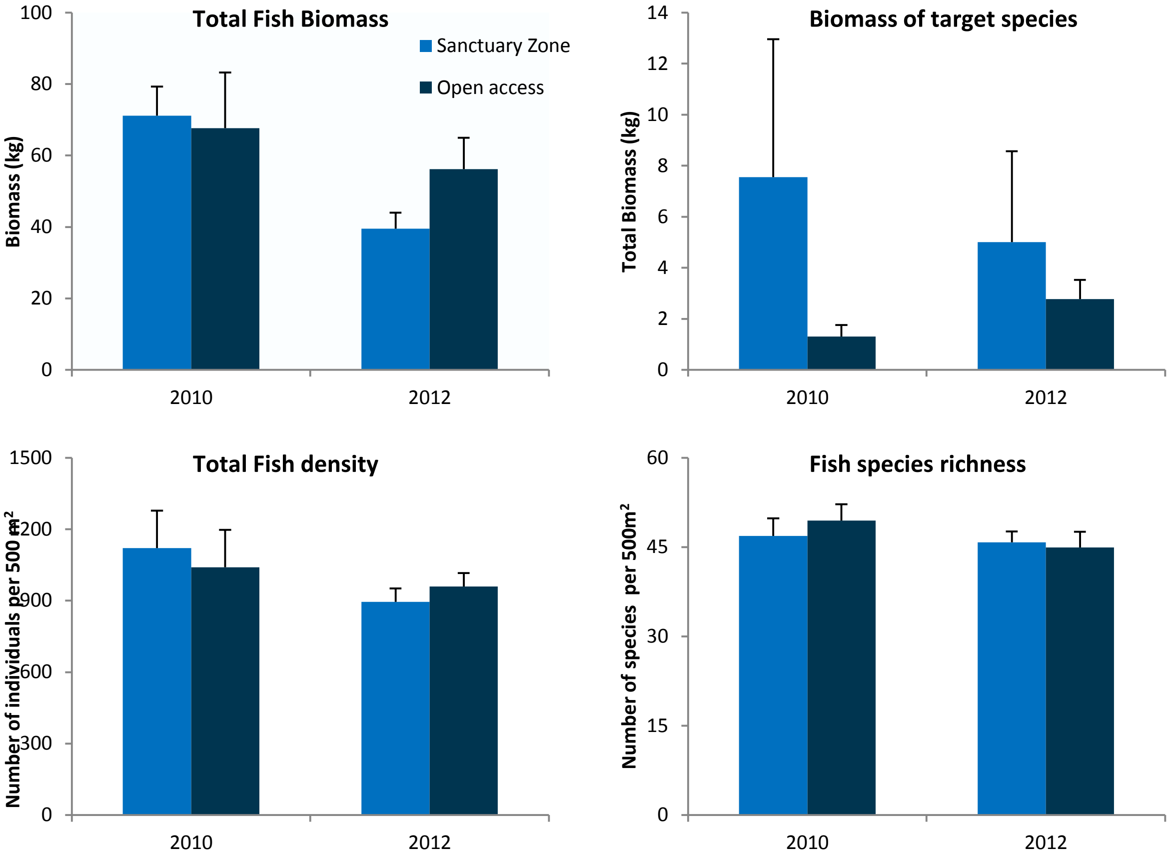

Figure 5. Fish community metrics inside and outside sanctuary zones in Ningaloo Marine Park in 2010 and 2012. Values represent averages per 500 m^2. Note that some different sites were surveyed in each year.

