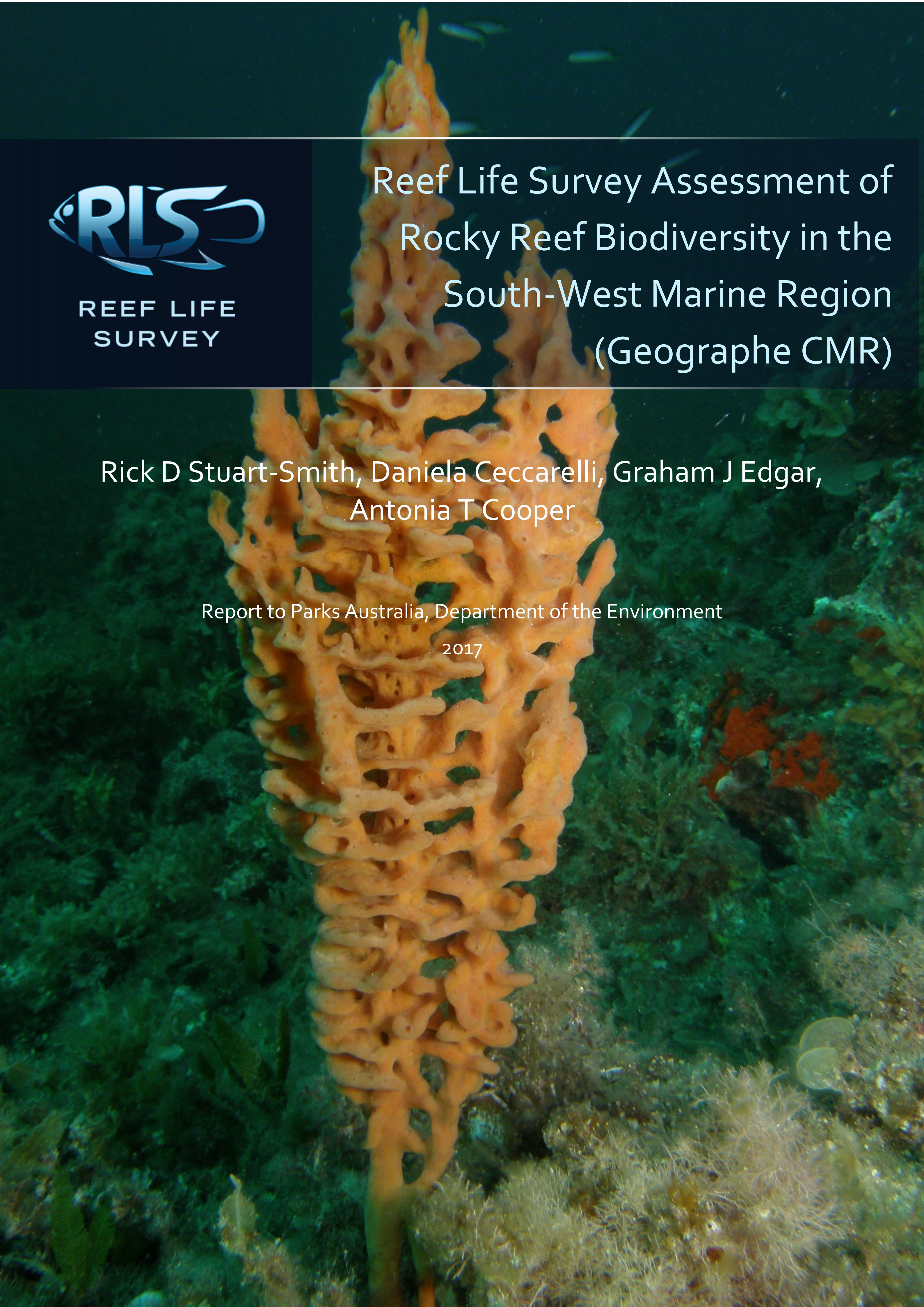

Reef Life Survey Assessment of Rocky Reef Biodiversity in the South-West Marine Region (Geographe CMR)

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Report to Parks Australia, Department of the Environment

2017

Citation

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Copyright and disclaimer

Important disclaimer

Images

Rick Stuart-Smith

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List of acronyms

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

Executive summary

The South-west Commonwealth Marine Reserve (CMR) Network includes Commonwealth waters from the eastern end of Kangaroo Island, South Australia, to 70 km offshore of Shark Bay, Western Australia, and covers an area of 1.3 million km^2. The Geographe CMR is one of 14 CMRs established in the South-west CMR Network, and is the only one to contain shallow rocky reef in depths surveyable by SCUBA divers. It covers 977 km^2, and a depth range of approximately 15 to 70 m within Georgraphe Bay. Three types of IUCN zoning exist within the Geographe CMR: Marine National Park Zone (IUCN Category II), Special Purpose Zone (IUCN VI) and Multiple Use Zone (IUCN Category VI). Reef Life Survey (RLS) dive teams surveyed 14 transects at seven sites on reefs in the vicinity of the Geographe CMR, including two transects at one site within the IUCN II area and six reference sites at nearby inshore locations. Reef Life Survey (RLS) involves recreational divers trained to a scientific level of data-gathering to make it possible to conduct ecological surveys across broad geographic areas in a cost-effective manner.

The Geographe CMR had a richer benthic assemblage than the reference sites and greater fish species richness and biomass, but this assessment is based on only two transects within the CMR, and reference sites were located inshore in shallower and different habitat. Thus, further surveys are required within the CMR and outside its boundaries, but along the same reef system, before the distinctiveness of the CMR fauna can be better characterised, and more reliable conclusions drawn from the inside-outside differences. The fish assemblage in the inshore reference sites appeared to transition along a geographical gradient, possibly in response to changing levels of exposure to the southwesterly swell.

RECOMMENDATIONS

- ongoing monitoring of the reef system in the Geographe CMR and nearby outside the zone boundaries should take place as frequently as possible (every 1-3 years), using methods consistent with those presented here;
- baseline data presented here should guide efforts to select sites;
- sampling effort should be increased to include at least three sites of multiple transects in the Geographe CMR. Given the impending re-zoning of the CMR and the difficulties of finding suitable reference sites in similar habitat outside CMR boundaries, reference sites may be inside the CMR, in the zone with lowest level of protection;
- research priorities should include development of indicators that track changes in reef condition and biodiversity;
- detailed mapping of distribution and impact of natural disturbances and human impacts should be undertaken; and
- ecological monitoring surveys should be expanded to other CMRs in the South-west CMR Network that include reefs within their boundaries.

1 Introduction

The South-west Commonwealth Marine Reserve (CMR) Network includes Commonwealth waters from the eastern end of Kangaroo Island, South Australia, to 70 km offshore of Shark Bay, Western Australia (WA), encompassing a total area of 1.3 million km^2. Marine ecosystems within the South-west CMR Network range from temperate to subtropical climate regimes. Waters possess relatively low-nutrient levels due to a lack of significant upwellings and river runoff. Numerous features of conservation value are present, including species listed as threatened or migratory, endemic species, unique ecological communities, and unusual geological features (McClatchie et al. 2006). For example, the low-turbidity waters allow light-dependent organisms to exist in relatively deep environments, with seagrasses and macroalgae unusually found as deep as 120 m (Commonwealth of Australia 2007).

The oceanography in the South-west CMR Network is dominated by the Leeuwin Current and the subsurface Leeuwin Undercurrent on the west coast, the Flinders Current on the south coast, and the seasonal and coastal Cape and Cresswell Currents. Geologically, the continental slope has what is considered one of Australia's most complex networks of submarine canyons (Commonwealth of Australia 2007).

Geographe Bay, a large, sheltered embayment located 270 km south of Perth, measures approximately 134 km^2. A variety of habitats are present, including a limestone substratum covered in sand and protruding in patches to form small patch reefs, interspersed with extensive seagrass beds that cover 70% of the bay (McMahon et al. 1997). Isolated massive *Porites* mounds also occur throughout the bay, and a ridge of limestone reef runs parallel to the shore at approximately 18 m depth (Westera et al. 2009). The seagrass meadows in the bay are among the largest and most continuous temperate seagrass in Australia, with at least ten different seagrass species recorded (McMahon et al. 1997). The bay also hosts a high diversity of fish species (White et al. 2011).

The Geographe CMR is one of 14 CMRs established in the South-west CMR Network. It covers 977 km^2, and a depth range of approximately 15 to 70 m within Georgraphe Bay. Three types of IUCN zoning currently exist within the Geographe CMR: Marine National Park Zone (IUCN Category II), Special Purpose Zone (IUCN VI) and Multiple Use Zone (IUCN Category VI). The conservation values listed specifically for this CMR include foraging areas for seabirds, migratory habitat for humpack whales and blue whales (Recalde-Salas et al. 2014), seagrass beds (White et al. 2011), rock lobster habitat (MacArthur et al. 2007), and high benthic productivity and biodiversity. This report covers results from surveys at one reef site within the IUCN II Zone and six nearby reference sites.

