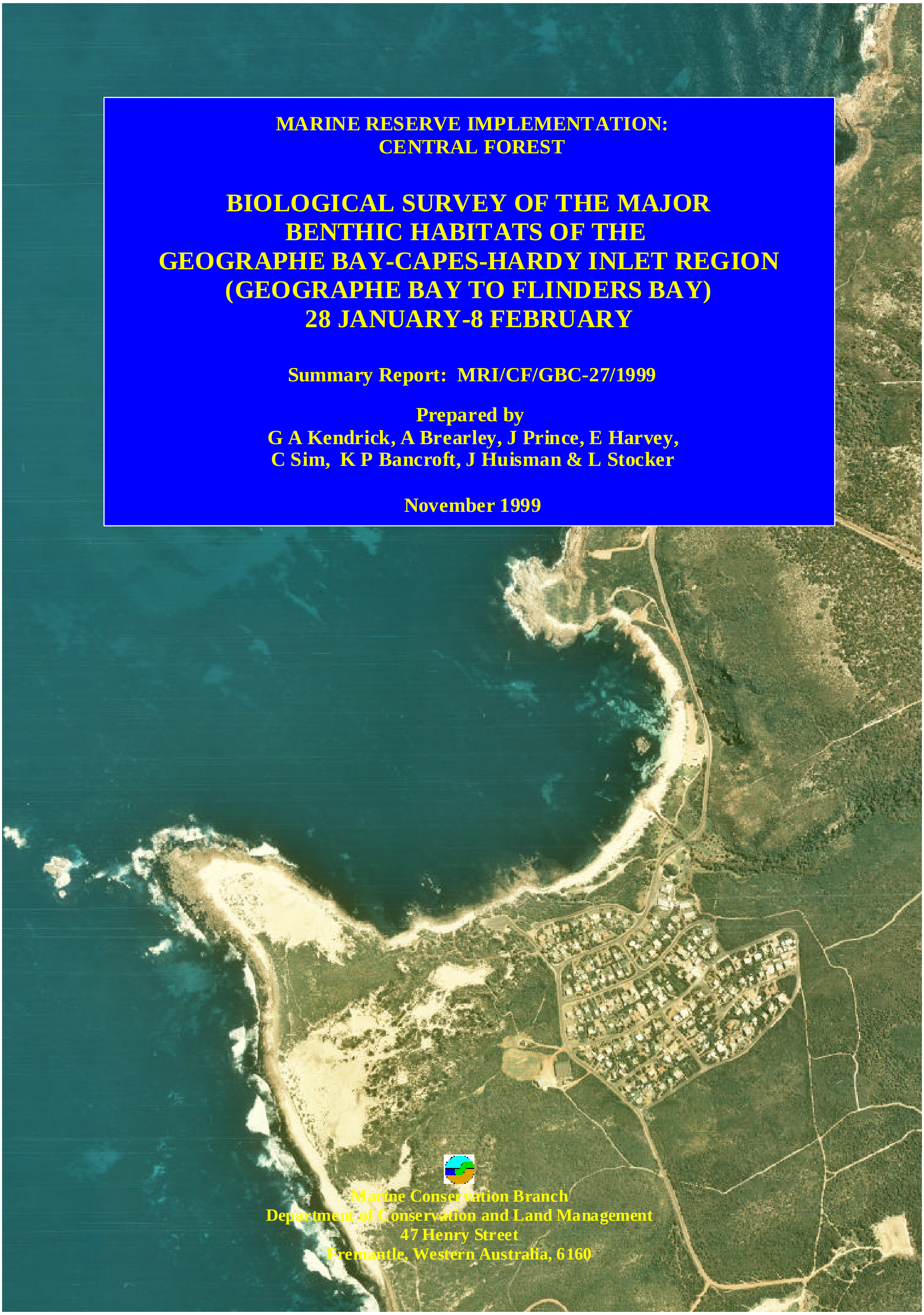

MARINE RESERVE IMPLEMENTATION:
CENTRAL FOREST

BIOLOGICAL SURVEY OF THE MAJOR BENTHIC HABITATS OF THE GEOGRAPHE BAY-CAPES-HARDY INLET REGION (GEOGRAPHE BAY TO FLINDERS BAY) 28 JANUARY-8 FEBRUARY