Differences between years were evident in a few metrics, most notably in the density of *Drupella* spp., which were much higher in 2012 surveys. Given a number of different sites were surveyed in each year (see Table 2) and 2012 surveys included three sites outside the lagoon habitat compared to none outside the lagoon in 2010, care must be taken in interpretation of results comparing years. The differences in *Drupella* densities are unlikely to be the result of different sites surveyed, however, as this species was in high densities across the majority of sites surveyed in the lagoon (and not outside), and its ubiquitously high density in 2012 and the location of different sites surveyed (with respect to its preferred habitat of live hard coral) suggest that the boom in *Drupella* numbers represents a real pattern. Indeed, unusually dense feeding aggregations of *Drupella* were observed on large hard coral colonies during the 2012 surveys. In contrast, the differences observed between years in the abundance of all invertebrate and only sea urchins are likely to be a direct result of these site differences, driven by high abundances of *Echinometra mathaei*, and to a lesser extent *Echinostrephus* spp., in the three sites outside the lagoon near Coral Bay (NMP25, NMP26, NMP27).

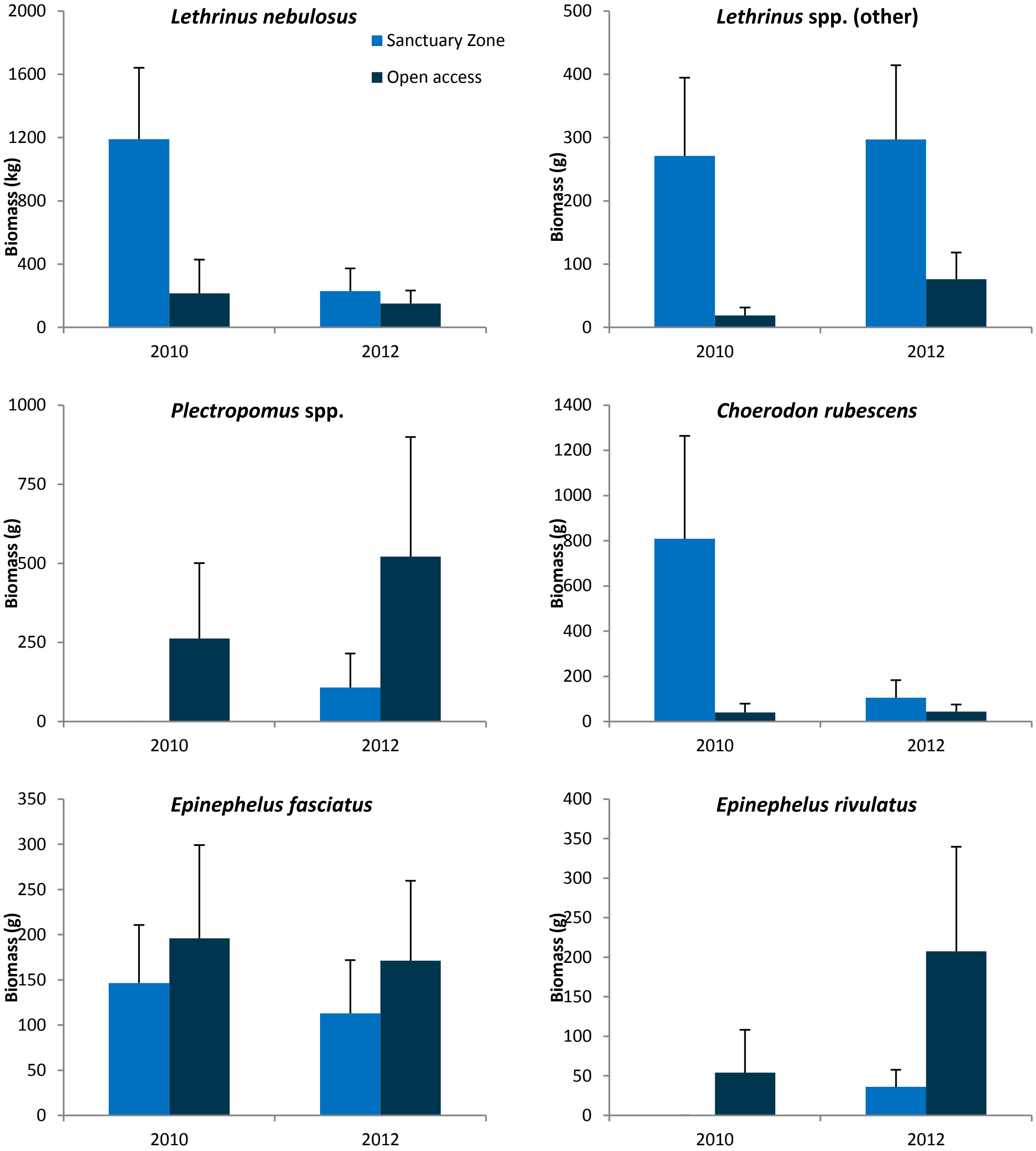

Figure 6. Biomass of key target species inside and outside sanctuary zones in Ningaloo Marine Park in 2010 and 2012. Values represent averages per 500 m^2. Note that some different sites were surveyed in each year.

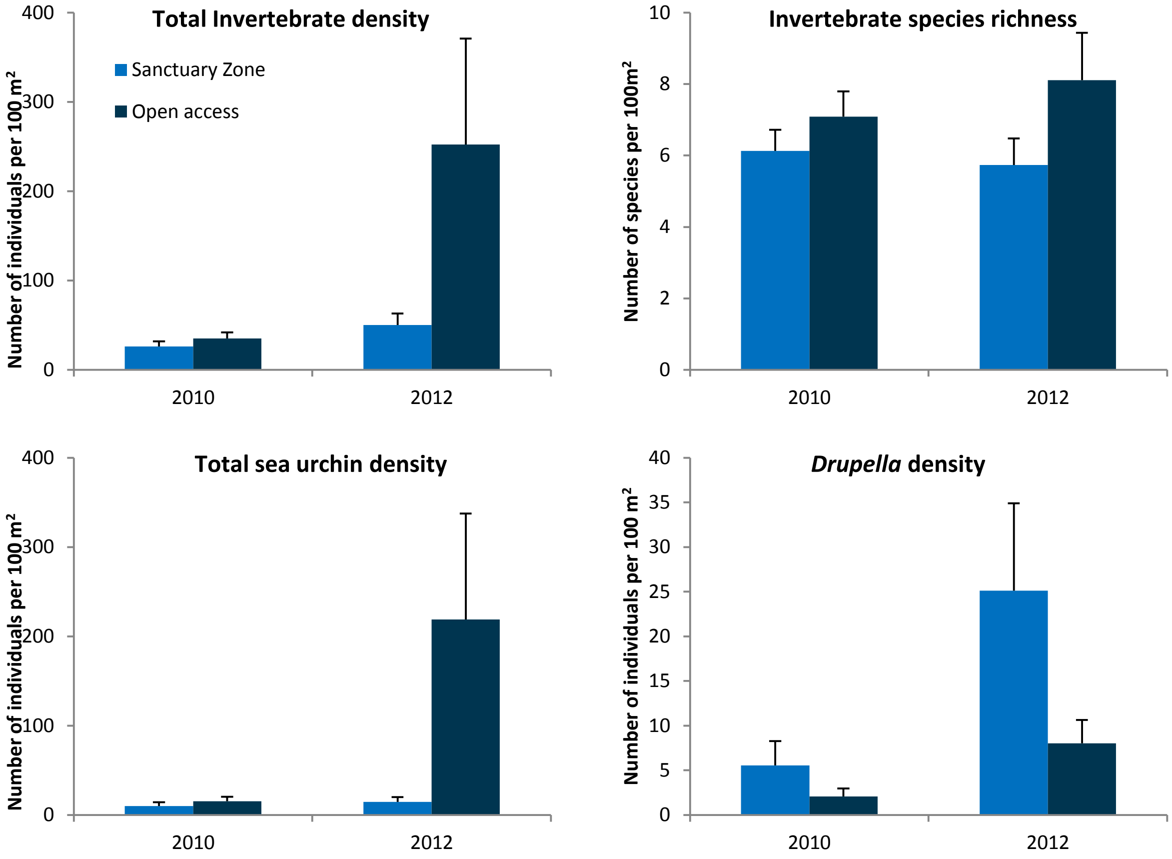

Figure 7. Invertebrate community metrics and *Drupella* density inside and outside sanctuary zones in Ningaloo Marine Park in 2010 and 2012. Values represent averages per 100 m^2. Note that some different sites were surveyed in each year.

