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

ROTTNEST ISLAND MARINE RESERVE

Project by the Reef Life Survey Foundation Incorporated

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Contents

List of acronyms

ACRONYM	EXPANDED
RLS	Reef Life Survey
RLSF	Reef Life Survey Foundation Incorporated
GPS	Global Positioning System
DEC	Department of Environment and Conservation
RIA	Rottnest Island Authority
NRM	Natural Resource Management
UEC	Underwater Explorers Club of Western Australia
UWA	University of Western Australia
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 Environment and Conservation, 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.

This report is for Rottnest Island, where 11 RLS divers surveyed 43 transects across 16 sites between 24th May and 27th May 2012. Four sites were within sanctuary zones and twelve sites were in open access areas. Collectively, 143 species of fish were recorded, the most commonly sighted were *Chromis westaustralis* (West Australian puller), *Trachinops brauni* (blue-lined hulafish), *Coris auricularis* (western king wrasse) and *Pempheris klunzingeri* (rough bullseye). Of the 143 species, 33 were of tropical origin, including *Scarus ghobban* (blue barred parrotfish), *Chlorurus microhinus* (steephead parrotfish), *Abudefduf sexfasciatus* (scissortail sergeant) and *Acanthurus triostegus* (convict surgeonfish).

The mobile macroinvertebrate fauna was dominated by echinoderms and molluscs, with *Centrostephanus tenuispinus* (thin-spined sea urchin), *Fromia polypora* (many-pored star) and *Turbo torquatus* (turban shell) the most common. Collectively, 78 species of mobile macroinvertebrates were recorded, with species in the order Nudibranchia relatively diverse.

The sessile community was dominated by macroalgae (*Ecklonia radiata* predominant) established over limestone reef. Surveys on the south side of the Island included the area of *Pocillopora* reef at Parker Point where the settlement of tropical species is best observed (Hutchins and Pearce 1994).

1 Introduction

1.1 Rottnest Island

Rottnest Island (RI) lies 18 km offshore to the west of Perth at ~ 32.00^{o} S, 115.52^{o} E. It possesses a unique marine environment, located on the outer continental shelf and bathed by the warm, southward flowing waters of the Leeuwin Current. This low salinity current from the tropics transports larvae down the west coast and on into the Australian Bight (Hutchins and Pearce 1994), and shapes species distributions and marine communities along the west coast. For example, it is responsible for the presence of a living coral reef (made up by *Pocillopora damicornis*) on Rottnest Island at Parker Point (Richardson et.al 2005; Pearce and Walker 1991).

Rottnest Island is a popular destination for visitors who come to the island for boating, recreational fishing and diving, as well as land-based activities. The Island receives over 500,000 visitors annually and is managed by the Rottnest Island Authority (RIA). Established in 1987, RIA manages both the terrestrial and marine environment through the implementation of The Rottnest Island Management Plan. RIA actions this plan under the Rottnest Island Authority Act (1987) which enables it to:

- provide and operate recreational and holiday facilities on the Island;
- protect the flora and fauna of the Island; and
- maintain and protect the natural environment and the man-made resources of the Island and, to the extent that the RIA resources allow, repair its natural environment.

The Island also has cultural and spiritual significance for Aboriginal communities. The Noongar people know the island as *Wadjemup*, meaning ‘place of spirits’ (Rottnest Island Authority 2009).

1.2 Threats to Rottnest Island Marine Reserve

Some of the major potential and current pressures to the biodiversity of Rottnest Island Marine Reserve (RIMR) are listed in table 1. Specific management objectives and strategies to reduce or remove these pressures are identified in the RIA management plan, *Rottnest Island Management Plan 2009-2014.*

Table 1. Potential and current major pressures affecting the ecological values of Rottnest Island Marine Reserve.

Ecological value	Pressures
Geomorphology. Complex limestone sub-tidal and intertidal features forming important habitat types.	Physical disturbance from infrastructure development, trampling and boating.
Water and sediment quality. Maintenance of good water and sediment quality is required for ecosystem health.	Toxic discharge from waste water, boating and shipping related waste.
Seagrass communities. Important primary producer plays an important role in sedimentation and provides nursery habitat for invertebrates and finfish.	Physical disturbance from boating (anchoring, propeller scour and mooring installation), waste water.
Macroalgae (sub-tidal reef) communities. Important primary producers with high diversity. Provide important refuge areas for many finfish and invertebrate species.	Physical disturbance from vessels (similar to seagrass), toxic discharge and waste water.
Cetaceans. Cetaceans hold special conservation status with humpback whales (*Megaptera novaeangliae*) frequently seen within the reserve.	Physical disturbance from human activities, entanglement, toxic discharge and collisions with vessels.
Finfish. Finfish diversity contributes to the biodiversity of the marine reserve and plays a major role in food webs.	Recreational fishing. Habitat degradation through anthropogenic activities.
Invertebrates. The diversity and abundance of the invertebrate fauna forms a critical element of the food web supporting finfish, seabirds and shorebirds.	Recreational and commercial fishing, by-catch and habitat degradation through anthropogenic activities.

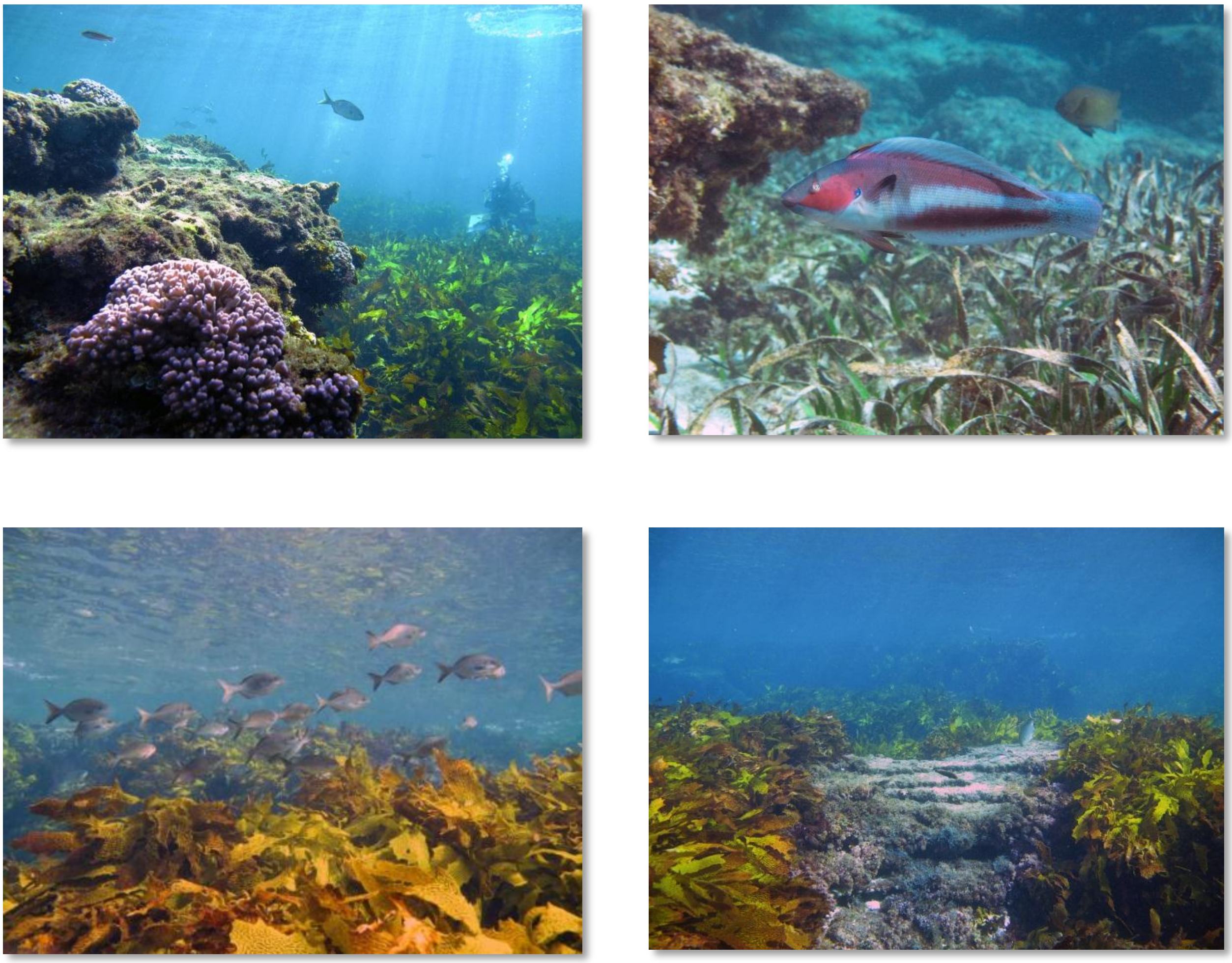

Plate 1. Rottnest Island reef habitats

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, space and taxonomic coverage.

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.