Summary Report: MRI/CF/GBC-27/1999

Prepared by
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C Sim, K P Bancroft, J Huisman & L Stocker

November 1999

Marine Conservation Branch
Department of Conservation and Land Management
47 Henry Street
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A collaborative project between CALM's Marine Conservation Branch and South West Capes District Office, and the University of Western Australia

A project partially funded through the Natural Heritage Trust's
Coast and Clean Seas Marine Protected Area Programme
Project No: WA9703

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- Laura Stocker, Institute for Science and Technology Policy, Murdoch University.
- Mark Westera, Centre for Ecosystem Management, Edith Cowan University.
- Eva Boogard, Professional underwater photographer.
- Skipper and crew of the *MV Voyager*.

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The Geographe Bay-Capes biological survey is partially funded by a grant of $72,000 through the Natural Heritage Trust's Coast and Clean Seas Marine Protected Area Program.

Resources including scientific supervision, technical assistance, logistical support and instrumentation were provided by the MCB ($87,000).

Cover. Cowaramup Bay (orthophotograph)

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EXECUTIVE SUMMARY

In January/February 1999, a biological survey was undertaken in the Geographe Bay-Capes-Hardy Inlet area. These areas were recommended by the Marine Parks and Reserves Selection Working Group (Marine Parks and Reserves Selection Working Group, 1994) for consideration as marine conservation reserves under the *Conservation and Land Management (CALM) Act (1984)*. This survey was a collaboration between the Department of Conservation and Land Management and the University of Western Australia.

The objectives of the survey were achieved and are as follows:

- to develop a quantitative description of marine biota at representative sites within the major benthic habitats of the region;
- to perform a quantitative analysis of species richness within the major benthic community types;
- to investigate the influence of physical parameters, such as substrate type and wave exposure, on community diversity;
- to acquire a collection of fauna and flora density and biomass data as baseline information for long-term monitoring of communities before and after marine reserve implementation, and;
- the secondary objective of the survey was the opportunistic collection of qualitative information on visually dominant marine fauna and flora.

Assemblages of marine algae in the study area were high in species diversity, with 154 species recorded from the survey. Many species were rarely sampled and were not recorded at many sites. Algal assemblages on granite reef and boulder fields have not previously been characterised in temperate Western Australia. There was a significant difference between the algal assemblages on deeper offshore granite reefs and shallow onshore reefs (both limestone and granite).

Sponges and ascidians were diverse components of the sessile benthos. They were not sampled intensively in this survey, but show some patterns, suggesting that more research effort should be expended on these groups.

Spatial patterns of fish abundance and size indicate that all sites are homogenous over the study area, however there is statistical difference in the fish community between inshore and offshore reefs.

The fauna on the intertidal rock platform sampled in this survey had a low diversity and the spatial analysis demonstrated that the limestone platforms had a different faunal assemblage to that of the intertidal granitic boulder fields. Assemblages in the boulder fields were similar across the study area, however the assemblages on limestone platforms differed from the granitic boulder fields and from each other.

The difference between the fauna of limestone and granitic areas can be explained by differences in their microtopography. Granites have relatively smooth surfaces in comparison to limestone areas, which have an irregular outline and surface.

RECOMMENDATIONS

SUBTIDAL

Zoning

Recommendation 1. *Any zoning strategy for the proposed marine conservation reserve should replicate full and partial conservation zones in the northern, western and southern sections of the*

Recommendation 2. *Distribution of marine algae was significantly influenced by m, 10-20 m) for*

regions.