With respect to the *Drupella* densities, a quick assessment of plots and correlation coefficients of the density of *Drupella* and the biomass of large fish species was undertaken to provide an initial idea of whether predation pressure by large fishes may be an important regulator of *Drupella* population size, and thus whether protection from fishing may be an important management strategy to reduce the likelihood of future *Drupella* population booms. A few weak negative associations were evident between the biomass of fish species classified as exploited and the density of *Drupella* spp. recorded at NMP sites (Figure 8). In particular, *Drupella* densities were typically low at sites where the mean biomass of *Choerodon schoeleinii*, *Choerodon cyanodus*, *Plectropomus leopardus*, *Epinephelus merra*, *Carangoides fulvoguttatus*, *Epinephelus fasciatus*, *Lethrinus nebulosus*, and *Lutjanus carponotatus* was reasonably high, but the low proportion of sites with each of these species, and variation likely associated with other factors (e.g. habitat), meant that explanatory power with such an approach was very weak.

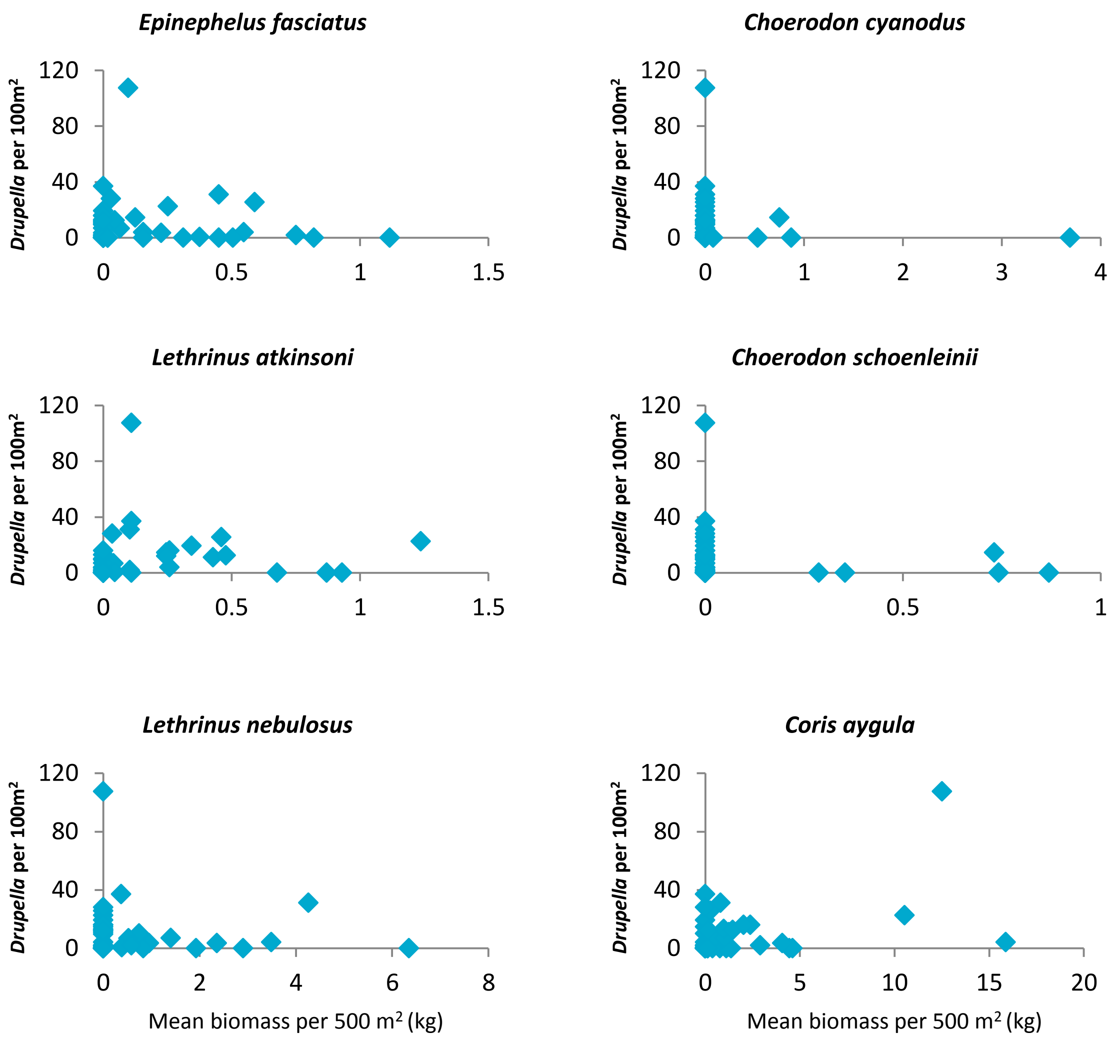

Figure 8. Density of *Drupella* spp. in relation to the biomass of larger fishes on transects in Ningaloo Marine Park. Note that *x*-axis scales differ between plots.

4 Discussion

Marine biodiversity surveys by Reef Life Survey divers at Ningaloo Marine Park in 2012, funded by a Coastwest grant and supported by the Department of Parks and Wildlife, Department of Fisheries and Murdoch University, have extended the monitoring by skilled community members to a second year. This provided the opportunity to review the data collected over the two years of monitoring and provide a synopsis of the community structure and assemblages of fishes and mobile invertebrates. Components of the ecosystem which are well or poorly represented in the parks sanctuary zones were also investigated.