*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

2.4 Data analysis

Data collected in this project were analysed in conjunction with data collected at Rottnest Island in previous years by RLS teams. This included annual surveys from 2008 to 2012 (Table 2, Fig. 1). While some differences exist between years with regard to the sites surveyed, a reasonable number of sites were surveyed on all occasions. The same methodology and many of the same divers were involved in repeat surveys, and surveys in different years were undertaken at a similar time of year (generally in May). Details of statistics used in analyses are provided in Appendix 2.

Table 2. Details of RLS surveys and sites at Rottnest Island since 2008. The number of 50 m transects surveyed is indicated for each site under each year.

SiteCode	Site	Latitude	Longitude	Zone	2008	2009	2010	2011	2012
RI1	Green Island Reserve 1	-32.01725	115.50014	Sanctuary Zone	3	3	7	3	4
RI2	The Count	-32.01552	115.55708	Open to fishing	5	4	3	3	1
RI3	Eagle Bay	-32.01805	115.4523	Open to fishing		3	5		4
RI4	The Grottos Rottnest	-31.98926	115.51746	Open to fishing		4		4	2
RI5	Crystal palace	-32.02498	115.54514	Open to fishing	4	3	2	2	2
RI6	Pocillopora Reef	-32.02575	115.52968	Sanctuary Zone	1	3	6	2	2
RI7	Green Island Wall	-32.02472	115.50535	Open to fishing		2	5	3	3
RI8	Fish Hook Bay	-32.02435	115.45157	Open to fishing		3	5	3	4
RI9	Armstrong Bay	-31.9902	115.5047	Sanctuary Zone			7	5	2
RI10	Kingston Reef	-31.98618	115.557	Sanctuary Zone			3	3	2
RI11	Mini Swirl Stragglers	-32.05237	115.62358	Open to fishing		1			
RI12	West End Rottnest	-32.03073	115.4411	Open to fishing		1			3
RI13	Collindar	-32.03047	115.52309	Sanctuary Zone	1				
RI14	Parker Point	-32.02967	115.53069	Open to fishing	3				
RI15	Little Salmon Bay Rottnest	-32.02603	115.52353	Sanctuary Zone	1				
RI16	Jackson Rocks	-32.02567	115.58404	Open to fishing	1	1	4		3
RI17	Salmon Bay	-32.02329	115.51787	Sanctuary Zone	4				
RI18	Dyer Island	-32.02078	115.5477	Open to fishing	3		2		2
RI19	Parakeet	-31.9891	115.5159	Open to fishing		1	2	1	
RI20	Swirl Reef Rottnest	-31.99976	115.46846	Open to fishing		1			3
RI21	Duck Rock South	-31.9885	115.54114	Open to fishing			4	3	3
RI22	Parakete Bay North	-31.98754	115.51443	Open to fishing			1		
RI23	Roe Reef	-31.97427	115.53757	Open to fishing	2	3	5	3	3
RI24	Flat top	-32.00435	115.4518	Open to fishing					1
WA91	Lionfishcave - Rottnest	-31.97733	115.51566	Open to fishing			1		

Figure 1. Map of RLS sites at Rottnest Island. See Table 2 for site details.

3 Results

Surveys at RIMR in 2012 were undertaken for the fifth annual RLS survey extended weekend between 24th May and 27th May 2012. A total of 43 transects were surveyed at 16 sites by 11 RLS divers.

3.1 Fish surveys

Collectively, 143 species of fish were recorded in 2012 surveys with a mean number of species per 500 m^2 transect of 26.3, taking the total number of fish species recorded at Rottnest Island by RLS surveys over 5 years to 211, with an overall average of 21.8 per 500 m^2. Table 3 presents general summaries from fish surveys in 2012 by site.

The most common species sighted during the 2012 surveys were *Chromis westaustralis* (West Australian puller), *Trachinops brauni* (blue-lined hulafish), *Coris auricularis* (western king wrasse) and *Pempheris klunzingeri* (rough bullseye) (Plate 3). Of the 143 species, 33 could generally be considered to have tropical affinities, including *Scarus ghobban* (blue barred parrotfish), *Chlorurus microhinus* (steephead parrotfish), *Abudefduf sexfasciatus* (scissortail sergeant) and *Acanthurus triostegus* (convict surgeonfish).

Plate 3. Common fish species recorded at Rottnest Island. *Chromis westaustralis*, *Trachinops brauni*, *Coris auricularis* and *Pempheris klunzingeri*.

Table 3. Results of fish surveys for RLS monitoring sites at Rottnest Island in 2012. Values represent the mean per 500 m^2 transect at each site.

Site Code	Number of transects	Number of fish species	Total fish density	Total fish biomass (kg)
RI1	4	26.7	471.7	13.479
RI2	1	33.0	1286	42.929
RI3	4	14.0	714.0	13.207
RI4	2	28.5	1414.5	45.145
RI5	2	24.0	343.5	25.756
RI6	2	31.5	889.0	55.671
RI7	3	26.0	1100.6	38.313
RI8	4	26.2	319.7	31.468
RI9	2	43.0	1528.5	131.710
RI10	2	30.5	423.5	34.113
RI12	3	24.6	1401.3	41.314
RI16	3	27.3	1606.6	57.758
RI18	2	12.5	177.0	13.792
RI20	3	27.6	633.3	19.156
RI21	3	27.3	488.6	35.958
RI23	3	29.6	1216.3	42.672
RI24*	1	26.0	1341.0	77.601

*RI24 was surveyed in April 2012 and has been added to the 16 sites surveyed between the 24th & 27th May 2012.

Assessment of temporal patterns in Rottnest fish communities based on data from 2008 to 2012 revealed a rise in the mean number of fish species per 500 m^2 in 2011 and 2012 (to 26 species per 500 m^2 in 2012), following a relatively stable period during 2008-2010 in which there was an average of 19 species per 500 m^2 (Fig. 2). A trend in total fish density also followed this pattern, but mean fish biomass remained fairly stable, with the exception of a peak in 2009. Although these comparisons are based on some different sites in different years, the same comparisons made using only those sites surveyed in all years generally confirm that they were representative of overall trends, particularly in the case of species richness (Appendix 3).

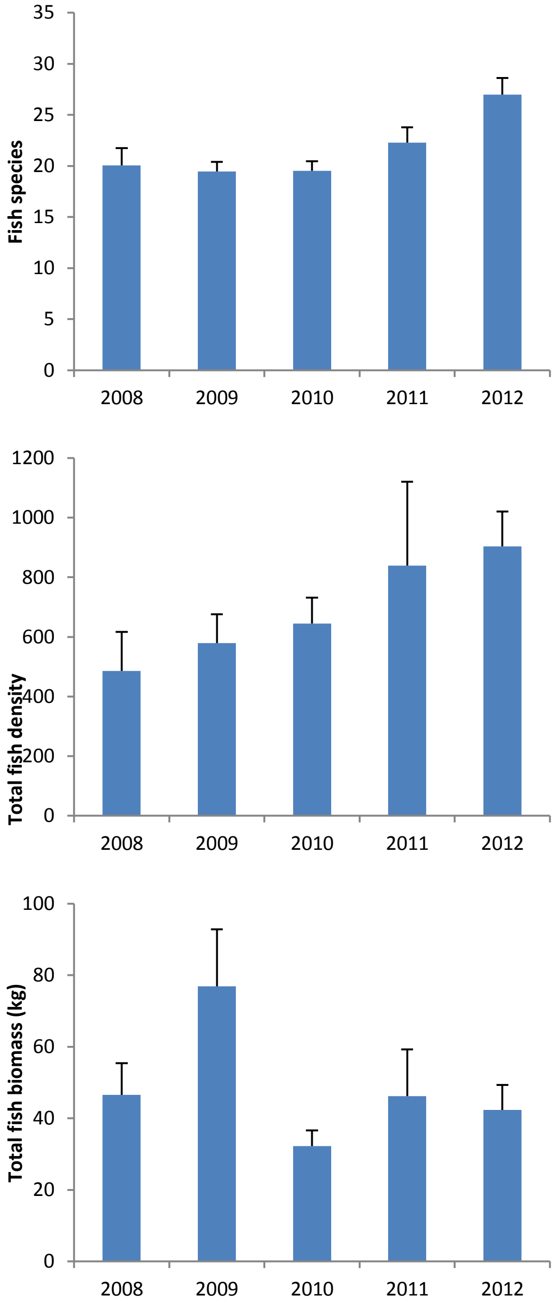

Figure 2. Mean fish biomass, density and number of species (per 500m^2) for years 2008-2012.

Principal Coordinates analysis (PCO) of fish community abundance data (Fig. 3) revealed a general shift in fish community structure with time, characterized by a general movement towards low values of PCO2 and slightly higher values of PCO1. This suggests a general shift towards increasing similarity of sites to RI6 (*Pocillopora* Reef), which is the shallow, coral-dominated site where species with tropical affinities are most common. RI6 remained relatively similar through time.