Recommendation 3. *Algal assemblages on high relief reef were not significantly different from low relief reef, but this more likely reflects the sampling intensity of the survey. Including this stratum in a zoning strategy is recommended.*

Algae

Recommendation 4. *The stratified biodiversity survey design was able to differentiate clear differences between algal assemblages across geographical regions, reef type and water depth with a minimum number of sites and replicates within sites. Further use of this design is recommended.*

algal species, species distributions and species turnover suggest that marine algae in the study area are major components of the Algal assemblages should be a key component of further surveys.

Ascidians

Recommendation 6. *Both sponges and ascidians were poorly studied during this survey, but show high diversity and high species turnover within and between sites. Both sponges and ascidians are candidates for future surveys.*

Fish

> **Recommendation 7.** *There were more species of fish occurring in offshore versus onshore sites, however fish density seems to be more site specific. It is recommended that an offshore versus onshore stratum is included in the future zoning strategy.*

> **Recommendation 8.** *Both species richness and fish density were shown to have high levels of observer bias. Observer bias is generally larger than differences between sites. The non-destructive scuba visual survey methods seems inappropriate, and the effort expended (a team of five scuba divers) is not cost effective. We recommend that visual surveys of fish are not included in future biodiversity surveys.*

> **Recommendation 9.** *The use of remote video should be investigated and if necessary, developed to replace the present visual survey method.*

INTERTIDAL

Zoning

> **Recommendation 10.** *Limestone intertidal reefs areas of Yallingup, Kilcarnup and Prevelly are warranted special protection because of their accessibility and high diversity of species.*

> **Recommendation 11.** *Granitic boulder fields in sheltered habitats such as Cowaramup and Sugar Loaf should also be protected because of the high diversity of species found in the immediate subtidal.*

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1 INTRODUCTION

This report summarises the data collected on a biological survey in the Geographe Bay-Capes-Hardy Inlet region. It presents the results and makes recommendations in regards to survey design, future surveys and implications to management zoning.

This report has been divided into three major sections. The first being the introduction which describes the background, objectives, survey area and survey design. The second presents the results of the Subtidal survey conducted from the *MV Voyager* and the last section presents the results of the land based intertidal survey.

1.1 BACKGROUND

In recognition of the importance of conserving the State's marine biodiversity, the Minister for the Environment established the Marine Parks and Reserves Selection Working Group (MPRSWG) in 1986. The main aim of the MPRSWG was to identify representative and unique areas of Western Australia's marine waters for consideration as part of a statewide system of marine conservation reserves under the *Conservation and Land Management (CALM) Act* 1984. The MPRSWG's report was released in June 1994 and identified over seventy such candidate areas throughout the coastal waters of Western Australia (Marine Parks and Reserves Selection Working Group, 1994).

The State's vesting body for marine conservation reserves is the Marine Parks and Reserves Authority (MPRA) which was established in 1997. The MPRA has prioritised the candidate areas for implementation as marine conservation reserves and the Geographe Bay-Capes-Hardy Inlet region was one of the MPRA's high priority candidate areas.

Under the State Government's marine and conservation strategy detailed in *New Horizons - The way ahead in marine conservation and management* released by the Western Australian Government in 1998 (WA Government, undated), there is a requirement for:

> *"Extensive assessment, community consultation and management planning before a new marine conservation reserve is established."*

An essential component of this is that:

> *"A comprehensive assessment of the area's biological and economic resources, and social values is carried out."*

In view of the high standing that the Geographe Bay-Capes-Hardy Inlet region has in the MPRA's priority list for new marine conservation reserves, CALM applied to Environment Australia for funding to perform a biological survey in the area. Partial funding of $72,000 for the project has been obtained through Environment Australia's Natural Heritage Trust, via the Coast and Clean Seas Marine Protected Area Programme. CALM will contribute further resources to the project, valued at approximately $87,000.

The data acquired during this project will be important in the determination of the relative conservation values of the respective major habitats of the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve. It will also contribute to the information base required for the marine reserve planning process, during which marine reserve boundaries and zones for multiple-use will be considered for the area.