2 Methods

Reef Life Survey (RLS) dive teams surveyed 14 transects at seven sites on reefs in the vicinity of the Geographe CMR, including two transects at one site within the IUCN II area and six reference sites (Table 1). All surveys were conducted using the standardised underwater visual census methods applied globally by Reef Life Survey. Reef Life Survey (RLS) involves recreational divers trained to a scientific level of data-gathering to make it possible to conduct ecological surveys across broad geographic areas in a cost-effective manner. RLS divers partner with management agencies and university researchers to undertake detailed assessment of biodiversity on coral and rocky reefs, but all divers and boat crew do so in a voluntary capacity.

A summary of these methods is provided here. Full details can be downloaded at: http://reeflifesurvey.com/files/2008/09/NEW-Methods-Manual_15042013.pdf.

Each RLS survey involves three distinct searches undertaken along a 50 m transect line: for fishes, invertebrates and cryptic fishes, and sessile organisms such as corals and macroalgae (described individually below). Underwater visibility and depth were recorded at the time of each survey, with visibility measured as the furthest distance at which large objects could be seen along the transect line, and depth as the depth (m) contour followed by the diver when setting the transect line.

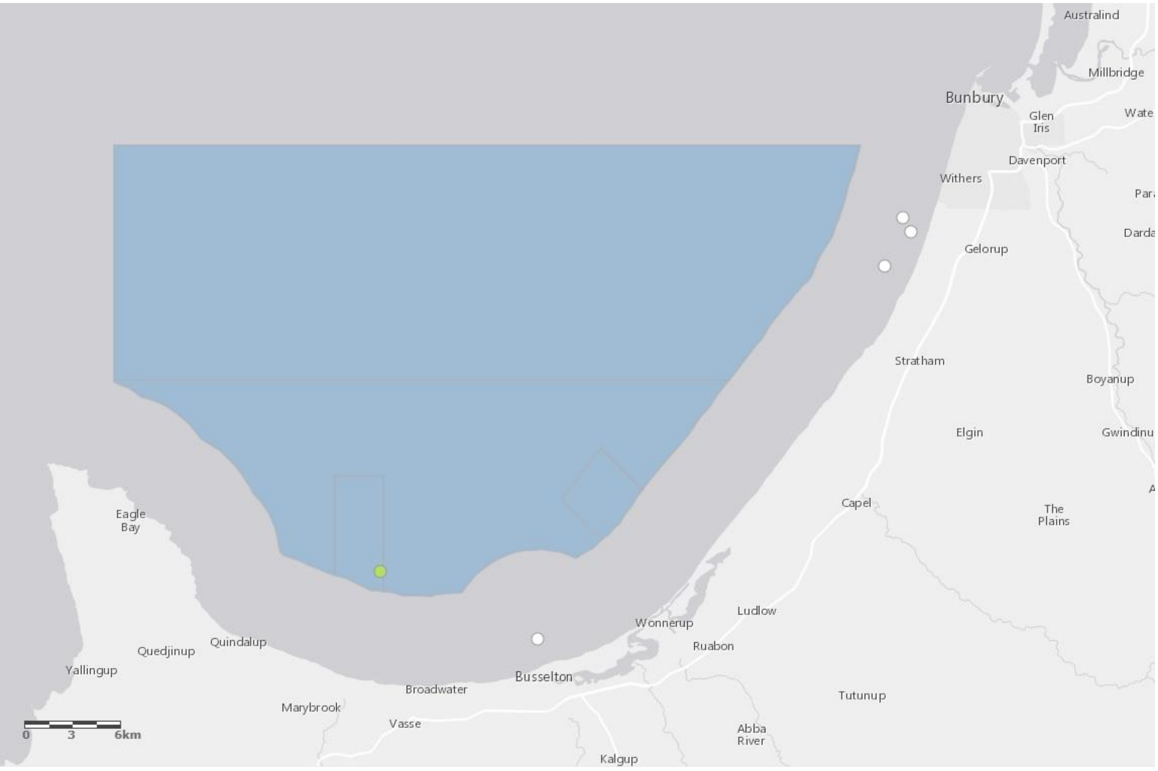

Figure 1. Map of South-West sites surveyed during 2009 and 2011.

Table 1. Site details including CMR status (Geographe CMR and Reference sites outside reserve), IUCN category, geographical coordinates (datum = WGS84), depth of transect line, and underwater visibility for each site surveyed.

Site No.	CMR status	IUCN category	Site name	Latitude	Longitude	Depth	SurveyDate
WA18	Geographe	Marine National Park Zone (IUCN II)	Coral Gardens 2	-33.5923	115.2313	17.5	12/04/2009
	Geographe	Marine National Park Zone (IUCN II)				18	12/04/2009
WA17	Reference	Open	Busselton Jetty	-33.6306	115.3382	7	12/04/2009
	Reference	Open				7.5	12/04/2009
	Reference	Open				7.6	12/04/2009
	Reference	Open				8	12/04/2009
WA23	Reference	Open	Dalyellup surf club	-33.3992	115.5921	9.3	7/03/2010
WA24	Reference	Open	Dalyellup offshore	-33.3912	115.5868	11.1	7/03/2010
WA25	Reference	Open	Bunbury North 1 - Leather Jacket Caves	-33.2463	115.6455	13.1	6/03/2010
WA26	Reference	Open	Bunbury North 2 - Leather Jacket Caves North	-33.229	115.6321	16	6/03/2010
WA89	Reference	Open	Temp	-33.4187	115.5743	11	27/02/2011
	Reference	Open				11.7	27/02/2011
	Reference	Open				13	27/02/2011
	Reference	Open				12.5	27/02/2011

FISH SURVEYS (METHOD 1)

All fish species sighted within 5 m x 50 m blocks either side of the transect line were recorded on waterproof paper as divers swam slowly along the line. The number and estimated size-category of each species were also recorded. Size categories used were 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, 400, 500, 625 mm, and above, which represent total fish length (from snout to tip of tail). All species sighted within the blocks were recorded, including those with unknown identity. Photographs were used to later confirm identities with appropriate taxonomic experts, as necessary. In occasional circumstances when no photograph was available, taxa were recorded to the highest taxonomic resolution for which there was confidence (e.g. genus or family, if not species). Other large pelagic animals such as mammals, reptiles and cephalopods were also recorded during the Method 1 fish survey, but were excluded for analyses focusing on fishes. Species observed outside the boundaries of the survey blocks or after the fish survey had been completed were recorded as 'Method 0'. Such records are a presence record for the time and location but were not used in quantitative analyses at the site level. 'Method 0' sightings were also made of invertebrates and any other notable taxonomic groups.