When analysed graphically, data for fishes revealed three distinct groups (Figure 2) which reflect the three different habitat types surveyed, reefs inside and outside the lagoon in Coral Bay and Bundegi Reef in Exmouth Gulf. Species composition differed between these sites with *Choerodon cyanodus, Choerodon schoenleinii, Choerodon cauteroma* and *Pomacentrus milleri* common at Bundegi but not elsewhere. A list of species that PCO identified as characteristic of those sites can be found in Appendix 2.

With respect to changes between years, PCO and PERMANOVA of temporal biomass data suggested fish community structure has remained relatively stable. However, PCO did reveal some sites were conspicuous with more separation between years than others. NMP2 and NMP9, changed more than other sites, characterized by changes in biomass of *Stethojulis bandanensis, Chaetodon trifasciatus, Lethrinus nebulosus* and *Cheilinus chlorourus.*

The reduction in mean biomass of *Lethrinus nebulosus* between years, especially noticed inside sanctuary zones, was the most notable of these changes. Although it was not statistically significant, it is potentially cause for concern. *Lethrinus nebulosus* is a high value species, important to commercial and recreational fisheries throughout its range (Carpenter and Allen 1989), including Ningaloo Marine Park, where it is targeted by recreational fishers using line around coral reefs, close to shore (Marriott *et. al.* 2010). Work by Marriott *et. al.* (2010) revealed significant differences in the catch-at-age data for *Lethrinus nebulosus* from different time periods (Marriott *et. al.* 2010; Medley *et al* 1993), suggesting historical effects of fishing on the population age structure of this species. Similarly, catch-curve analysis of data from recreational fishing catches of this species between 2007-2008 produced rates of fishing mortality beyond the limit reference point, suggesting the sustainability of the stock was compromised (Marriott *et. al.* 2010).