This project was collaboration between CALM's Marine Conservation Branch (MCB) and the Central Forest Region, South West Capes District Office, and the University of Western Australia.

1.2 OBJECTIVES

1.2.1. Primary Objectives

The primary objectives of the survey are:

- quantitative description of marine biota at representative sites within the major benthic habitats;
- quantitative analysis of species richness within the major benthic community types;
- investigation of the influence of physical parameters, such as substrate type and wave exposure, on community diversity, and;
- collection of fauna and flora density and biomass data as baseline information for long-term monitoring of communities before and after marine reserve implementation.

1.2.2. Secondary Objective

The secondary objective of the survey is the opportunistic collection of qualitative information on visually dominant marine fauna and flora.

2 STUDY AREA

The study area is the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve. This area encompasses the Leeuwin-Naturaliste and the Hardy Inlet which are two of the few areas of south west Western Australia recommended for marine reservation by the Marine Parks and Reserves Selection Working Group (1994) (Figure 1).

The study area extends from the Busselton Jetty in Geographe Bay to Black Point in eastern Flinders Bay.

3 DESIGN

This biodiversity survey was designed to document how major geographical, geomorphological and oceanographic influences in the proposed Capes-Geographe Bay-Hardy Inlet marine conservation reserve affect the distribution of reef dwelling organisms (algae, sponges, ascidians, fish).

The survey was divided into two components:

Part A: Subtidal Habitats

Part B: Intertidal Habitats

The results of these components are presented separately.

The survey was not designed to present an exhaustive list of all species and their distribution in the study area. Rather, it is designed to assess differences in species assemblages (species diversity, species abundance, species turnover) from a small intensive study of sites, habitats and depths that represent the range of reefs found within the Capes-Geographe-Hardy Inlet region.

It will form a biological basis for zoning and protected area designation within the proposed marine conservation reserve, as well as, a baseline for designing further surveys and monitoring programs. This analysis, along with the broad survey of benthic marine environments (Bancroft & Colman, 1998) will aid in assessing the representativeness and uniqueness components when zoning the proposed marine conservation reserve.