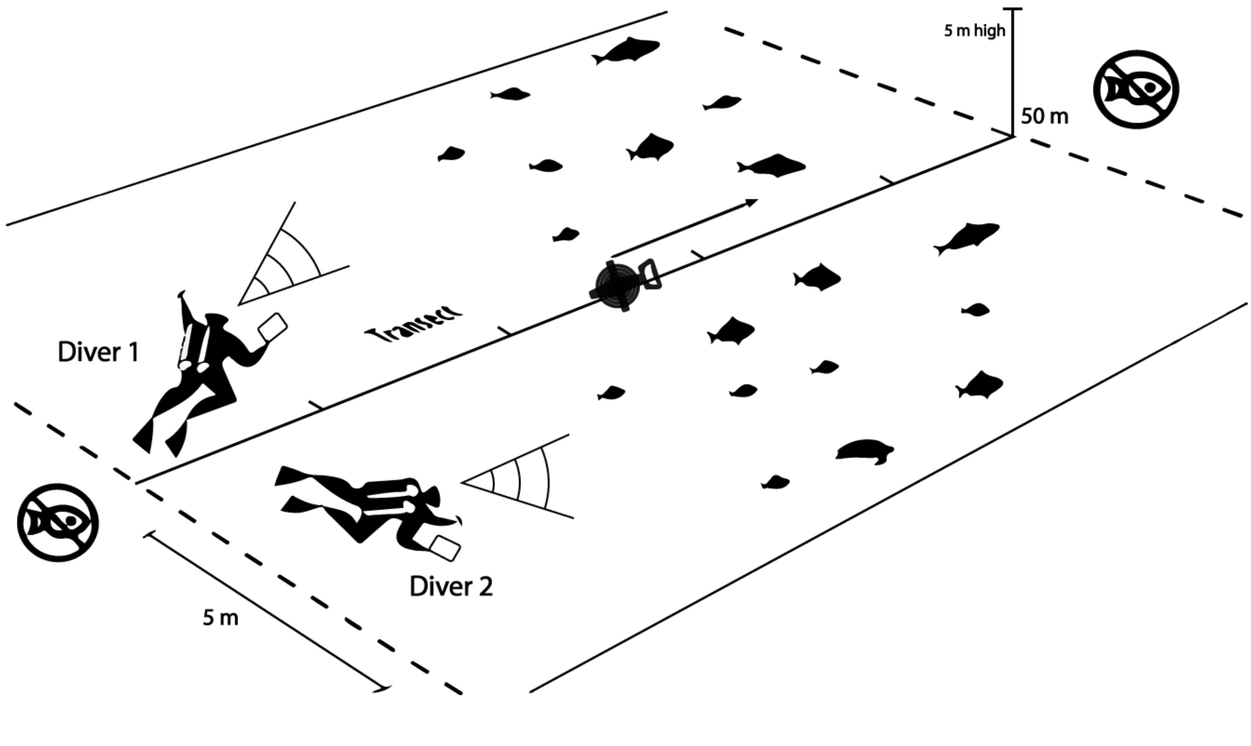

Figure 2. Stylised representation of method 1 survey technique

MACROINVERTEBRATE AND CRYPTIC FISH SURVEYS (METHOD 2)

Large macroinvertebrates (echinoderms, and molluscs and crustaceans > 2.5 cm) and cryptic fishes were surveyed along the same transect lines set for fish surveys. Divers swam near the seabed, up each side of the transect line, recording all mobile macroinvertebrates and cryptic fishes on the reef surface within 1 m of the line. This required searching along crevices and undercuts, but without moving rocks or disturbing corals. Cryptic fishes include those from particular, pre-defined families that are inconspicuous and closely associated with the seabed (and are thus disproportionately overlooked during general Method 1 fish surveys). The global list of families defined as cryptic for the purpose of RLS surveys can be found in the online methods manual. As data from Method 2 were collected in blocks of a different width to that used for Method 1 and were analysed separately from those data, individuals of cryptic fishes known to already be recorded on Method 1 were still recorded as part of Method 2. Sizes were estimated for cryptic fishes using the same size classes as for Method 1.

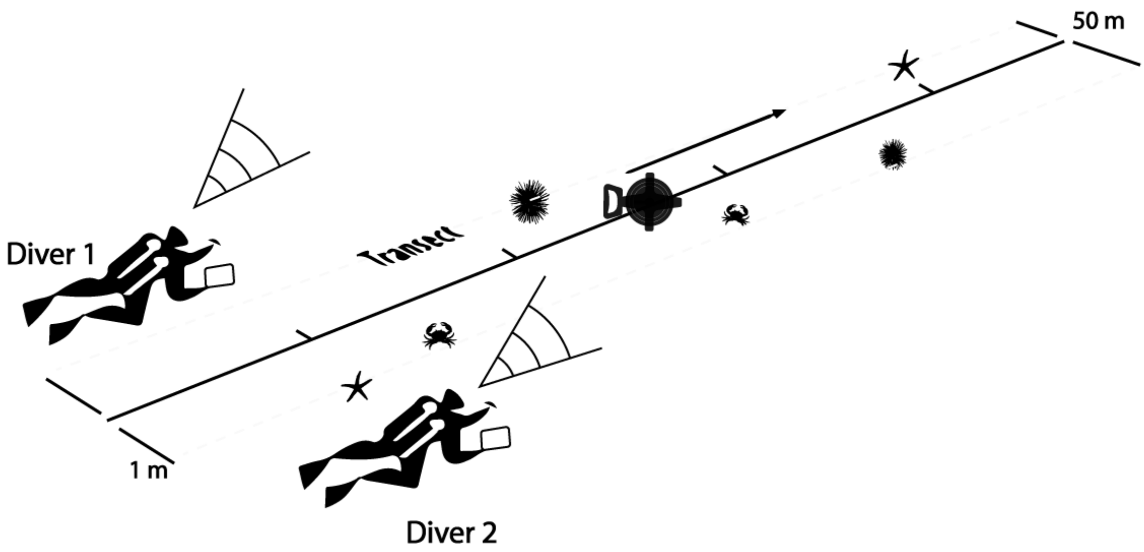

Figure 3. Stylised representation of method 2 survey technique

MACROALGAL AND SESSILE INVERTEBRATE SURVEYS

Information on the percentage cover of sessile animals and macroalgae along the transect lines set for fish and invertebrate surveys were recorded using photo-quadrats taken every 2.5 m along the 50 m transect. Digital photo-quadrats were 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 was obtained from photo-quadrats by recording the functional group observed under each of five points overlaid on each image, such that 100 points were usually counted for each transect (thus percentage cover was calculated as the number of points each group was scored under).

Functional groups for photo-quadrat processing comprised the standard 50 categories applied in broad-scale analysis of RLS data (APPENDIX 1), which are aligned with the CATAMI classification system (Althaus et al. 2015). With greater time investment by a specialist operator than was achievable for this report, higher taxonomic resolution analyses are possible using the photo-quadrat set for groups such as corals and algae. Images have been archived and are available for processing at any resolution through the future.

INDICATORS

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

STATISTICAL ANALYSES

Collection of detailed data on fishes, including species-level identities, length classes and abundance information, allow the calculation of species-specific biomass estimates. The RLS database includes coefficients for length–weight relationships obtained for each species from Fishbase (www.fishbase.org) (in cases of missing length-weight coefficients, these are taken from similar-shaped species). When length–weight relationships were described in Fishbase in terms of standard length or fork length rather than total length, additional length-length relationships provided in Fishbase allowed conversion to total length, as estimated by divers. For improved accuracy in biomass estimates, the bias in divers' perception of fish size underwater was additionally corrected using the mean relationship provided in Edgar et al. (2004), where a consistent bias was found amongst divers that led to underestimation of small fish sizes and overestimation of large fish sizes. Note that estimates of fish abundance made by divers can be greatly affected by fish behaviour for many species (Edgar et al. 2004); consequently, biomass determinations, like abundance estimates, can reliably be compared only in a relative sense (i.e. for comparisons with data collected using the same methods) rather than providing an accurate absolute estimate of fish biomass for a patch of reef. At most sites, multiple transects were surveyed at different depths (see Table 1). Thus, the unit of replication was the summed value(s) of the two blocks per transect (i.e. giving values per 500 m^2 for fishes and per 100 m^2 for mobile macroinvertebrates).

Univariate analyses

A range of univariate metrics were calculated from survey data: total fish abundance, fish species richness, abundance of fish functional groups, total fish biomass, abundance and biomass of large fishes (> 20 cm), and percent cover of corals and other key benthic organisms. All metrics represent total values per 500 m^2 transect area for Method 1 fishes, per 100 m^2 transect area for Method 2 fishes and invertebrates, and percent cover of benthic organisms from photo-quadrats. Analysis of Variance (ANOVA) with appropriate transformations was conducted on the above metrics.

Multivariate analyses

Relationships between sites in the Geographe CMR and reference sites in percent cover of sessile biota, reef fish and invertebrate communities were initially analysed using non-metric Multi-Dimensional Scaling (MDS). These were run using the PRIMER+PERMANOVA program (Anderson et al. 2008). This analysis reduces multidimensional patterns (e.g. with multiple species or functional groups) to two dimensions, showing patterns of similarity between sites. MDS was used to investigate differences in community structure between reefs.

Data were converted to a Bray-Curtis distance matrix relating each pair of sites after square root transformation of raw data. The transformation was applied to downweight the relative importance of the dominant species at a site, and so allow less abundant species to also contribute to the plots. MDS was followed up with ANOSIM to test the significance of differences between reefs.

3 Results

FISH SURVEYS

Transects surveyed with Method 1 yielded 69 species of temperate reef fishes; 35 species were recorded in the two transects within the Geographe CMR, and 65 species were recorded at reference sites (APPENDIX 2). The top five species in terms of biomass were *Dinolestes lewini*, *Pempheris klunzingeri*, *Pseudocaranx dentex, Coris auricularis* and *Trachinops noarlungae* within the Geographe CMR; at the reference sites the fish assemblage was dominated by *Trachurus novaezelandiae, Trachinops noarlungae, Pempheris klunzingeri, Scobinichthys granulatus* and *Pempheris multiradiata.* Both inside and outside the CMR, planktivores and herbivores were among the species that contributed most to the overall biomass.