It is not possible to identify causality of the decline suggested by analysis of RLS data, where fishing effort and broad scale oceanographic influences, as well as finer-scale habitat differences are not considered in this report, closer examination and further monitoring is certainly warranted.

The study by Marriott *et. al.* (2010) also highlighted the deficiency of data on target species in tropical fisheries in general, but particularly in the Ningaloo region as a result of no commercial catch statistics due to exclusion of commercial fishing from Point Maud to Tantabiddi. Data collected by RLS in 2010 and 2012 in NMP will assist in filling the gaps in the knowledge of highly-exploited species, such as *Lethrinus nebulosus*, by providing size and abundance estimates which are independent of catch data. Detection of changes in community structure, including flow-on trophic effects of increases or declines in target species, are key benefits of RLS monitoring.

With respect to the benthic invertebrate community, PCO and PERMANOVA of abundance data suggested that community structure has been relatively similar between years and inside and outside sanctuary zones. This is largely with the exception of mean densities of the Drupe shell, *Drupella cornus*.

Drupella cornus is a muricid gastropod that preys on corals and is known throughout the Indo-Pacific region for sudden increases in population densities (Shoepf *et al* 2010). Such an increase was observed at Ningaloo Reef in the early 1980's and 1990's, resulting in significant coral damage along 100 km of the reef, with coral mortality close to 100% in the worst affected areas (Armstrong 2009). When compared to outbreaks in different regions of the world at that time, the density of *Drupella cornus*, spatial distribution and level of coral damage at Ningaloo was unprecedented (Armstrong 2009).

In response to this threat, Department of Parks and Wildlife has been monitoring coral health and population densities of *Drupella cornus* as part of their broader management plan, undertaking surveys at least every three years, adding to a data set that dates back to 1987 (Armstrong 2009; Department of Environment and Conservation 2005). RLS monitoring of Department of Parks and Wildlife sites at Ningaloo Marine Park replicates many of the long term monitoring locations and produces detailed biodiversity data that can be fed directly into the management plan to complement the existing data set. Of particular value in the RLS data is the co-location of fish, mobile invertebrate and coral data such that relationships between these faunal components can be assessed. Although far from conclusive, an initial exploration of relationships between densities of *Drupella* and biomass of its potential predators in this report suggested further research into such relationships is warranted. Continued monitoring of NMP by RLS will allow testing of whether such relationships hold through time, but further finer-scale observational work to complement this would also be highly valuable.

Surveys carried out at Bundegi Reef not only recorded a different suite of fish species, but also confirmed a recent mass mortality of corals. The well documented warm water event that occurred between 2010 and 2011 where sea surface temperatures at Exmouth peaked at 31.2^{o}C in January 2011 (Pearce and Feng 2013) resulted in mass coral bleaching from Montebello and Barrow Islands to Rottnest Island, the first time this kind of event has been recorded in Western Australia (Department of Environment and Conservation 2012). Bundegi suffered the highest level of coral bleaching with 95% of coral affected. Likewise, mortality was highest with 84% of corals lost (Department of Environment and Conservation 2012). As the RLS photographs show, little recovery appears to have occurred and anecdotal observations by RLS divers indicate high cover of epiphytic algae over large areas of the reef. Although not yet processed for quantification of coral cover and extent of coral mortality, all photo-quadrats taken during the RLS surveys in this project remain as a permanent archive of current coral condition at Bundegi.