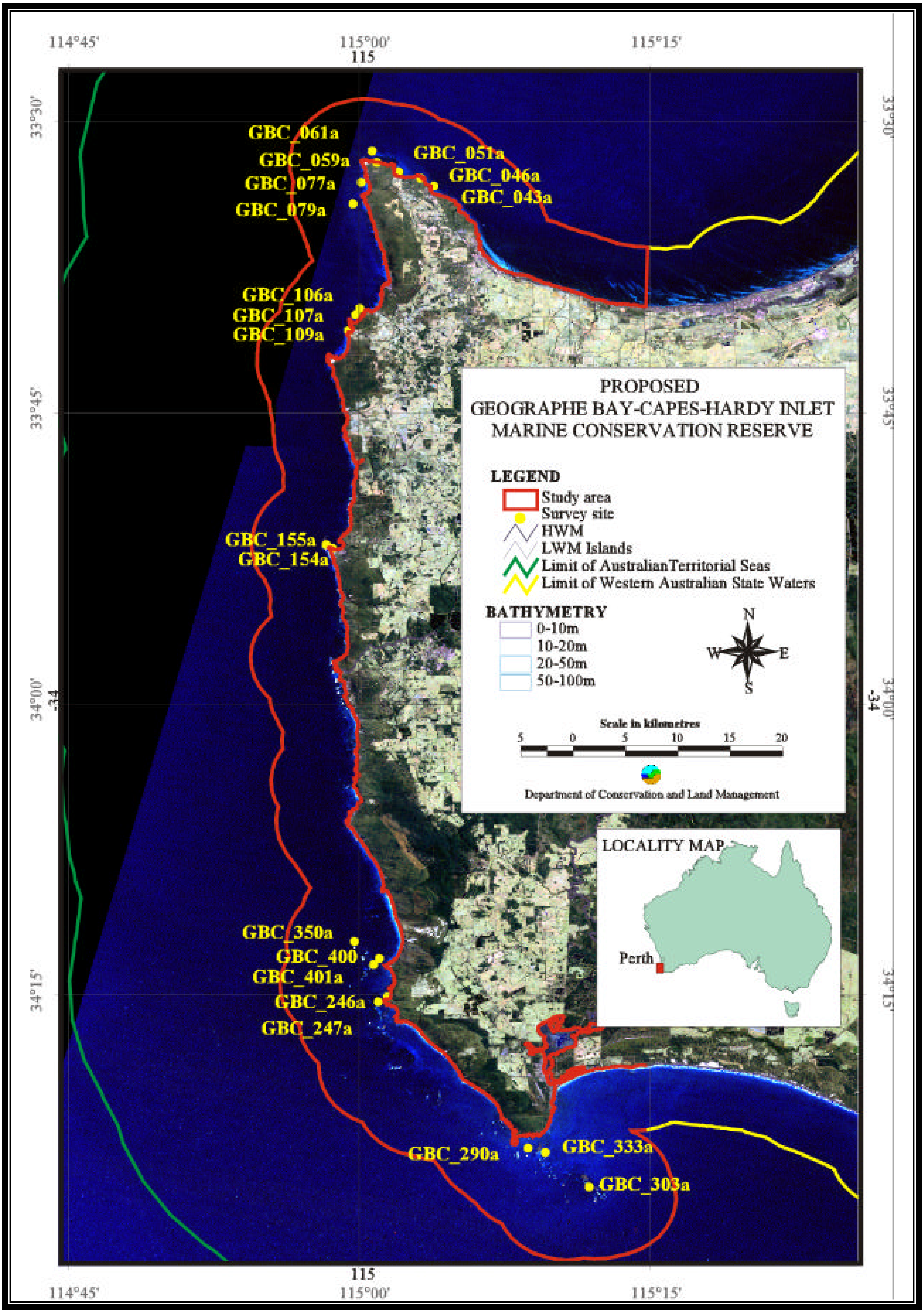

Figure 1. Study Site (Geographe Bay-Capes-Hardy Inlet region)

4 PART A: SUBTIDAL HABITATS

Prepared by

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November 1999

4.1 INTRODUCTION

This report presents data and data analyses from surveys of subtidal benthic marine habitats between Geographe Bay and Flinders Bay on the southwest coast of Western Australia. The surveys carried out between 28 January and 8 February, 1999 were conducted to examine regional-scale (10's km) biodiversity of marine algae, fish and sessile invertebrates (sponges, ascidians) in nearshore waters (<20 m depth) in the proposed Geographe Bay-Capes-Hardy Inlet marine conservation reserve.

The survey design incorporated:

- 3 geographical regions: Southern, Western and Northern shores
- 2 reef types: Limestone and Granite
- 2 reef aspects: high and low relief
- 2 depths : <10 m, 10 –20 m

The design is not fully orthogonal and in some regions, reef type aspect and depth were difficult to sample. For example, limestone reef was restricted to the southwest portion of the study area and only occurred in shallow waters generally <10 m deep.

4.2 METHODS

4.2.1. Survey sites.

Reefs were sampled from 20 sites between Geographe Bay and Flinders Bay (Figure 1). Sites were located within three broad-scale regions:

1. the northern region (north of Cape Naturaliste);
2. the western region (between Cape Naturaliste and Cape Leeuwin), and;
3. the southern region (south-east of Cape Leeuwin).

Sites were chosen based on a pilot study, which surveyed benthic marine environments using remote video techniques (Bancroft & Colman, 1998). Sites visited during the present study encompassed a variety of habitat types (limestone and granite), reef morphology (high relief; >3 m relief and low relief; <3 m relief) and depths (deep; >10 m and shallow; <10 m) which are encountered within state waters in the area. Sites deeper than 20 m depth were not surveyed due to diving regulations. Site names, corresponding latitude and longitude, depths and environmental information are shown in Tables 1 & 2.