Changes in the dominant fish species reflected the geographic position of the sites (Figure 4), with no significant difference in the fish communities of CMR and open sites (ANOSIM Global R = -0.22, p = 0.71). The two northern sites, WA25 and WA26, were characterised by a greater proportion of *Urolophus paucimaculatus*, *Scorpis georgiana* and the planktivore *Neatypus obliquus*. Two of the sites in the central part of Geographe Bay had a high abundance of *Siphonognathus caninis* and *Siphamia cephalotes*, whilst a third had a more even representation of most species. The Geographe CMR and the open site closest to it, in contrast, were characterised by high species richness of fishes.

The overall biomass and species richness of reef fishes was higher in the CMR than at open sites, but the difference was only significant for biomass ($F_{1,9} = 5.75$, $p = 0.04$; $F_{1,12} = 0.898$, $p = 0.362$, respectively, Figure 5). To analyse the biomass data, three transects were removed from the site WA17, as the artificial structure of the Busselton Jetty attracted very large schools of *Trachurus novaezelandiae*. Benthic invertivores and piscivores had significantly higher biomass at CMR sites, omnivores and carnivores showed a trend of increased biomass at CMR sites, farmers tended towards higher abundance at reference sites, and the other functional groups had similar biomass at CMR and reference sites (Figure 6, Table 2). The biomass of large fishes (>20cm TL) was higher at Geographe CMR sites than at reference sites, but not significantly so ($F_{1,9} = 2.68$, $p = 0.136$).

Community temperature index (CTI) values were similar for CMR and open sites, and threatened species listed on the IUCN Red List were present only at open sites, in highly variable proportions (Figure 8).

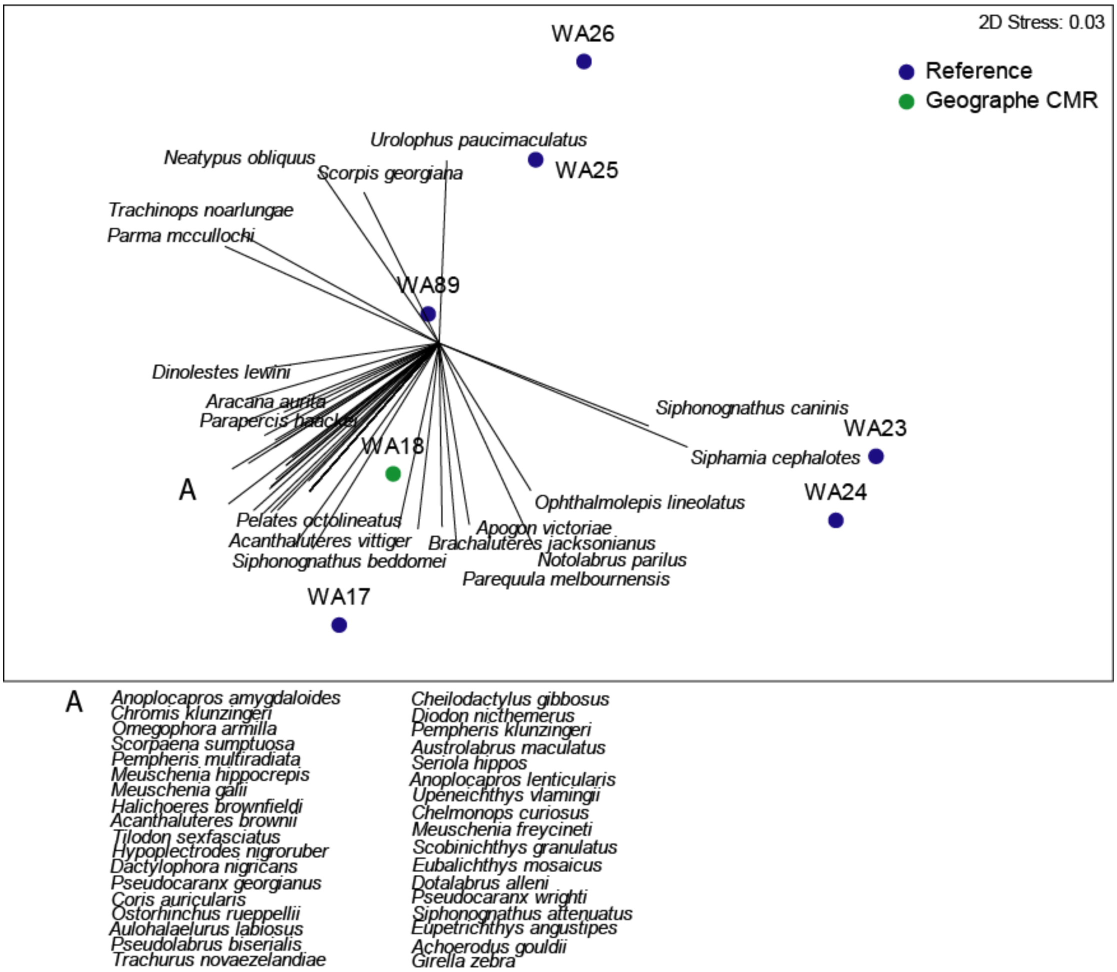

Figure 4. Multidimensional Scaling (MDS) plot of reef fish biomass in the Geographe CMR and reference sites, performed on the Bray-Curtis similarity matrix of the square-root transformed data. Sites are shown by CMR categories. Species vectors are shown if they had a correlation value of at least 0.6; the numerous species represented by the dense vectors on the lower LHS are shown under the plot for clarity.

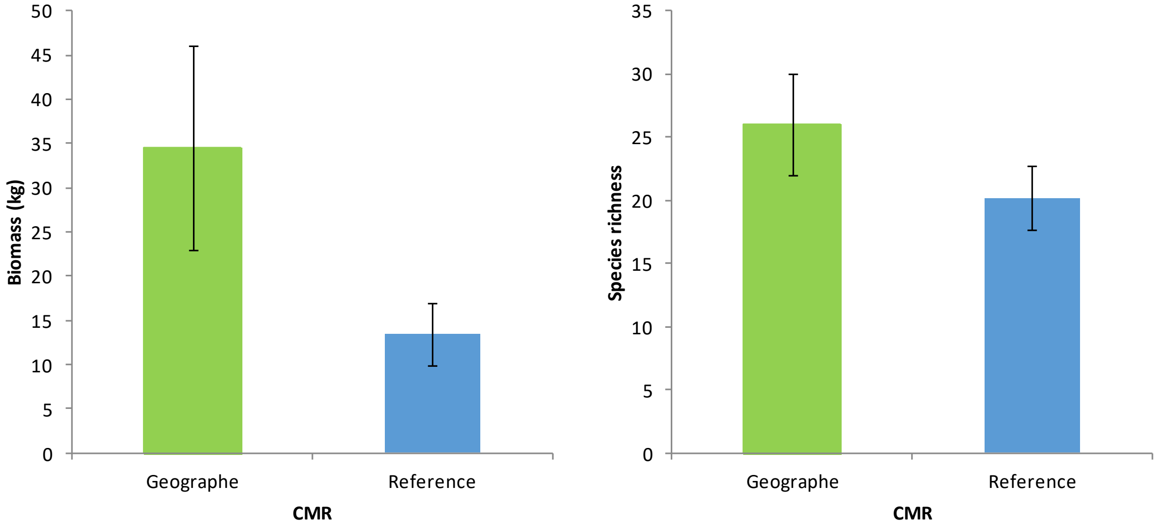

Figure 5. Biomass in kg per 500 m^2 and species richness of reef fishes at Geographe CMR and reference sites in the South-west CMR Network. Three transects associated with the Busselton Jetty (WA17) were removed for the biomass plot. Error Bars = 1 SE.

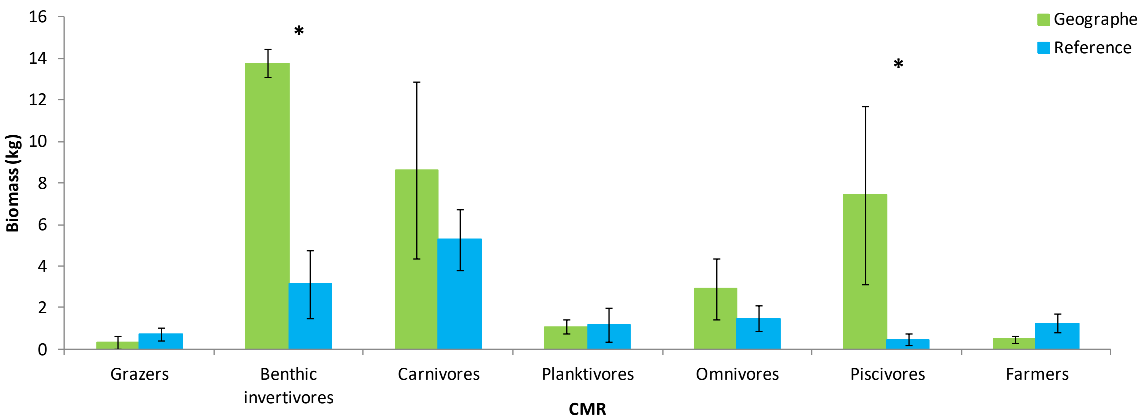

Figure 6. Biomass in kg per 500 m^2 of functional groups of reef fishes at Geographe CMR and reference sites in the South-west CMR Network. Three transects were removed from WA17. Error Bars = 1 SE.