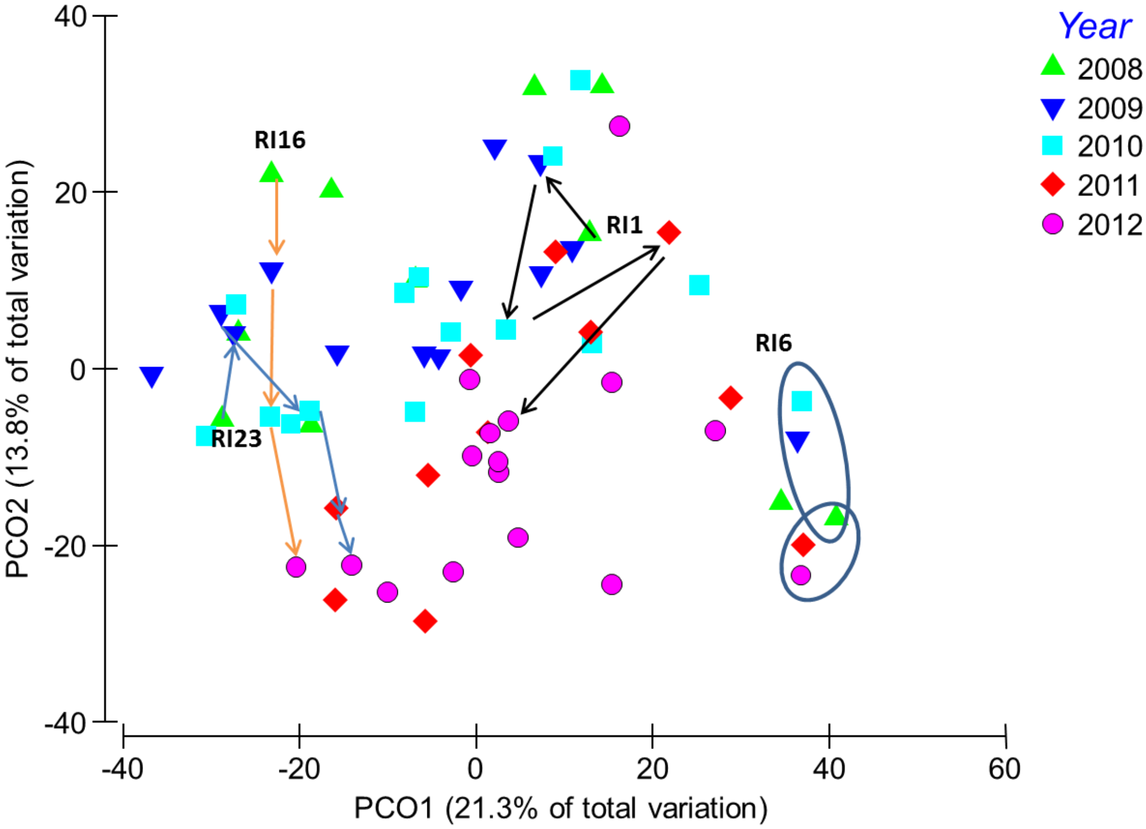

Figure 3. PCO plot of fish community structure in different years at Rottnest Island. Arrows indicate movement of sites RI1, RI16 and RI23, which showed greatest inter-annual differences in fish community structure. RI6 (Pocillopora Reef) remained relatively stable and is circled. PCO was based on Bray-Curtis dissimilarity of log (x+1) transformed abundance data.

Canonical Analysis of Principal Coordinates (CAP) revealed increases in density of *Anampses geographicus, Pomacentrus coelestis, Thalassoma lutescens* and *Coris auricularis* (Fig. 4, Plate 4) as most correlated to the CAP axis which best defines inter-annual differences in community structure (Table 4), with a Mann-Whitney U test indicating a significant difference in the mean density of all four species.

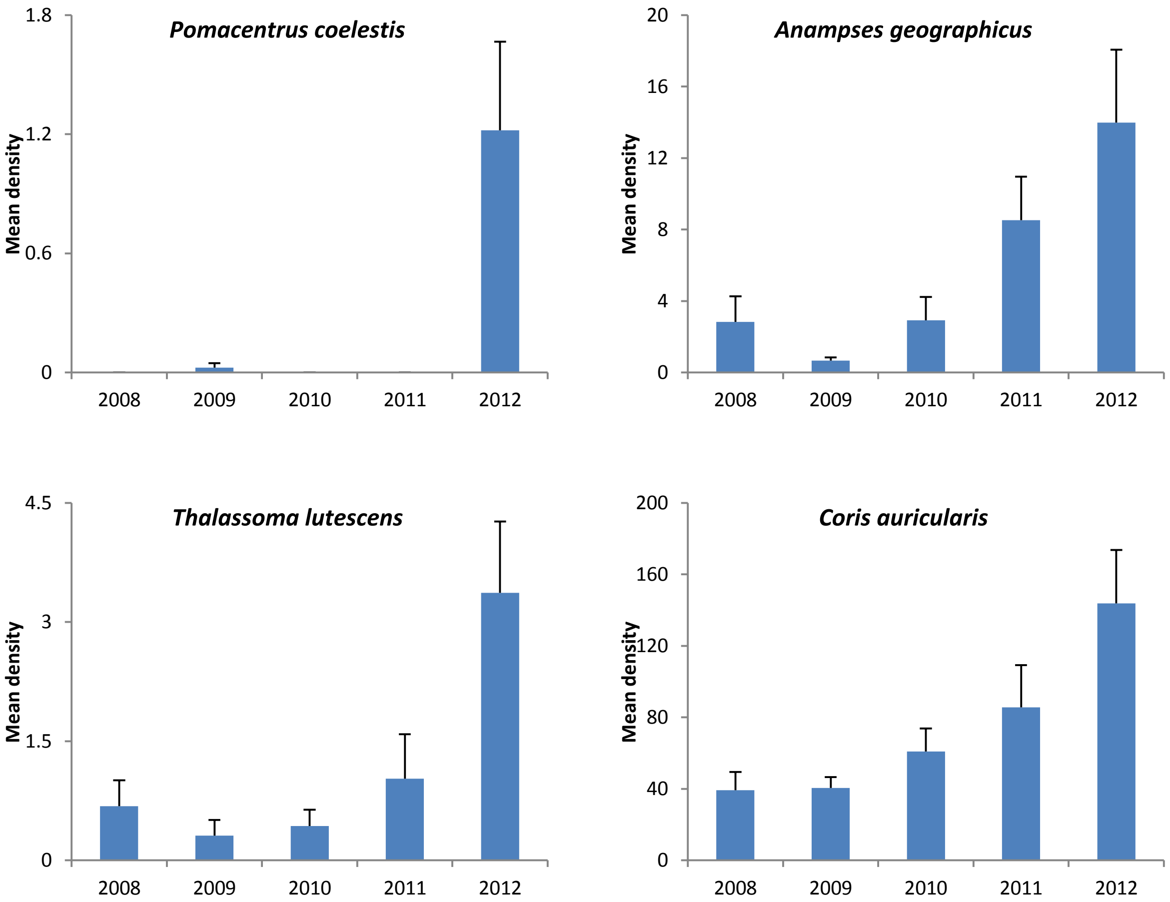

Figure 4. Trends in the mean density (per 500 m^2) of *Pomacentrus coelestis, Anampses geographicus, Thalassoma lutescens* and *Coris auricularis* at Rottnest Island from 2008 to 2012.

Table 4. Differences in mean density (per 500m^2) of species with the greatest correlation ($r>0.4$) to the first CAP axis. P values obtained from Mann-Whitney U tests ($\alpha=0.05$).

Species	Correlation Coefficient	Mean 2008	Mean 2012	*P*	Increase (↑) Decrease(↓)
Pomacentrus coelestis	-0.4999	0	0.86	0.002	↑
Anampses geographicus	-0.4929	3.08	11.91	0.002	↑
Thalassoma lutescens	-0.4802	0.74	3.41	0.018	↑
Coris auricularis	-0.4757	38.02	136.27	0.003	↑
Chromis westaustralis	-0.4683	0.05	131.51	0.005	↑
Parma mccullochi	-0.4117	9.08	18.04	0.013	↑



Plate 4. Key species which have been increasing in density on Rottnest Island reefs: *Anampses geographicus, Pomacentrus coelestis, Thalassoma lutescens* (and *Coris auricularis*, see plate 3).

Estimates of the biomass of each species were obtained using fish abundance and size information and species-specific length-weight relationships provided in Fishbase (www.fishbase.org). Community structure using biomass data for fish communities was also assessed using PCO and CAP and showed a similar, but slightly less obvious shift in community structure through time (Fig. 5).

CAP on biomass data confirmed the importance of *Anampses geographicus, Pomacentrus coelestis* and *Coris auricularis* in characterising community changes associated with time (Table 5). *Hypoplectrodes nigroruber, Parupeneus spilurus* and *Thalassoma septemfasciatum* were additionally important in discriminating years based on biomass data.