Fourteen granite reefs and six limestone reefs were surveyed (Table 1). Five sites were surveyed in the northern region, twelve in the western region and three in the southern region. Of the granite reefs ten were low relief and four were high relief. Four limestone reefs were characterised by high relief morphology and two were low relief (Table 1). Depths ranged between 4.5 m to 26 m.

Table 1. List of survey sites showing region, habitat type, reef morphology and depths for 20 sites between Geographe Bay and Flinders Bay in south Western Australia visited between 28 January and 8 February 1999.

Sites	Site #	Region	Habitat type	Reef morphology	Depth (m)
Eagle Bay	GBC-043	Northern	Granite	Low relief	7-8.9
Rocky Bay	GBC-046	Northern	Granite	Low relief	6.4-8.1
Bunker Bay	GBC-051	Northern	Mixed predom. granite	Low relief	6-8.6
Cape Naturaliste (inshore)	GBC-059	Northern	Mixed predom. granite	Low relief	6-8.2
Cape Naturaliste (offshore)	GBC-061	Northern	Granite	High relief	16.4-18.1
Windmills	GBC-077	Western	Granite	Low relief	20-23.8
Sugarloaf	GBC-079	Western	Granite	High relief	20-26
Canal Rocks (north)	GBC-106	Western	Granite	High relief	8.7-15.5
Canal Rocks (offshore)	GBC-107	Western	Granite	Low relief	12-18.6
Canal Rocks (inshore)	GBC-109	Western	Granite	Low relief	6-9
Cowaramup Bay (inshore)	GBC-154	Western	Granite	Low relief	5.9-7.0
Cowaramup Bay (offshore)	GBC-155	Western	Granite	Low relief	14-18.8
Foul Bay (inshore)	GBC-246	Western	Granite	Low relief	8
Foul Bay (offshore)	GBC-247	Western	Limestone	High relief	6-9.7
Edith Rock (offshore)	GBC-350	Western	Granite	High relief	16-21.4
Peak Island	GBC-400	Western	Limestone	High relief	4.5-10.2
Hamelin Island	GBC-401	Western	Limestone	High relief	5-7.7
Cape Leeuwin (inshore)	GBC-290	Southern	Mixed predom. Limestone	Low relief	8-10.8
St Alouarn	GBC-303	Southern	Limestone	Low relief	10-13.8
Seal Island	GBC-333	Southern	Limestone	High relief	6-8.9

Table 2. The latitude and longitude for the 20 sites in the survey

Site number	Latitude	Longitude
GBC-043	33° 33.17’	115° 04.02’
GBC-046	33° 32.77’	115° 03.35’
GBC-051	33° 32.44’	115° 02.20’
GBC-059	33° 31.95’	115° 01.06’
GBC-061	33° 31.36’	115° 00.84’
GBC-077	33° 32.98’	115° 00.28’
GBC-079	33° 34.09’	114° 59.84’
GBC-106	33° 39.483’	115° 00.196’
GBC-107	33° 39.82’	114° 59.98’
GBC-109	33° 40.638’	114° 59.622’
GBC-154	33° 51.85’	114° 58.80’
GBC-155	33° 51.67’	114° 58.46’
GBC-246	34° 14.97’	115° 01.62’
GBC-247	34° 15.21’	115° 01.14’
GBC-290	34° 22.78’	115° 08.86’
GBC-303	34° 24.78’	115° 12.01’
GBC-333	34° 22.98’	115° 09.75’
GBC-350	34° 12.11’	114° 59.93’
GBC-400	34° 12.9792’	115° 01.1988’
GBC-401	34° 13.08’	115° 00.88’

4.2.2. Benthic Macroalgae

At each site, divers collected all macroalgae within randomly placed 0.25 m^2 quadrats. Six quadrats were sampled at each site with the exception of St. Alouarn Island and Sugarloaf where two and five quadrats were sampled, respectively. Sampling was stratified such that only quadrats, which fell on horizontal surfaces, were sampled. For encrusting algae only voucher specimens were collected because of difficulties removing the entire encrusting layer at some sites. Samples from each of the quadrats were placed in separate calico bags and brought to the surface.