Table 2. ANOVA results for functional groups between CMR categories, log(x+1) transformed.

Trophic group	$F_{1,9}$	p
Grazers	0.10	0.77
Benthic invertivores	5.40	0.045
Carnivores	0.56	0.47
Planktivores	0.89	0.37
Omnivores	1.27	0.29
Piscivores	6.08	0.036
Farmers	0.40	0.55

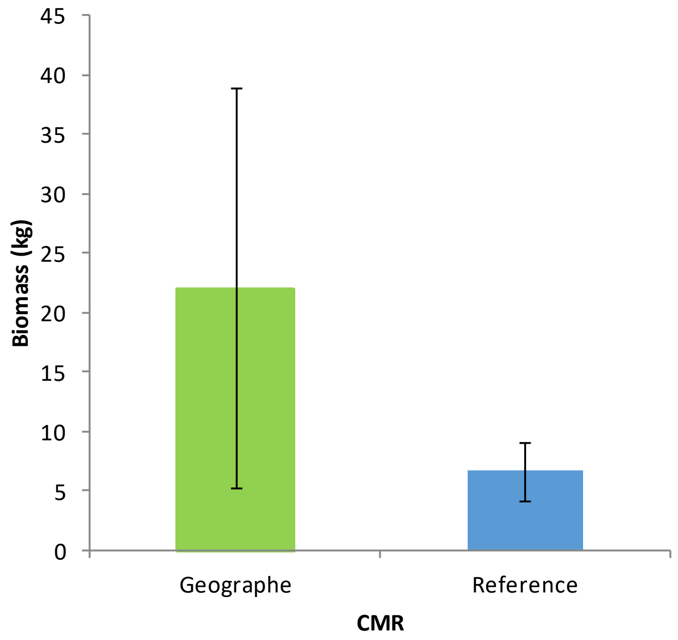

Figure 7. Biomass in kg per 500 m^2 of large (>20cm TL) reef fishes in the Geographe CMR and reference sites in the South-west CMR Network. Error Bars = 1 SE.

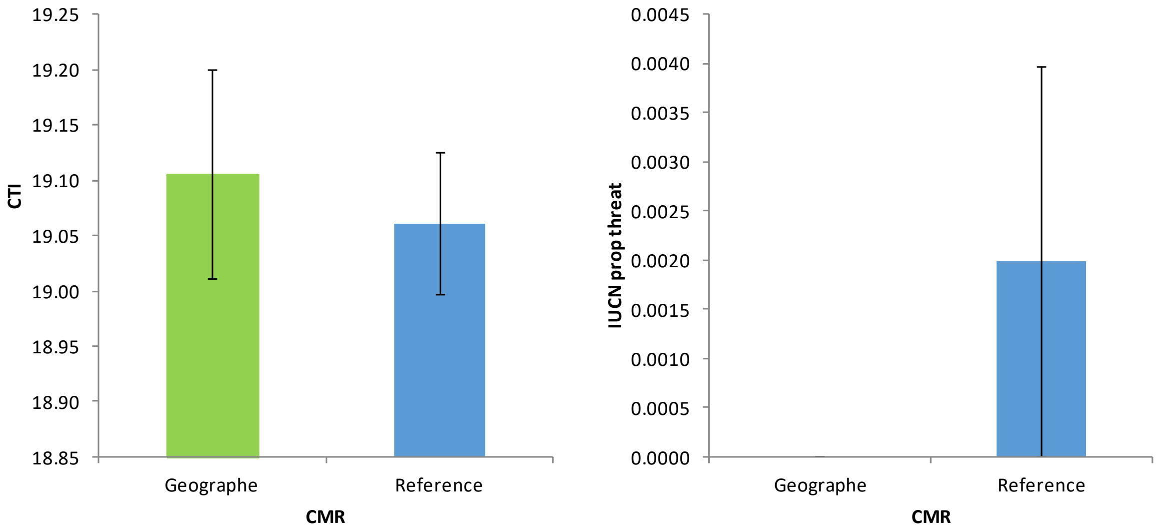

Figure 8. Indices of reef health – CTI and the proportion of threatened species listed in the IUCN Red Book - in the Geographe CMR and reference sites. Error Bars = 1 SE.

BENTHIC SURVEYS

Seven transects were surveyed with photoquadrats: two inside the Geographe Bay CMR (WA18) and five at reference sites (WA17, WA23 and WA24). The CMR had similar average numbers of benthic categories as the two transects outside (~9), but there was a different benthic composition in the CMR. At the reference sites there was a high cover of red and brown algae; one transect also had relatively high (27%) seagrass cover. In the Geographe Bay CMR the three dominant benthic types were brown algae (23.4% +/- 6.2 SE), seagrasses (22.0% +/- 11.8 SE) and turf (13.6% +/- 5.4 SE). The transects inside the CMR also had ascidians, bryozoans, encrusting leathery algae and soft corals, which were not recorded at the other sites.

MOBILE MACROINVERTEBRATE SURVEYS

A total of 38 species of mobile invertebrates were recorded in the Geographe CMR and reference sites (APPENDIX 3). Only 14 species were recorded along the two transects inside the Geographe CMR; 36 species were recorded in total from the other sites (noting there were more reference sites). The most abundant species in the CMR were *Comanthus trichoptera*, *Australostichopus mollis* and *Centrostephanus tenuispinus*; however, none of these exceeded densities of 10 per 100 m^2. At reference sites, the most abundant species were *Heliocidaris erythrogramma* and *Phyllacanthus irregularis*; *Centrostephanus tenuispinus* was also highly abundant.

Unlike the fish community, the macroinvertebrate community was not distinguished by their geographic location, but like the fish community, the Geographe CMR was not distinct from the nearby open sites (ANOSIM Global R = -0.145, p = 0.6). There were clearer distinctions around the species or groups of species that characterised the different sites (Figure 9). WA25 hosted a high proportion of the sea urchin *Centrostephanus tenuispinus*, whereas Geographe CMR site WA18, WA17 and the more northern site WA26 had high proportions of *Turbo torquatus*, *Zoila friendii* and *Astralium* spp. The central sites had higher species richness and a variety of holothurians, sea stars and other invertebrates. Two sub-legal individuals of western rock lobster, *Panulirus cygnus*, were recorded at the reference site WA89.

The overall abundance and species richness of macroinvertebrates did not differ between the CMR and reference sites ($F_{1,12}$ = 0.111, p = 0.745; $F_{1,12}$ = 0.297, p = 0.595, respectively), but there was a general trend of higher abundance at reference sites and higher species richness in the CMR (Figure 10). No significant differences were evident between the CMR and reference sites in any of the three major invertebrate groups present (echinoderms, molluscs and crustaceans), but some trends were evident. Echinoderms were the dominant group, with higher abundance at reference sites and higher species richness at CMR sites (Figure 11). Molluscs and crustaceans were generally more abundant at reference sites, but none of these differences were significant (Table 3).