A study at Orpheus Island and Pandora Reef in the Great Barrier Reef between 1998 and 2000 examined patterns and dynamics of algal recruitment after the major bleaching event that occurred in early 1998. The findings suggest that disturbance (caused by bleaching) could lead to relative changes in the abundance of both corals and algae but with reversed causality suggesting that the decline in coral abundance is the cause of increased algal abundance (Guillermo and McCook 2002). The implications are significant, if corals are unable to recover due to either sustained climate forcing or adverse anthropogenic activities, algal succession could progress to species which under certain conditions may inhibit the recovery of corals. Continued monitoring of Bundegi by RLS will be important in helping track the condition of the whole reef community, in terms of not only coral cover, but also how changes in coral cover are translating to changes in mobile invertebrates and fishes, as well as cryptic fishes, which may otherwise go unnoticed. Continued monitoring will also contribute to understanding of how coral communities respond to thermal stress and what that may mean in the context of climate change and pressure from anthropogenic activities, particularly when data from Bundegi are combined with those from other recently bleached areas (such as Lord Howe Island) monitored by RLS using the same methods.

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Acknowledgements

Reef Life Survey acknowledges the ongoing support from Department of Parks and Wildlife, Kate Sputore and Perth region NRM, Department of Fisheries, Murdoch University, particularly Mike Van Keulan and Frazer Mcgregor, Reef Life Survey would not be possible without the huge efforts and ongoing support of its volunteer divers. Divers who assisted in Ningaloo Marine Park surveys include: Andrew Green, Bill Barker, Carolina Garcia, Don Love, German Soler, Graham Edgar, Rick and Jemina Stuart-Smith, Jennifer Hoskin, Kate Tinson, Keith and Terina Saunders, Kevin Smith, Margo Smith, Paul Day, Sylvia Buchanan and Tim Alexander. We would also like to acknowledge the Yamatji Marlpa Aboriginal Corporation (YMAC), the native title representative body for the traditional owners of the Pilbara, Murchison and Gascoyne regions of Western Australia.

University of Tasmania staff and RLS organisers who assisted with the project include: Just Berkhout, Antonia Cooper, Marlene Davey, Elizabeth Oh and Jemina Stuart-Smith.

This report forms an additional part of a Western Australian Planning Commission's Coastwest project “Community-assisted scientific assessment and management of Western Australian Marine Protected Areas’, with support from the Australian Government’s Caring for our Country initiative.

The RLSF is a non-profit environmental organisation. Donations to the RLS are tax-deductible and support ongoing monitoring of the marine environment at Ningaloo Marine Park, Rottnest Island and around Australia.

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Appendix 1. Families considered cryptic and for which members are recorded also on the invertebrate and cryptic fish survey

FAMILY	COMMON NAME	FAMILY	COMMON NAME
Acanthoclinidae	Basslets	Liparidae	Snailfishes
Agonidae	Poachers	Lotidae	Burbots
Anarhichadidae	Wolf eels	Monocentridae	Pineapplefishes
Antennariidae	Anglerfishes	Moridae	Beardies
Aploactinidae	Velvetfishes	Muraenidae	Moray eels
Apogonidae	Cardinalfishes	Nototheniidae	Icefishes
Ariidae	Catfishes	Ophichthidae	Snake and worm eels
Aulopidae	Sergeant bakers	Ophidiidae	Lings
Bathymasteridae	Ronquils	Opistognathidae	Jawfishes
Batrachoididae	Frogfishes	Orectolobidae	Wobbegongs
Blenniidae	Blennies	Parascyllidae	Catsharks
Bovichtidae	Thornfish	Pataecidae	Prowfishes
Brachaeluridae	Blind sharks	Pegasidae	Seamoths
Brachionichthyidae	Handfishes	Pholidae	Gunnels
Bythitidae	Blindfishes and cuskeels	Pinguipedidae	Grubfishes
Callionymidae	Dragonets	Platycephalidae	Flatheads
Carapidae	Pearlfish	Plesiopidae	Longfins
Centriscidae	Razorfish	Plotosidae	Catfishes
Chaenopsidae	Tubeblennies, flagblennies	Priacanthidae	Bigeyes
Chandidae	Glassfishes	Pseudochromidae	Dottybacks
Chironemidae	Kelpfishes	Pseudogrammatidae	Soapfishes
Cirrhitidae	Hawkfishes	Psychrolutidae	Fatheads
Clinidae	Weedfishes	Rajidae	Skates
Congridae	Conger eels	Rhinobatidae	Shovelnose rays
Cottidae	Sculpins	Scorpaenidae	Scorpionfish, orbicular velvetfish
Creediidae	Sand divers	*Serranidae - excluding Anthiinae	Rockcods & Seaperches
Cryptacanthodidae	Wrymouths	Solenostomidae	Ghostpipefishes
Cyclopteridae	Lumpsucker	Sticharidae	Prickleback
Dasyatididae	Stingrays	Syngnathidae	Pipefish & Seahorses
Eleotrididae	Gudgeons	Synodontidae	Lizardfishes and Sauries
Gnathanacanthidae	Red velvetfish	Tetrabrachiidae	Anglerfishes
Gobiesocidae	Clingfishes	Torpedinidae	Numbfish
Gobiidae	Gobies	Trachichthyidae	Roughies
Grammistidae	Soapfishes	Tripterygiidae	Threefins
Heterodontidae	Bullhead sharks	Uranoscopidae	Stargazers
Holocentridae	Squirrel and soldier fishes	Urolophidae	Stingarees
Labrisomidae	Tropical blennies	Zaproridae	Prowfish
Leptoscopidae	Pygmy stargazers	Zoarcidae	Eelpouts