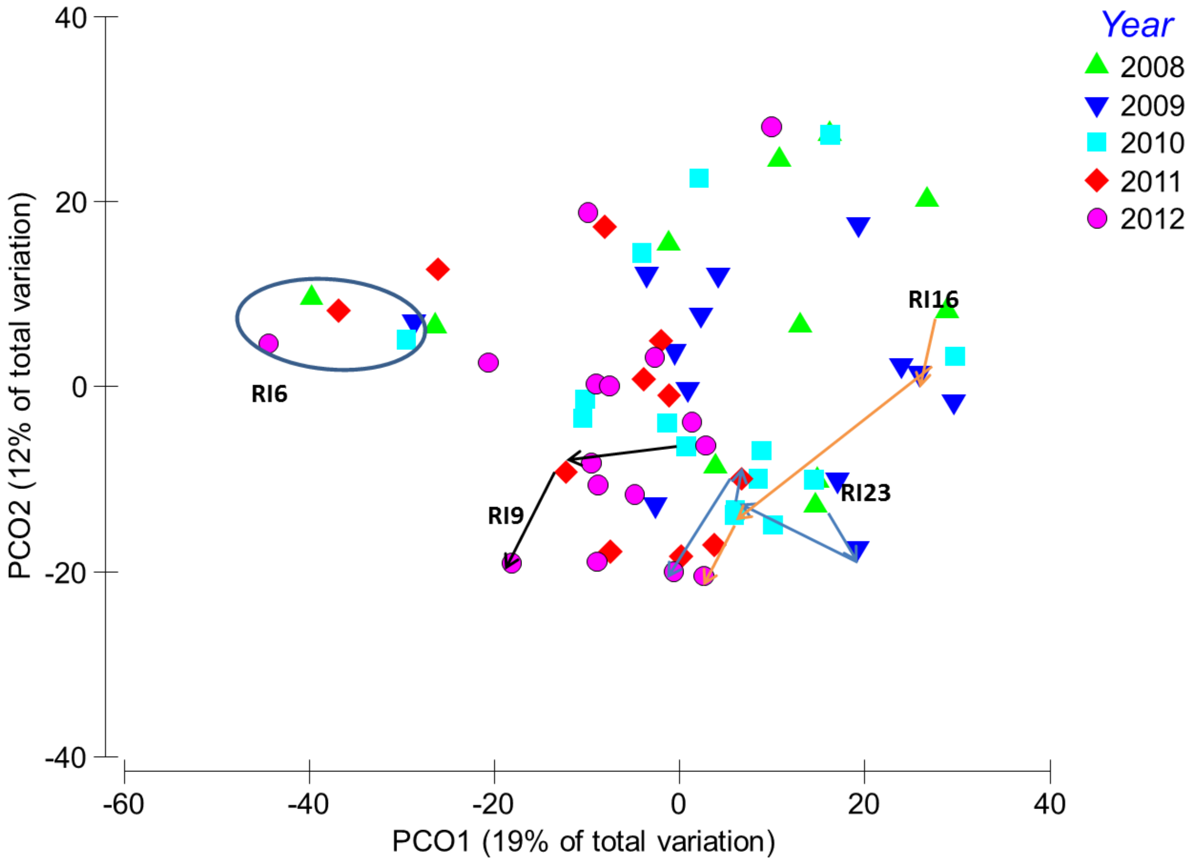

Figure 5. PCO plot of fish community biomass structure in different years at Rottnest Island. Arrows indicate movement of sites RI9, RI16 and RI23, which showed greatest inter-annual differences in fish community biomass structure. RI6 (*Pocillopora* Reef) remained relatively stable and is circled. PCO was based on Bray-Curtis dissimilarity of log (x+1) transformed biomass data.

Table 5. Differences in mean biomass of species with the greatest correlation to the first CAP axis. Mean biomass is grams per 500m^2. P values obtained from Mann-Whitney U tests (α=0.05).

Species	Correlation coefficient	Mean biomass 2008	Mean biomass 2012	Increase (↑) Decrease(↓)	*P*
Anampses geographicus	0.43	55	498	↑	0.007
Coris auricularis	0.43	809	2,443	↑	0.017
Parupeneus spilurus	0.40	155	400	↑	0.046
Thalassoma septemfasciatum	0.38	54	35	↓	0.281*
Pomacentrus coelestis	0.36	0. 1 (2009)	3	↑	0.003
Hypoplectrodes nigroruber	0.28	0	41	↑	-

P.coelestis was not recorded in the RLS data for Rottnest until 2009. P values in italics obtained from Mann-Whitney U tests, *Kruskal-Wallis test with remaining value from a one-way ANOVA with post-hoc test.

3.2 Invertebrate and cryptic fish surveys

The mobile macroinvertebrate fauna surveyed at Rottnest Island in 2012 was dominated by echinoderms and molluscs, with *Centrostephanus tenuispinus* (thin-spined sea urchin), *Fromia polypora* (many-pored star), *Turbo torquatus* (Turban shell) and *Dicathais orbita* (Dog welk) amongst the most common (Plate 5). Collectively, 78 species of macroinvertebrates were recorded with a mean of 7.8 species per transect (100 m^2). A summary of the key results from mobile invertebrate and cryptic fish surveys is provided in Table 6, and the most frequently recorded invertebrates are listed in Table 7.

Table 6. Results of mobile invertebrate and cryptic fish surveys at RLS monitoring sites at Rottnest Island in 2012. Values represent the average density per 100 m^2 at each site.

Site	Invertebrate density	Invertebrate species	Sea urchin density	Lobster density	Cryptic fish density	Cryptic fish species
RI1	11	5.75	1.5	1.25	54	3.25
RI10	38	12	10	5	5	2.5
RI12	47.66	8.33	12.66	0	15.33	1.66
RI16	55.33	12.33	30	0	90	3.66
RI18	17.5	6.5	5	0	1	1
RI2	34	9	18	0	0	0
RI20	75	13	33.66	3.33	13.33	3
RI21	20	7	4	0.66	2	1.66
RI23	56.33	10.66	25	0.33	16.66	2.66
RI24	12	2	3	0	0	0
RI3	14	5.25	0.5	2.25	54.75	2.5
RI4	11.5	7	1	0	1	1
RI5	20	7.5	7.5	0	10	2
RI6	19.5	7	2.5	0.5	5	2.5
RI7	78	11.33	19.33	0	7	2.33
RI8	10.75	3.75	0.25	0.25	3.5	2
RI9	9	5.5	0	0	5.5	2

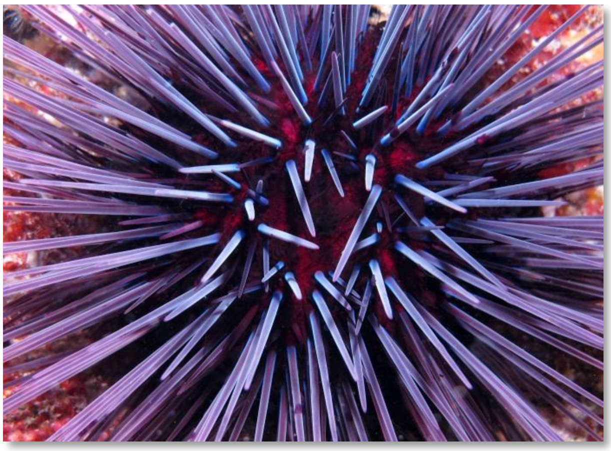
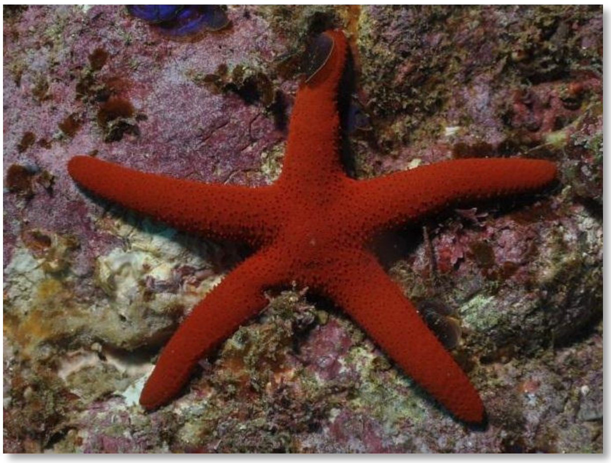
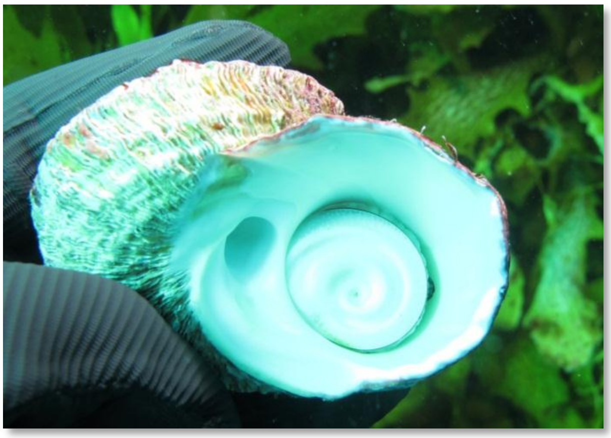


Plate 5. Most common mobile invertebrates on Rottnest Island reefs: *Centrostephanus tenuispinus* (top left), *Fromia polypora* (top right), *Turbo torquatus* (bottom left) and *Dicathais orbita* (bottom right).