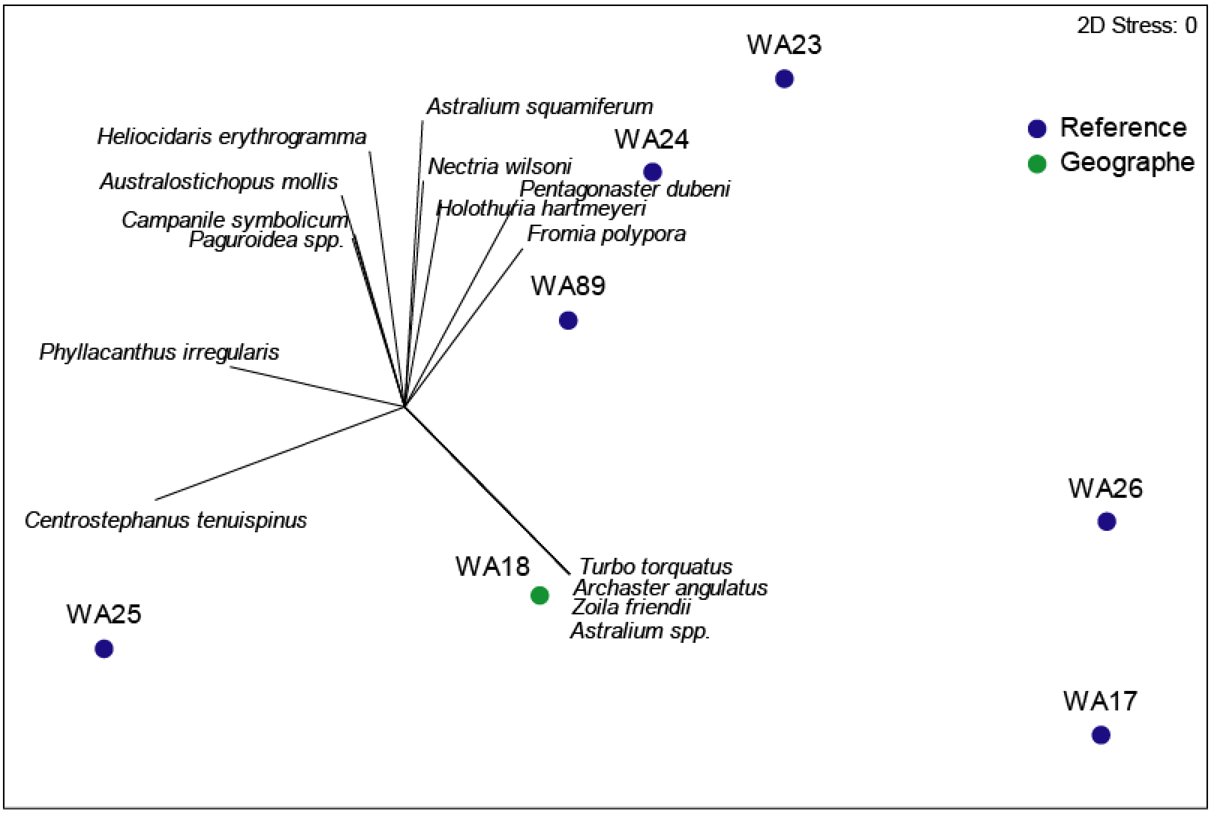

Figure 9. Multidimensional Scaling (MDS) plot of macroinvertebrate abundance at Geographe CMR and reference sites, performed on the Bray-Curtis similarity matrix of the square-root transformed data. Sites are shown by site and CMR. Species vectors are shown if they had a correlation value of at least 0.5.

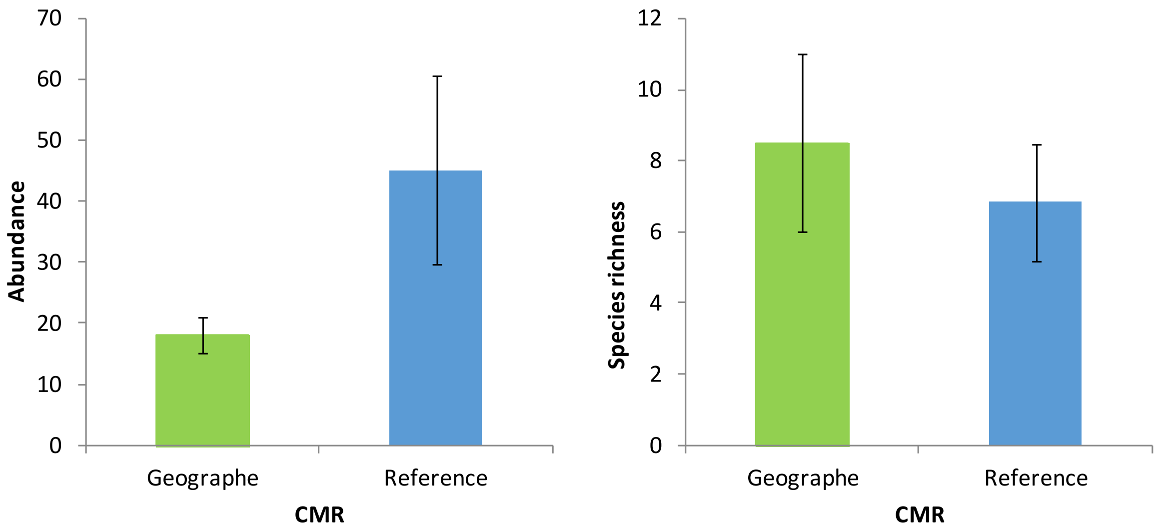

Figure 10. Abundance and species richness per 100 m^2 of macroinvertebrates in the Geographe CMR and reference sites. Error Bars = 1 SE.

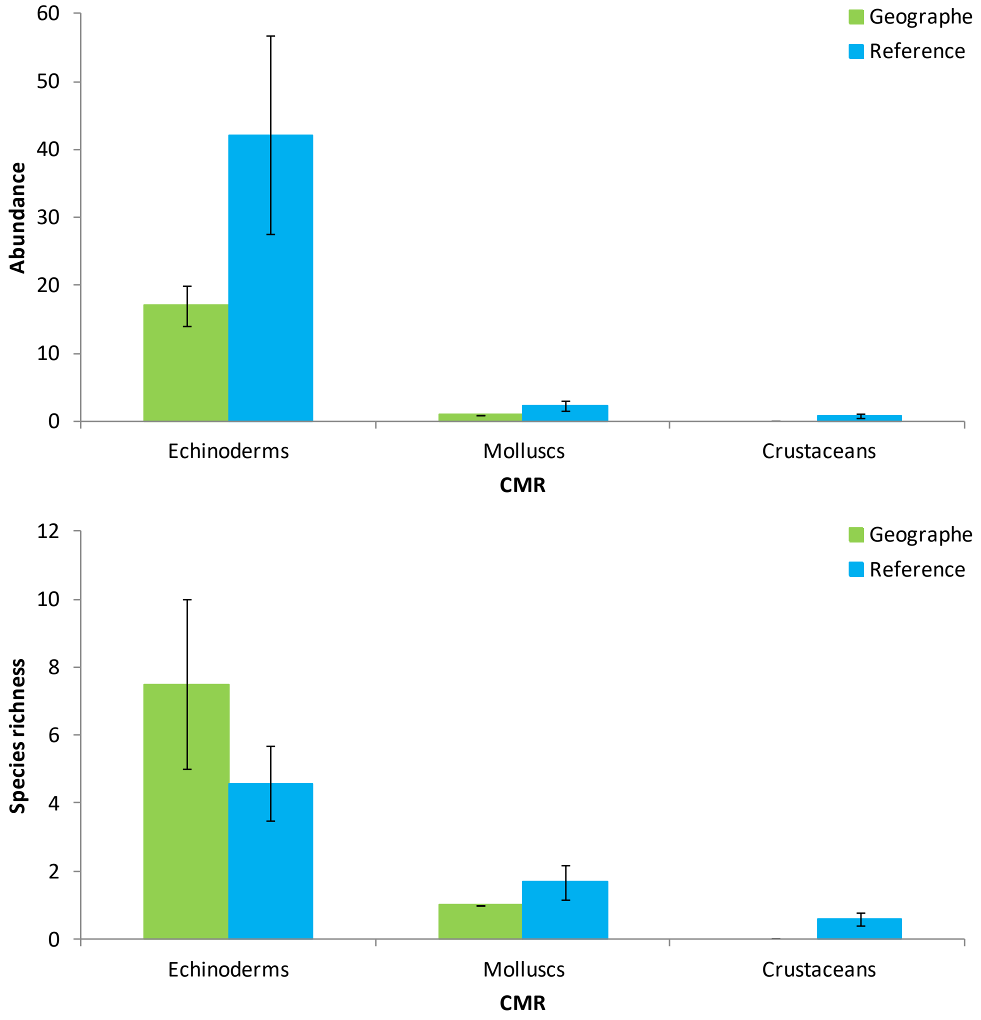

Figure 11. Abundance and species richness per 100 m^2 of the three key macroinvertebrate groups at Geographe CMR and reference sites in the South-west CMR Network. Error Bars = 1 SE.

Table 3. ANOVA results for macroinvertebrate classes for which the abundance and species richness was significantly different between CMR categories, square-root transformed.

Metric	Group	$F_{1,12}$	p
Abundance	Echinoderms	0.081	0.78
	Molluscs	0.047	0.83
	Crustaceans	1.538	0.24
Species richness	Echinoderms	0.918	0.36
	Molluscs	0	0.99
	Crustaceans	1.646	0.22

CRYPTIC FISH SURVEYS

Only 13 species of cryptic fishes were identified along 100 m^2 transects; the Geographe CMR had three species, and the reference sites had all 13 species (APPENDIX 4). *Hypoplectrodes wilsoni*, *Nesogobius* sp. and *Eviota* sp. were the only three species found inside the CMR. *Hypoplectrodes wilsoni* is endemic to south-western WA and is likely a rare species, unless more common in depths below dive surveys. At reference sites, the most abundant species were *Ostorhinchus rueppellii*, *Nesogobius* sp. and *Helcogramma decurrens*.