Appendix 2. Species identified by vector overlay (r>0.5) which characterize the three groups revealed by PCO (Figure 1).

Species-(Lagoon, Coral Bay)	Species-(Bundegi, Exmouth Gulf)	Species-(Outside reef, Coral Bay)
Chaetodon lunulatus	*Abudefduf bengalensis*	*Acanthurus grammoptilus*
Chaetodon plebeius	*Acanthurus dussumieri*	*Acanthurus olivaceus*
Cheilodipterus quinquelineatus	*Bodianus axillaris*	*Amphiprion clarkii*
Dischistodus prosopotaenia	*Choerodon cauteroma*	*Aprion virescens*
Epibulus insidiator	*Choerodon cyanodus*	*Cantherhines fronticinctus*
Labrichthys unilineatus	*Choerodon schoenleinii*	*Cantherhines pardalis*
Meiacanthus grammistes	*Cirripectes filamentosus*	*Carangid spp.*
Oxymonacanthus longirostris	*Ctenochaetus striatus*	*Chaetodon assarius*
Plectroglyphidodon lacrymatus	*Ecsenius yaeyamaensis*	*Chanos chanos*
Pomacentrus moluccensis	*Eviota* sp. *[cf. guttata]*	*Chromis weberi*
Stegastes lividus	*Helcogramma striatum*	*Cirrhilabrus temminckii*
Stegastes nigricans	*Lutjanus carponotatus*	*Cirrhitichthys oxycephalus*
	Neoglyphidodon nigroris	*Coris caudimacula*
	Plectorhinchus multivittatus	*Ecsenius bicolor*
	Plectropomus leopardus	*Epinephelus fasciatus*
	Pomacentrus milleri	*Epinephelus rivulatus*
	Psammoperca waigiensis	*Galeocerdo cuvier*
	Pseudochromis fuscus	*Lethrinus nebulosus*
	Scarus rivulatus	*Paracirrhites forsteri*
		Parupeneus multifasciatus
		Pomacanthus imperator
		Pseudochromid spp
		Ptereleotris evides
		Scolopsis xenochrous

The Reef Life Survey program was established in 2007 by divers, managers and University of Tasmania researchers, and now forms the core activity of the Reef life Survey Foundation Incorporated, a not for profit Australian organisation.

CONTACT US:

enquiries@reeflifesurvey.com
Reef Life Survey Foundation
60 Napoleon St
Battery Point
TAS, 7005
Telephone: +61 3 6227 7214

Postal address:
RLS data team
c/o Institute for Marine and Antarctic Studies
Private bag 49
Hobart, 7001