Table 7. The most commonly recorded mobile invertebrate species at Rottnest Island, 2012. Mean densities are across sites at which each species was recorded.

Species	Frequency (% of transects)	Mean density (per $100m^2$)
Chromodoris westraliensis	61.1	2.8
Dicathais orbita	61.1	3.5
Phyllacanthus irregularis	51.2	2.5
Fromia polypora	47.3	5.0
Turbo torquatus	45.8	5.0
Turbo pulcher	45.3	2.8
Heliocidaris erythrogramma	41.4	5.0
Centrostephanus tenuispinus	39.4	10.7
Panulirus cygnus	25.1	3.3
Astralium pileola	20.2	2.6

Densities of the lobster, *Panulirus cygnus*, have been relatively stable across all years surveyed, with the exception of a drop in 2009 (Fig. 6). This provides an overall synoptic picture of lobster densities around Rottnest Island, but inclusion of only sites which have been surveyed in every year, while also confirming this sharp drop from 2008 to 2009, also shows reduced densities in 2011 and 2012 (Appendix 3). See section 3.3 for more results relating to lobster densities inside and outside sanctuary zones.

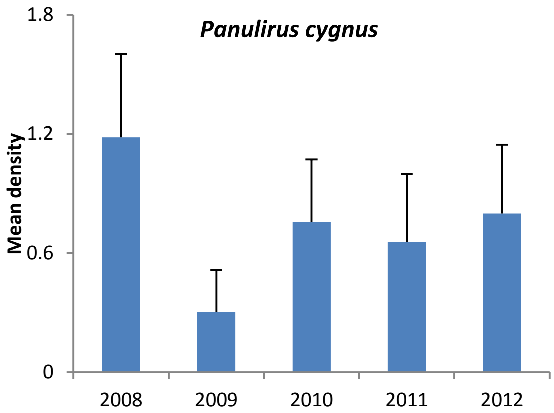

Figure 6. Mean density (per 100m^2) of *Panulirus cygnus* (western rock lobster) at Rottnest Island from 2008 to 2012.

The density of sea urchins on Rottnest Island reefs is relatively low compared to other temperate Australian locations, but has been increasing since 2008 (Fig. 7). Plots of both all sites and only those surveyed in all years (Appendix 3) show highest densities of urchins in 2011 and 2012, although the latter suggests numbers may now be decreasing after a peak in 2011.

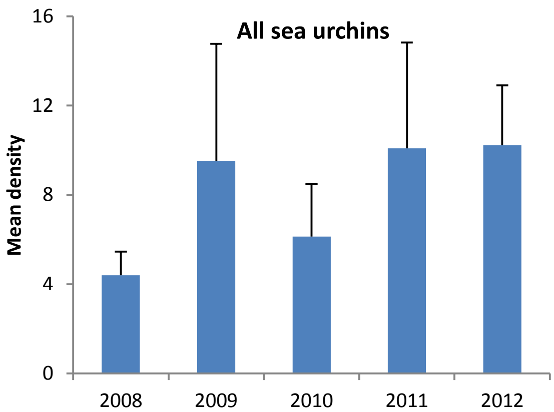

Figure 7. Mean sea urchin density (all species) at Rottnest Island sites from 2008-2012.

Densities of the charismatic and iconic *Paraplesiops meleagris* (southern blue devil) were relatively high for this species, averaging 1.2 per 100 m^2 (at sites where it was recorded). Likewise, the frequency of *Othos dentex* (Harlequin fish) on transects, although low in absolute terms at 2 % of transects, is also relatively high for this species (Table 8).

Table 8. Mean densities of cryptic fish species (when present) and frequency of recordings on transects 2008-2012

Species	Frequency (% of transects)	Mean number (per 100m^2)
Helcogramma decurrens	42.4	5.4
Parapercis haackei	21.2	1.9
Ostorhinchus victoriae	11.3	2.5
Epinephelides armatus	5.9	1.3
Hypoplectrodes nigroruber	5.4	1.1
Cirripectes hutchinsi	3.0	4.0
Paraplesiops meleagris	3.0	1.2
Scorpaena sumptuosa	2.5	1.0
Orectolobus spp.	2.5	1.0
Othos dentex	2.0	1.0

Plate 6. Rottnest Island is a hotspot for iconic cryptic fishes such as *Othos dentex* (left) and *Paraplesiops meleagris* (right).

When the mobile invertebrates and cryptic fishes are considered together as a mobile benthic faunal assemblage, PCO shows some changes across years (Fig. 8), but more in terms of a trend towards increasing similarity among sites, towards values of PCO2 closer to zero.

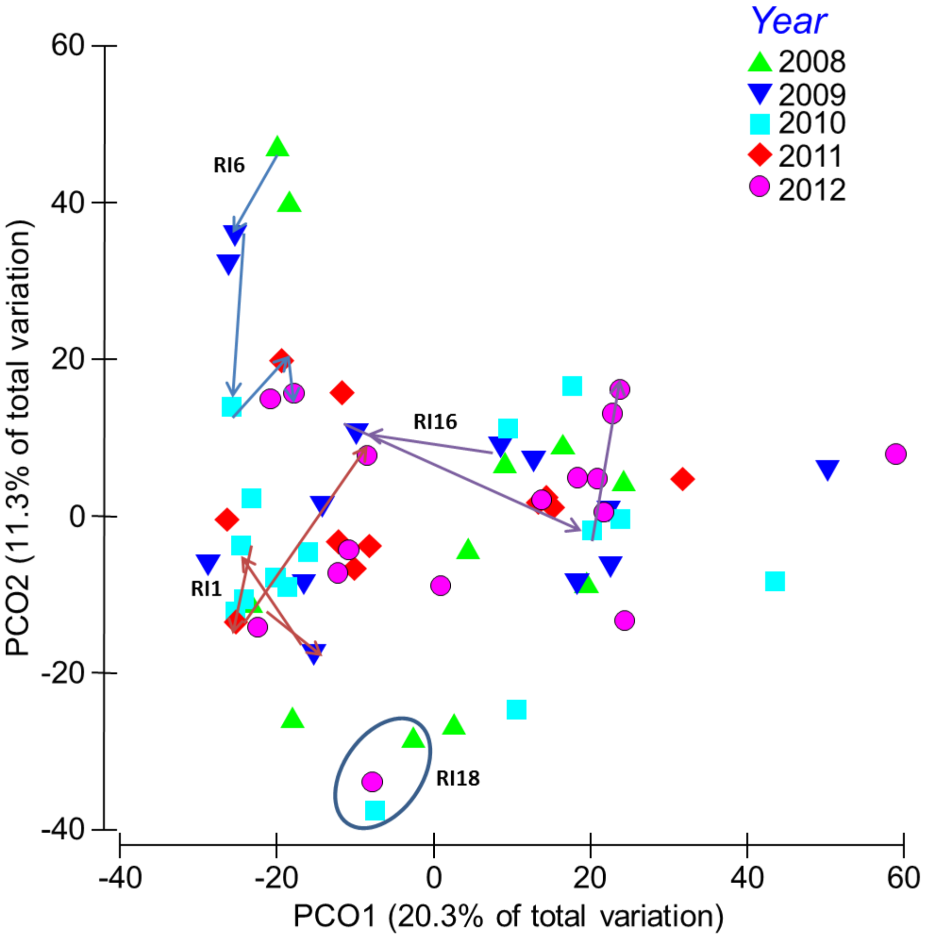

Figure 8. PCO plot of mobile benthic faunal (mobile invertebrates and cryptic fishes) community structure in different years at Rottnest Island. Arrows indicate movement of sites RI1, RI6 and RI16, which showed greatest inter-annual differences in fish community biomass structure. RI18 remained relatively stable and is circled. PCO was based on Bray-Curtis dissimilarity of log (x+1) transformed abundance data.

CAP suggested a decline in mean density of *Turbo torquatus* from 2008 -2012 was most correlated to the axis best distinguishing years. This pattern was largely driven by high densities of this species at RI18 (surveyed in years 2008, 2010 and 2012), and at RI14 in 2008. The mean density of *Chromodoris westraliensis* and *Octopus* spp. were also correlated to CAP axis 1, both increasing between 2008 and 2012 (Fig. 9).