The abundance and species richness of cryptic fishes were not significantly different between reference sites and those in the Geographe CMR ($F_{1,12}$ = 0.349, p = 0.566; $F_{1,12}$ = 0.003, p = 0.958, respectively). This was despite the seemingly higher abundance at reference sites – any differences were masked by the considerable variability between individual sites (Figure 12).

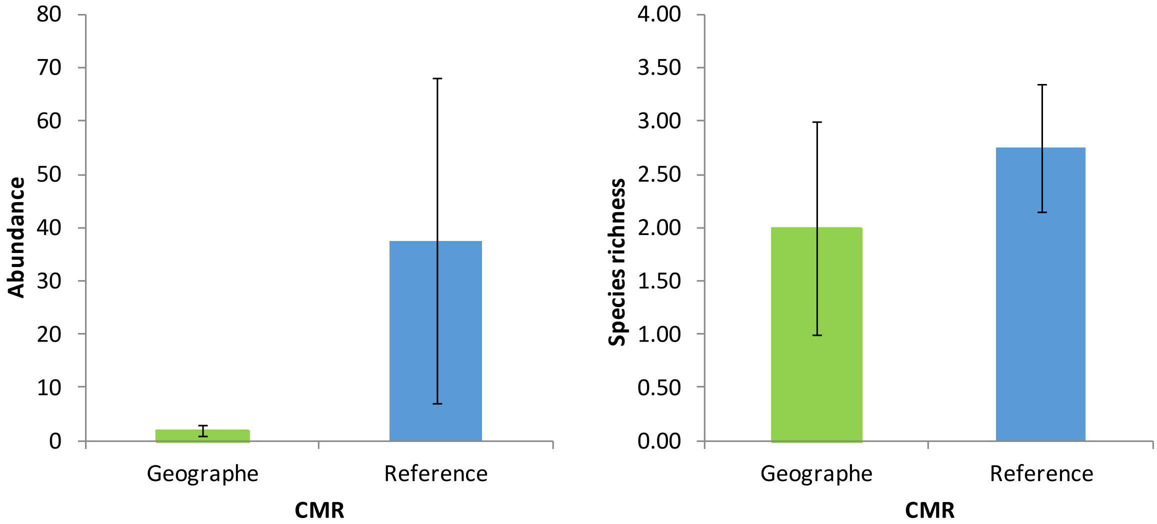

Figure 12. Abundance and species richness per 100 m^2 of cryptic fishes in the CMRs and reference sites. Error Bars = 1 SE.

THREATENED AND PROTECTED SPECIES

A single shark was encountered during the surveys: a black spotted catshark (*Aulohalaelurus labiosus*), listed as Least Concern, at the Bussleton Jetty (WA17). No other species of conservation interest were recorded, although *H. wilsoni*, recorded in the Geographe CMR is rare, only recorded at four sites in the entire RLS global database, two of these in Geographe Bay.

4 Discussion

The Geographe CMR, one of 14 CMRs in the South-west CMR Network, appears to possibly support a greater local richness and biomass of fishes, but reduced invertebrate abundance, when compared to the other rocky reefs surveyed along the coast. Between-site differences most probably reflect environmental gradients and habitat structure, but any interpretation based on only one site inside the CMR must be made with caution. The surveys did not reveal remarkable species or populations of conservation or commercial significance, although the observation of two spotty seaperch (*Hypoplectrodes wilsoni*) is notable.

The benthic communities grew on either sand or hard limestone substratum, and were dominated by seagrass and algae (McMahon et al. 1997). Fucoids were present but not dominant; in other parts of the temperate south-western Australia, including areas surveyed closer to Perth in the north, and Albany around the south coast, they are the major habitat formers. Despite the efforts of this survey to target reef habitat, seagrass beds adjacent to the target reefs were also captured in the transects. Seagrass beds are highly productive, providing habitat and primary production to marine organisms in multiple stages of their life cycles. Currently, there is global concern over the loss of coastal seagrass beds due to pollution, eutrophication, overfishing and physical disturbance (Kendrick et al. 2000). There was some degree of epiphytic filamentous overgrowth of the seagrasses, but epiphytes made up a low percentage cover (3-7%), suggesting they did not pose a threat to the integrity or health of the seagrass beds (Waycott et al. 2009). Usually the focus of research on seagrass grazing is centred around megafauna such as turtles and dugongs; recently studies in the South-west region have found that some fishes also use seagrasses as a major food source (White et al. 2011).

A geographical gradient was apparent in the fish assemblage, possibly related to increasing exposure to southwesterly swell towards the northern end of the sampling area, and high species richness and abundance of fishes in Geographe Bay. Greater sampling effort may reveal significant patterns. A rich variety of temperate species characterises the Geographe CMR and nearby sites, with specific groups of one or a few species distinguishing most sites. At least three of the species known to include seagrass in their diet, *Scobynichthys granulatus*, *Brachaluteres jacksonianus* and *Meuschenia freycineti* (White et al. 2011), were prominent members of the fish assemblage in the Geographe CMR, but not sites further north, suggesting that changing resources may have played a part in driving fish community structure. However, herbivore abundance tends to be low on temperate reefs (Edgar and Shaw 1995), as was also found in this survey, where benthic invertivores, carnivores and piscivores tended to dominate. The exception was a large school of planktivores that typically resides under the Bussleton Jetty. In temperate systems, other studies have found that more fish species associate with seagrass habitat than unvegetated habitat, even for assemblages where most species feed on invertebrates (Edgar and Shaw 1995).

Invertebrate communities in the Geographe CMR appeared more similar to the northernmost sites than to those geographically adjacent. This could be driven by greater similarities in the habitat structure and benthic community composition, although unfortunately benthic replication was too low to determine this. Elevated abundance of western rock lobsters was not found in the protected Geographe CMR, possibly due to low sampling effort, but also possibly due to the status of the CMR protection not yet under active management.

Fishing and shipping are some of the key impacts listed for the general Geographe Bay area. The no-take parts of the Geographe CMR will therefore most probably undergo the greatest changes over time (Russ and Alcala 2004). Surveys through the future with greater replication are expected to show increased abundance and biomass of commonly-exploited fish species in protected zones (Graham et al. 2011). In turn, selective removal of top predators or herbivores by fishing could potentially affect trophic structure, with repercussions for species at lower trophic levels and perhaps also benthic communities (McClanahan and Shafir 1990; Mumby et al. 2006; McClanahan 2008; Sandin et al. 2008). The time scale of such changes is difficult to predict given great variability in population recovery between species (Green et al. 2014).

5 Recommendations

- ongoing monitoring of South-west CMR reefs should take place on annual basis, using methods consistent with those presented here;
- baseline data presented here should guide efforts to select sites;
- sampling effort should be increased to include at least three sites of multiple transects in the Geographe CMR;
- research priorities should include development of indicators that track changes in reef condition and biodiversity;
- detailed habitat mapping should be undertaken, including categorisation of reef types, their location and extent;
- detailed mapping of distribution and impact of natural disturbances and human impacts should be undertaken; and
- ecological monitoring surveys should be expanded to other CMRs in the South-west CMR Network that include reefs within their boundaries.

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8 Appendices

APPENDIX 1 - REEF LIFE SURVEY BENTHIC FUNCTIONAL GROUPS.