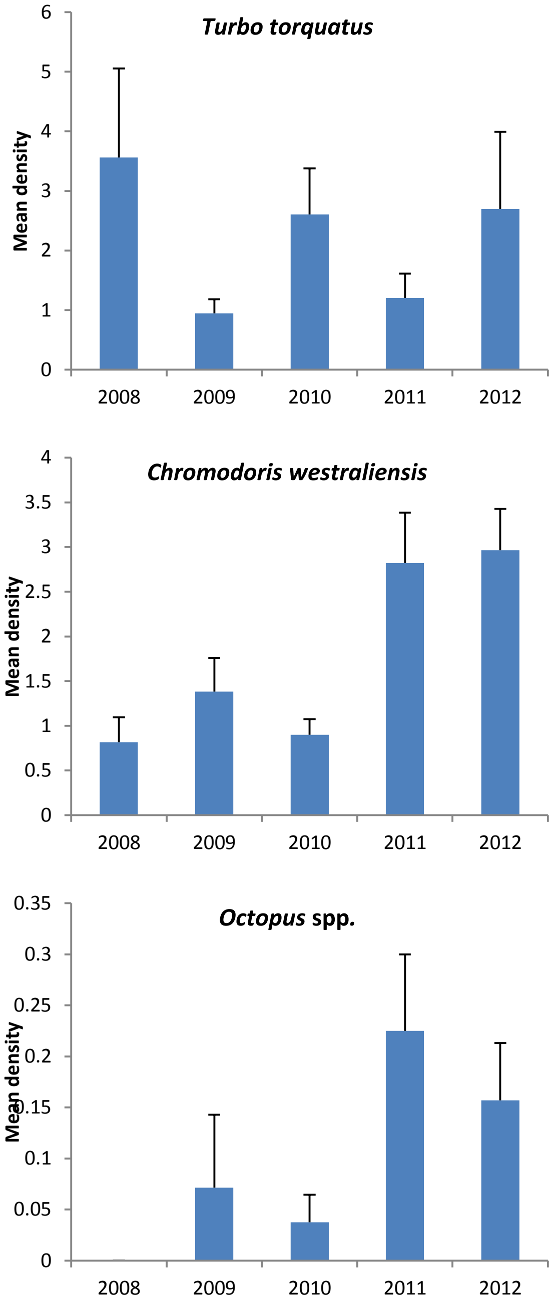

Figure 9. Mean densities per 100m² of *Turbo torquatus, Chromodoris westraliensis,* and *Octopus* spp.; species identified by CAP as contributing most to the variation best distinguishing sites across years.

3.3 Sanctuary zone analysis

Both the fish and mobile benthic faunal community (cryptic fishes plus mobile invertebrates) structure differed at sites inside and outside sanctuary zones at Rottnest Island (Table 9). Although not statistically significant, the total fish biomass was generally higher at sites inside sanctuary zones in every year surveyed, despite differences in which sites were surveyed between years (Fig. 10). Significantly higher total fish density was observed at sites outside sanctuary zones, however, indicating a key difference in the fish community is that sanctuary zone sites have fewer, larger fish than sites located outside sanctuary zones. One recreationally and commercially important species that contributed to greater biomass in a few of the sanctuary zone sites in the last 3 years was *Glaucosoma hebraicum* (dhufish) – a species which is highly vulnerable to exploitation and has become increasingly rare in the Perth area (St. John and Syers 2005). The number of *G. hebraicum* observed on transects has increased from one across all sites surveyed in 2008 to eight in 2012. As previously noted, the species richness of fishes increased between 2008 and 2012. This trend was highly significant and was independent of whether sites were inside or outside sanctuary zones.

Table 9. Results of PERMANOVAs testing for differences between years (2008-2012, df = 4) and protection status (sanctuary zone vs open access, df = 1) for fish and mobile benthic faunal communities and species of interest at Rottnest Island (error df = 61).

Variable	Year			Protection status			Year*Protection			Error
	MS	*F*	*P*	*MS*	*F*	*P*	*MS*	*F*	*P*	*MS*
Multivariate										
Fish community	**2248.1**	**1.821**	***0.026***	**4531.9**	**3.679**	***<0.001***	1228.5	0.935	*0.601*	1313.5
Mobile benthic fauna	**3137.3**	**2.025**	***0.005***	**7471.2**	**4.75**	***<0.001***	1549.5	0.711	*0.958*	2180
Univariate										
Fish biomass	0.2	0.391	*0.817*	0.5	1.453	*0.283*	0.3	0.578	*0.679*	0.6
Fish density	1.2	2.058	*0.094*	**3.0**	**13.282**	***0.027***	0.2	0.381	*0.825*	0.6
Fish species richness	**201.3**	**7.702**	***<0.001***	25.9	0.654	*0.536*	40.1	1.533	*0.206*	26.1
Glaucomsoma hebraicum	9.1	2.467	*0.057*	13.4	4.179	*0.098*	3.2	0.861	*0.487*	3.7
Invertebrate density	0.3	0.677	*0.604*	1.6	12.773	*0.030*	0.1	0.282	*0.884*	0.4
Invertebrate species richness	4.5	0.586	*0.671*	33.8	7.265	*0.065*	4.5	0.593	*0.672*	7.7
Sea urchin density	0.3	0.222	*0.927*	**7.2**	**45.165**	***0.003***	0.1	0.107	*0.982*	1.1
Sea urchin species richness	0.2	0.215	*0.931*	**4.1**	**68.983**	***0.003***	<0.1	0.034	*0.998*	0.9
Panulirus cygnus	1.3	0.961	*0.425*	**12.7**	**15.524**	***0.026***	0.8	0.579	*0.663*	1.4

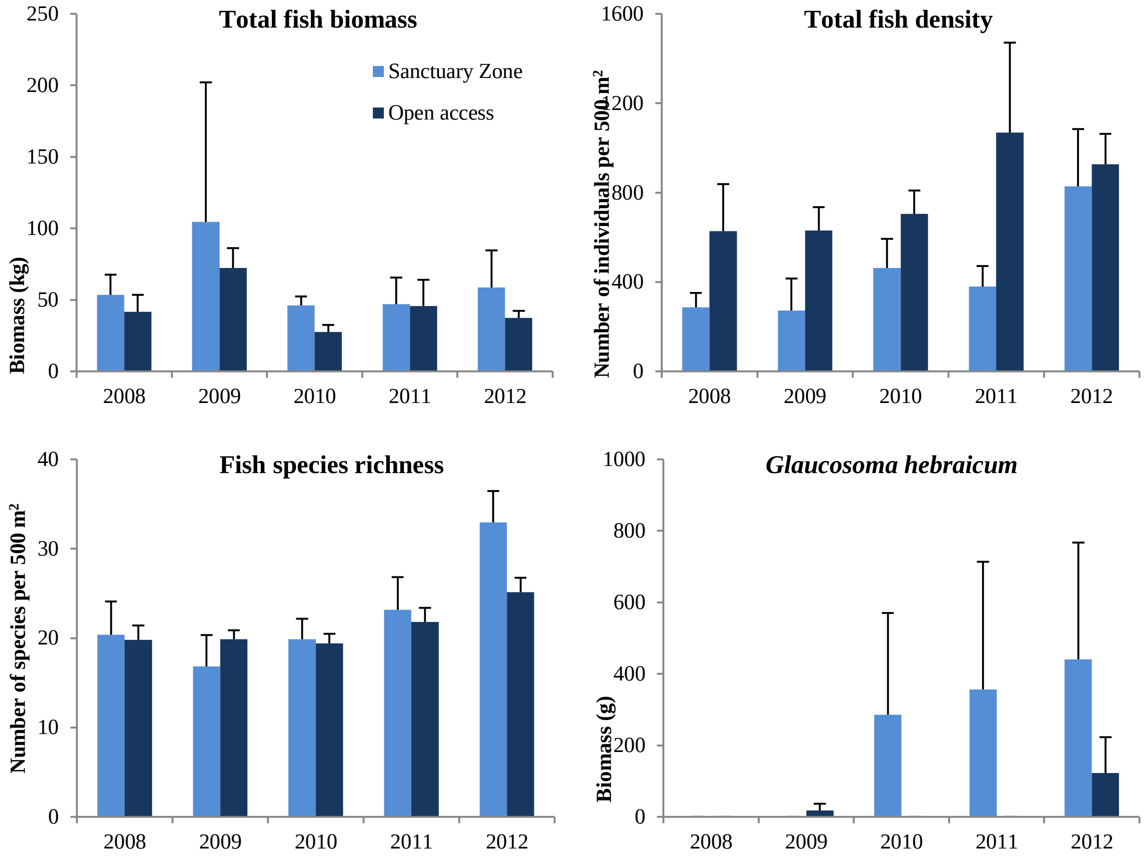

Figure 10. Fish community metrics and biomass of *Glaucosoma hebraicum* (dhufish) inside and outside sanctuary zones at Rottnest Island from 2008-2012. Values represent averages per 500 m2. Note that different sites were surveyed in each year.

Total invertebrate density, as well as just the sea urchin component, was significantly higher at sites outside sanctuary zones (Fig. 11). The density of *Panulirus cygnus* (western rock lobster), the most important invertebrate in terms of recreational and commercial value, was significantly higher in sanctuary zones though. This pattern was evident across all years, except in 2009, when lobster density was low at all sites (Fig. 12).