Broad group	RLS Functional group
Coral	Ahermatypic corals
Coral	Bleached coral
Coral	Branching *Acropora*
Coral	Encrusting corals
Coral	Hydrocoral
Coral	Large-polyp stony corals
Coral	Massive corals (Live)
Coral	Other branching/erect corals (Live)
Coral	*Pocillopora*
Coral	Soft corals and gorgonians
Coral	Tabular Coral (Live)
Other	Ascidians (stalked)
Other	Ascidians (unstalked)
Other	Bare Rock
Other	Barnacles
Other	Bryozoan (hard)
Other	Bryozoan (soft)
Other	Colonial Anemones, Zoanthids and Corallimorphs
Other	Dead Coral
Other	Hydroids
Other	Pebbles/unconsolidated rocky bottom/coral rubble
Other	Polychaete
Other	Sand
Other	Seagrass (*Halophila*)
Other	Seagrass (other)
Other	Sessile bivalves
Other	Sessile gastropods
Other	Solitary Anemones
Other	Sponges (encrusting)
Other	Sponges (erect)

Broad group	RLS Functional group
Other	Sponges (hollow)
Other	Sponges (massive)
Algae	algal mat/slime
Algae	*Caulerpa*
Algae	Crustose coralline algae
Algae	cyanobacterial mat/slime
Algae	*Desmarestia* and *Himantothallus*
Algae	*Durvillaea*
Algae	Encrusting leathery algae
Algae	Filamentous epiphytic algae
Algae	Filamentous rock-attached algae
Algae	Foliose red algae
Algae	Geniculate coralline algae
Algae	Green calcified algae
Algae	Large brown laminarian kelps
Algae	Other foliose green algae
Algae	Other fucoids
Algae	*Phyllospora*
Algae	Small to medium foliose brown algae
Algae	Turfing algae (<2 cm high algal/sediment mat on rock)

APPENDIX 2 - NUMBER OF TRANSECTS ALONG WHICH FISH SPECIES WERE RECORDED, AND BIOMASS PER 500 M2, FOR SITES STUDIED IN THE SOUTH-WEST CMR NETWORK AND REFERENCE SITES.

Species	Transects		Biomass	
	Geographe CMR	**Reference**	**Geographe CMR**	**Reference**
Aplodactylus westralis	0	1	0	0.98
Apogon victoriae	2	10	0.13	1.37
Ostorhinchus rueppellii	0	4	0	7.42
Siphamia cephalotes	0	2	0	0.01
Aulopus purpurissatus	1	0	0.70	0
Pseudocaranx dentex	2	3	12.2	4.95
Pseudocaranx wrighti	0	1	0	0.38
Seriola hippos	0	2	0	3.95
Trachurus novaezelandiae	0	3	0	1064
Chelmonops curiosus	2	10	0.83	2.51
Cheilodactylus gibbosus	1	4	0.27	5.27
Dactylophora nigricans	1	3	2.91	2.30
Dinolestes lewini	2	1	14.3	5.66
Diodon nicthemerus	1	2	0.13	0.68
Enoplosus armatus	2	2	1.27	0.13
Parequula melbournensis	0	7	0	0.54
Girella zebra	1	1	0.61	0.61
Neatypus obliquus	2	3	1.71	2.10
Scorpis georgiana	0	5	0	1.89
Tilodon sexfasciatus	1	1	1.79	0.51
Achoerodus gouldii	0	1	0	0.07
Austrolabrus maculatus	2	12	0.99	3.58
Bodianus frenchii	1	1	0.47	2.83
Coris auricularis	2	7	7.86	4.94
Dotalabrus alleni	1	2	0.22	0.20
Eupetrichthys angustipes	0	1	0	0.04
Halichoeres brownfieldi	1	6	0	0.74
Notolabrus parilus	1	11	0.58	3.48

Species	Transects		Biomass	
Ophthalmolepis lineolatus	2	2	0.06	0.83
Pictilabrus laticlavius	0	3	0	0.39
Pseudolabrus biserialis	1	7	0.39	2.41
Acanthaluteres brownii	0	5	0	6.72
Acanthaluteres vittiger	0	3	0	3.71
Brachaluteres jacksonianus	0	2	0	0.02
Eubalichthys cyanoura	0	2	0	2.61
Eubalichthys mosaicus	0	1	0	1.55
Meuschenia flavolineata	1	3	0.59	3.36
Meuschenia freycineti	0	1	0	0.66
Meuschenia galii	0	2	0	2.66
Meuschenia hippocrepis	1	3	0.30	2.98
Scobinichthys granulatus	0	4	0	15.94
Schuettea woodwardi	0	1	0	0.14
Parupeneus spilurus	0	2	0	0.65
Upeneichthys vlamingii	2	8	0.19	2.96
Siphonognathus attenuatus	1	2	0.26	0.18
Siphonognathus beddomei	0	3	0	0.54
Siphonognathus caninis	1	4	0.01	0.09
Anoplocapros amygdaloides	0	1	0	0.18
Anoplocapros lenticularis	0	2	0	0.64
Aracana aurita	0	3	0	0.45
Parapriacanthus elongatus	0	1	0	0.01
Pempheris klunzingeri	2	6	12.4	20.7
Pempheris multiradiata	1	9	0.28	7.55
Paristiopterus gallipavo	1	0	0.33	0
Parapercis haackei	0	2	0	0.02
Paraplesiops meleagris	2	2	0.48	0.28
Trachinops brauni	1	0	0.17	0
Trachinops noarlungae	2	11	3.04	44.4
Chromis klunzingeri	2	10	1.74	1.56
Parma mccullochi	2	9	0.81	7.37
Parma occidentalis	0	2	0	1.19

Species	Transects		Biomass	
Parma victoriae	1	9	0.15	4.83
Scorpaena sumptuosa	0	2	0	3.89
Aulohalaelurus labiosus	0	1	0	0.29
Hypoplectrodes nigroruber	2	3	0.49	0.71
Pelates octolineatus	0	2	0	6.85
Omegophora armilla	0	2	0	0.16
Trygonoptera testacea	1	0	0.48	0
Urolophus paucimaculatus	0	1	0	3.36

APPENDIX 3 - NUMBER OF TRANSECTS ALONG WHICH INVERTEBRATE SPECIES WERE RECORDED, AND ABUNDANCE PER 100 M2, FOR SITES STUDIED IN THE SOUTH-WEST CMR NETWORK AND REFERENCE SITES.

Species	Transects		Abundance	
	Geographe CMR	Reference	Geographe CMR	Reference
Echinaster arcystatus	1	1	0.50	0.08
Echinaster varicolor	1	1	0.50	0.08
Fromia polypora	0	5	0	0.42
Meridiastra gunnii	0	1	0	0.25
Nectria macrobrachia	0	2	0	0.25
Nectria wilsoni	0	2	0	0.25
Pentagonaster dubeni	2	5	1.00	0.67
Petricia vernicina	1	6	0.50	0.83
Plectaster decanus	1	4	0.50	0.58
Pseudonepanthia troughtoni	0	3	0	0.50
Tosia australis	0	1	0	0.08
Comanthus spp.	1	0	0.50	0
Comanthus trichoptera	2	2	4.00	0.42
Centrostephanus tenuispinus	2	4	2.50	1.33
Goniocidaris tubaria	0	1	0	0.25
Heliocidaris erythrogramma	0	6	0	30.42
Phyllacanthus irregularis	1	6	1.00	4.67
Australostichopus mollis	1	4	3.50	1.00
Ceto cuvieria	2	0	2.50	0
Holothuria hartmeyeri	0	1	0	0.08
Sepiid spp.	0	1	0	0.08
Astralium spp.	0	1	0	0.08
Astralium squamiferum	0	3	0	0.58
Astralium tentorium	0	1	0	0.17
Campanile symbolicum	0	4	0	0.33
Ceratosoma brevicaudatum	2	1	1.00	0.08
Dicathais orbita	0	1	0	0.08
Glossodoris rufomarginata	0	1	0	0.08
Gracilispira monilifera	0	1	0	0.08

Species	Transects		Abundance	
Hypselodoris saintvincentia	0	1	0	0.08
Nudibranchia spp.	0	1	0	0.08
Phyllidiella pustulosa	0	1	0	0.08
Turbo torquatus	0	1	0	0.08
Zoila friendii	0	1	0	0.08
Zoila venusta	0	1	0	0.25
Paguristes frontalis	0	2	0	0.17
Paguroidea spp.	0	4	0	0.42
Panulirus cygnus	0	1	0	0.17
Ceto cuvieria	2	0	5.00	0
***Comanthus* spp.**	1	0	1.00	0

APPENDIX 4 - NUMBER OF TRANSECTS ALONG WHICH INVERTEBRATE SPECIES WERE RECORDED, AND ABUNDANCE PER 100 M2, FOR SITES STUDIED IN THE SOUTH-WEST CMR NETWORK AND REFERENCE SITES.

Species	Transects		Abundance	
	Geographe CMR	Reference	Geographe CMR	Reference
Ostorhinchus rueppellii	0	1	0	310
***Nesogobius* spp.**	1	4	1	48
Helcogramma decurrens	0	5	0	39
Apogon victoriae	0	6	0	21
Parapercis haackei	0	6	0	18
Cochleoceps bicolor	0	3	0	6
Hypoplectrodes nigroruber	0	2	0	2
Eviota bimaculata	0	1	0	2
Hypoplectrodes wilsoni	2	1	2	1
***Eviota* spp.**	1	1	1	1
Heteroscarus acroptilus	0	1	0	1
Epinephelides armatus	0	1	0	1
Acanthistius serratus	0	1	0	1