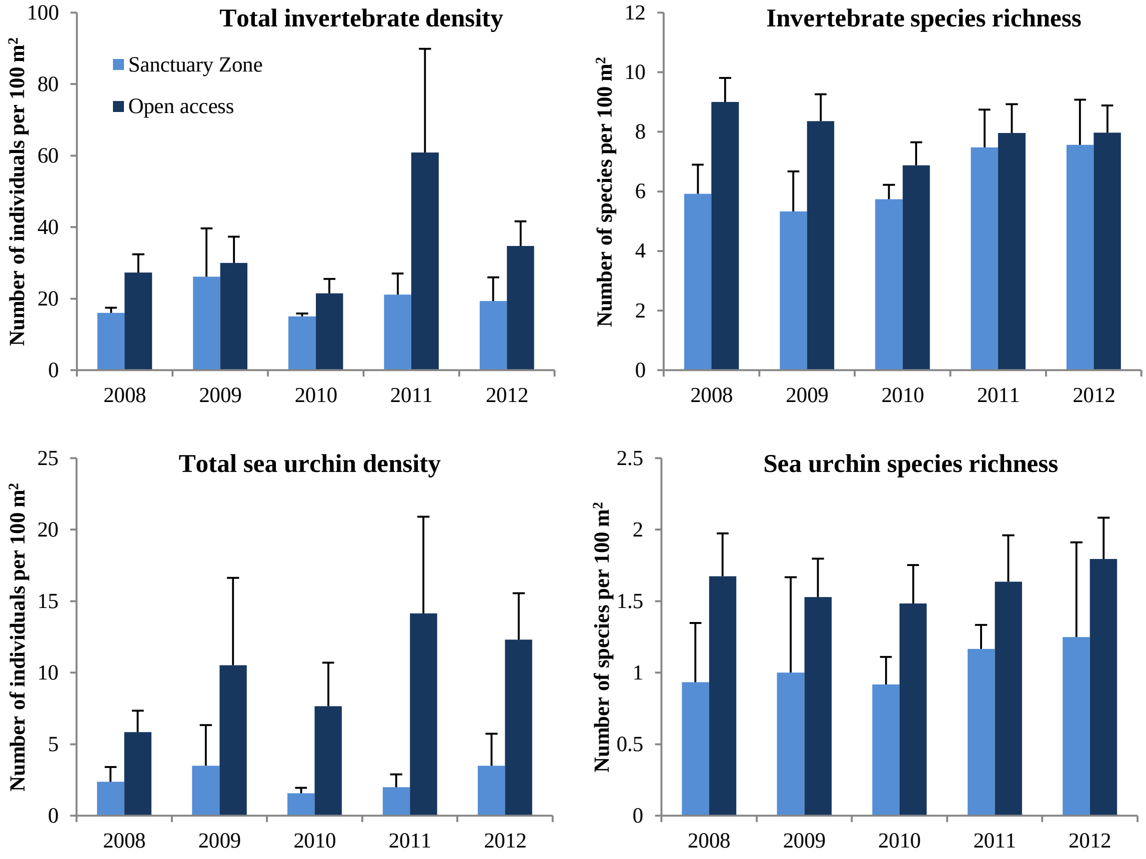

Figure 1. Invertebrate community metrics inside and outside sanctuary zones at Rottnest Island from 2008-2012. Values represent averages per 100 m^2. Note that different sites were surveyed in each year.

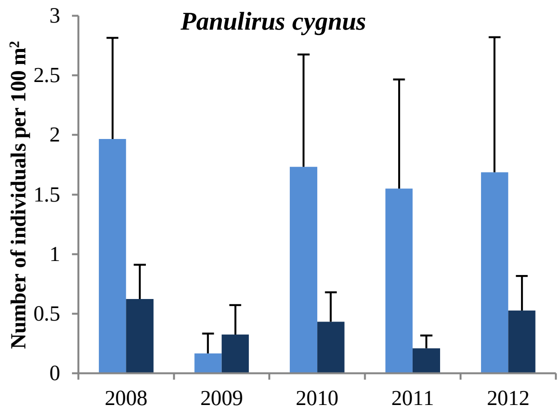

Figure 2. Density of *Panulirus cygnus* (western rock lobster) inside and outside sanctuary zones at Rottnest Island from 2008-2012. Values represent averages per 100 m^2. Note that different sites were surveyed in each year.

4 Discussion

Marine biodiversity surveys by Reef Life Survey divers at Rottnest Island in 2012, funded by a Coastwest grant and supported by the RIA, have extended the monitoring of Rottnest Island marine biodiversity by skilled community members to a fifth year in a row. This project provided the opportunity to review the data collected over the five years of monitoring and identify components of the ecosystem that have changed through time and/or are well or poorly represented in the revised sanctuary zones, put in place in 2007.

In relation to the changes between years, it is clear that the fish and mobile invertebrate communities on Rottnest reefs have changed from 2008 to 2012. PCO and CAP analysis of temporal biomass and abundance data for fishes reveal a significant shift in the community structure. The statistically significant increase in density and biomass of *Anampses geographicus, Pomacentrus coelestis* and *Coris auricularis* and an increase in the number of fish species observed are key aspects of this shift. A marginal increase in the density, but not biomass of fish, and increases in the densities of smaller species such as *Pomacentrus coelestis* and *Chromis westaustralis* suggest that the observed changes are characterized by recent increased recruitment of fishes, particularly of those species which are abundant (e.g. *Chromis westaustralis* and *Coris auricularis*).

A major oceanographic event occurred in the summer of 2010/2011, in which the WA coast experienced some of the warmest water temperatures on record, and it appears that this has had an observable effect on marine life at Rottnest Island. There has been a lot of research on what was termed 'the marine heatwave', identifying the causes and describing some of the effects it had on Western Australian marine life (Pearce and Feng 2013; Hutchins 2011; Micha 2011; Smith *et. al.* 2011). The RLS data from Rottnest Island show an increase in fish species richness, fish density and increases in the biomass and frequency of particular fish species (e.g. *Glaucosoma hebraicum*, *Pomacentrus coelestis*, *Anampses geographicus* and *Coris auricularis*), which generally coincide with the timing of the heatwave. Increasing fish species richness and the importance of species with tropical and sub-tropical affinities (e.g. *Pomacentrus coelestis*, *Anampses geographicus* and *Parupeneus spilurus;* Hutchins and Swainston 2006; Allen *et. al.* 2003) in describing the community-level changes would be expected under conditions where recruitment and survival of species with warmer water affinities are favoured due to a stronger southward flowing current carrying warmer water than usual. Interestingly, some of these observations were also apparent in 2012, suggesting that either some of the changes likely to have resulted from the heatwave have persisted for over one year (including over-wintering of tropical recruits), or that warm conditions in summer of 2011/2012 resulted in similar recruitment patterns.

While there are a multitude of other factors which may differentially affect these species and metrics, independently of ocean climate, and it is thus impossible to establish causality, at least some of these are consistent with expectations associated with the heatwave and the results are consistent with the findings of Pearce and Feng (2013); Hutchins (2011); Micha (2011); Smith *et. al.* (2011).

Repeat surveys in 2013 and ongoing monitoring by RLS will be important to help identify whether these recent changes observed persist and have any further effects on Rottnest Island marine biodiversity. Many interesting questions remain, and more specific studies on some of the ecological interactions that may occur as a result of the changes in community structure would also provide valuable insights into the ecological significance of what appears to be climate-forced change in marine biodiversity. More targeted research through honours and post-graduate research projects should be encouraged.

Although the results suggest less overall change in structure of the mobile benthic fauna (mobile invertebrates and cryptic fishes), increases in sea urchin densities and a reduction in densities of the gastropod *Turbo torquatus* are notable (although statistically non-significant). Sea urchin density has been increasing, although this appears to only be the case at RLS sites outside sanctuary zones, where the number of sea urchin species per transect is also much higher on average. Once again, it is difficult to determine the cause of these observations, which could result from either or a combination of biotic (e.g. differences in the abundances of predators of sea urchins) or abiotic (e.g. oceanographic climate) factors. It is important, however, to establish whether these changes persist or have further impacts at other levels of the ecosystem. For example, increasing densities of sea urchins could potentially result in overgrazing of the rich kelp beds (dominated by *Ecklonia radiata*) which form an important component of the reef habitat at Rottnest Island. Despite the increasing trend, densities observed in 2012 are generally still low by comparison to other temperate regions in Australia, and not considered high enough to trigger the formation of 'barrens' as established from research in other parts of Australia (Ling *et. al.* 2009). Thus, there appears to be no cause for alarm, but ongoing monitoring is certainly important.

Unusually high densities of *T. torquatus* at RI18 (Dyer Island) have decreased with each survey period, bringing the average densities around the Island down considerably. The reverse pattern was evident in *Octopus* densities, which were zero at RI18 on each survey occasion. Predation of *T. torquatus* by *Octopus* is certainly possible, but further study would be required to establish whether increasing Octopus densities may have impacts on mobile invertebrate populations, such as on *T. torquatus*, which may in turn affect other components of the ecosystem. Research in NSW has found densities of *T. torquatus* to be strongly linked to the cover of algal species it grazes as well as the cover of canopy kelps (Ettinger-Epstein and Kingsford 2008).

With respect to all temporal signals in this dataset, some variation may be evident as a result of some different sites being surveyed in different years; but consideration of only sites surveyed in all five years (Appendix 1) suggests that trends observed in the whole dataset are generally representative of real patterns. Thus, analysis of all sites together appears to provide a useful synoptic picture of inter-annual trends and differences associated with sanctuary zones.

Another clear and important observation from RLS monitoring of Rottnest Island reefs is that rock lobster densities are considerably higher at sites in sanctuary zones. This is the case across years, with the exception of 2009, regardless of which subset of sites was surveyed. The same pattern has been reported in a targeted study of rock lobsters at Rottnest (Babcock *et. al.* 2007). It is possible this pattern may be related to habitat differences between sanctuary zones and surrounding open access areas, but urchin and total invertebrate densities are highest at a different set of sites, and rock lobsters, urchins and other mobile invertebrates generally favour the same (structurally complex) habitats.

The density (and biomass) of dhufish (*Glaucosoma hebraicum*) appears to have been increasing at sanctuary zone sites in recent years. This species is a large-bodied, endemic fish which takes up residence near caves and drop-offs and tends not to move very far. Being site-attached, long-lived and considered an excellent table fish, it is highly vulnerable to over-exploitation, but also considered likely to respond well to protection in sanctuary zones. Although believed to be becoming increasingly scarce in the Perth region, RLS surveys have recorded 14 individuals ranging from 25 – 60 cm over 5 years, from only one recorded on transects in 2009 to eight in 2012.

Regardless of the reasons, the sanctuary zones at Rottnest Island harbour greater numbers of rock lobster and increasing numbers of large, vulnerable fish such as dhufish. As such, they appear to be fulfilling at least part of the purpose they were established for. In particular, the results of RLS surveys support success in achieving the Rottnest Island Strategy (2007) broad objective of 'protection and enhancement of the intrinsic values of Rottnest Island's natural….heritage', and Strategic Objective 1 ('To provide undisturbed areas representative of marine habitats for marine biodiversity conservation') and 4 ('To provide scientific reference areas and the opportunity for marine scientific research').

The Reef Life Survey program is committed to supporting the ongoing monitoring of Rottnest Island reefs into the future, with the support of the RIA and the committed members of the recreational SCUBA diving community, who provide an exceptional amount of time and skill at no cost. Future surveys will be important to follow any persistent ecological effects of the marine heatwave and track densities of lobsters and fishes in sanctuary zones, but support in the form of the modest funding required to enable this will be critical.

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

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Page	Plate	Image	Photographer
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6	2	Diver reeling in transect line	Tom Davis
9	3	*Chromis westaustralis* (Western Puller)	Rick Stuart-Smith
9	3	*Trachinops brauni* (Braun's hulafish)	Antonia Cooper
9	3	*Coris auricularis* (Western king wrasse)	Antonia Cooper
9	3	*Pempheris klunzingeri* (Rough bullseye)	Antonia Cooper
13	4	All images	Rick Stuart-Smith
16	5	*Centrostephanus tenuispinus* (Longspine sea urchin)	Antonia Cooper
16	5	All other images	Rick Stuart-Smith
18	6	All images	Rick Stuart-Smith

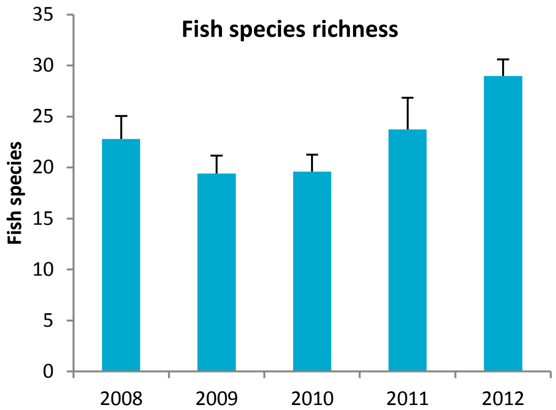
Appendix 1. Families considered cryptic and for which members are recorded also on the invertebrate and cryptic fish survey

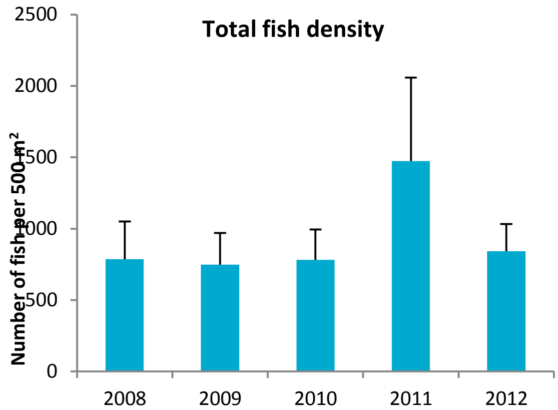
FAMILY	COMMON NAME	FAMILY	COMMON NAME
Acanthoclinidae	Basslets	Liparidae	Snailfishes
Agonidae	Poachers	Lotidae	Burbots
Anarhichadidae	Wolf eels	Monocentridae	Pineapplefishes
Antennariidae	Anglerfishes	Moridae	Beardies
Aploactinidae	Velvetfishes	Muraenidae	Moray eels
Apogonidae	Cardinalfishes	Nototheniidae	Icefishes
Ariidae	Catfishes	Ophichthidae	Snake and worm eels
Aulopidae	Sergeant bakers	Ophidiidae	Lings
Bathymasteridae	Ronquils	Opistognathidae	Jawfishes
Batrachoididae	Frogfishes	Orectolobidae	Wobbegongs
Blenniidae	Blennies	Parascylliidae	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

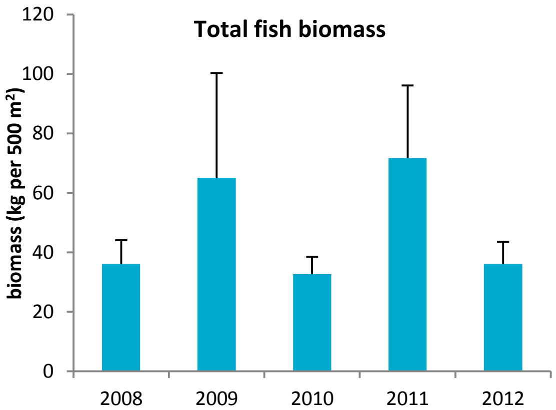
Appendix 2. Multivariate statistical methods details

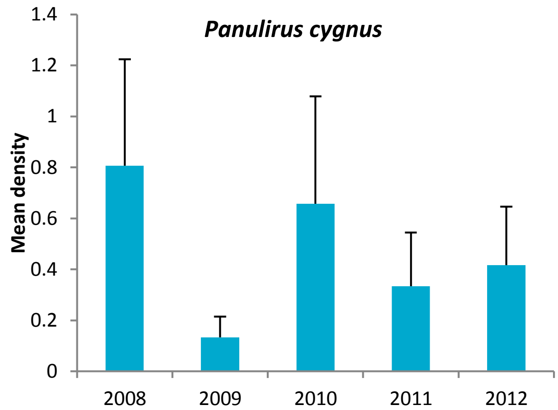
Multivariate fish and mobile invertebrate community structure data were assessed using principle coordinates analysis (PCO), with canonical analysis of principle coordinates (CAP) used to identify species which best characterised inter-annual differences. PERMANOVAs were also used to assess differences between years and MPA zone types (sanctuary zones versus fished zones). All multivariate tests were based on log(x+1) transformed abundance or biomass data and Bray-Curtis dissimilarity (Clarke & Gorley 2006). Species with high correlations to the first CAP axis, and thus represented those that best characterize differences in community structure between years (Anderson *et.al.* 2008), were analysed separately using a one-way ANOVA with post hoc tests (Scheffe) in SPSS v15. Assumptions of ANOVA were tested prior to these analyses with Shapiro-Wilk test of normality and Levene's test for homogeneity of variance (α=0.05). Transformations were undertaken as required and if ANOVA assumptions could not be made, the nonparametric Mann-Whitney U and Kruskall-Wallis tests were used.

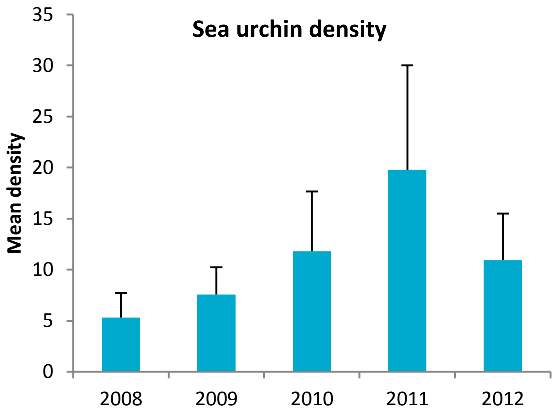
Appendix 3. Rottnest Island temporal comparisons based on only sites surveyed in all 5 years (RI1, RI2, RI5, RI6, RI23)











REEF LIFE SURVEY

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.

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