Samples were sorted, and a species list compiled for each quadrat shortly after collection onboard *MV Voyager*. The density of canopy-forming species was determined (holdfasts 0.25 m^{-2}) before thalli were dried and weighed. This was done for both adults and juveniles of canopy species. Canopy species were dried for at least 72 hours at 60°C at the Botany Department, University of Western Australia before being weighed to 3 decimal places.

Samples of understorey algae were sorted to species then fixed in 5% formalin in seawater onboard *MV Voyager*. Voucher specimens were prepared for each species and are presently being accessioned into the Herbarium at Botany (UWA). A species list is included in Appendix A2, Table A2.2.

4.2.3. Sponges and Ascidians

At each survey site, six quadrats were recorded and sampled by the follow methods:

1. Before the dive at each sampling location, a video still of the clapperboard containing site information was taken.

2. Quadrat was placed *in situ* (depending on whether the sample location was high relief or low relief reef, the quadrats were placed vertically or horizontally, respectively).

3. A video record (approximately ten seconds) of the quadrat was made.

4. Close-ups of individual sessile invertebrates for identification purposes were recorded by digital video.

5. When video record was completed, voucher specimens were sampled and placed individually into a 250 ml specimen jar together with a label. The label would contain site and quadrat information.

6. After the dive, the water in the specimen jars was replaced with 100% ethanol for preservation.

7. An individual sample record sheet for each voucher was completed.

Identification to species

For sponges, preliminary identifications of voucher specimens were performed with Dr Jane Fromont, Curator of Aquatic Invertebrates, Western Australian Museum. In some cases, *in situ* photographs were used and spicule digests were performed when necessary. Specimens were tentatively identified to Family level.

Dr Laura Stocker (Murdoch University) identified the ascidians.

Species lists are included in Appendix A2, Table A2.3 & A2.4.

Measuring species abundance

Video frames of the quadrats and voucher specimens were captured off tape by the Iomega Buzz capture kit. These images were saved as Jpeg (*.jpg) files. EHP image analysis software was used to quantify the sponge community from the captured images. The software rectified the quadrat image and calculated area by tracing specimens. This data was then exported as an Excel spreadsheet for further analysis.

4.2.4. Reef fish

At each site, two teams of divers collected data on the abundance and lengths of all fish species present from a total of 24 transects. Two widths of transects were used to census the reef fish community at each site. At the start of the first transect, a weight attached to the end of a fibreglass tape was placed on the substrate with the dive buddy reeling out the tape behind the observer and indicating when the transect was completed.

On the first swim, the observer counted and estimated the lengths of all of the relatively large and more mobile reef fishes seen within a transect 25 m long by 5 m wide and 5 m high. Upon completion of the transect the observer would swim back along the transect investigating the crevices and overhangs within a 2 m wide strip searching for more cryptic species. No attempt was made to enumerate blennys or triplefin species. Once a large and small transect had been completed the buddy pair would move the tape measure at least 10 m away from the location of the weighted end of the transect and resume counting. In this manner, the transects formed the spokes of a wheel, never covering habitat already censused. Each buddy pair attempted to complete six replicate counts of both the large and the small transects to give a pooled level of replication of 12 transects per site.

The level of replication and transect dimensions was determined by a pilot study which aimed to optimise the survey design (Appendix A1). The pilot study indicated that for the 10 most dominant species, a survey precision of between 10% and 25% could be obtained with twelve 25 x 5 x 5 m transects. The level of replication and transect size was also constrained by diver safety. The pilot study showed that buddy pairs could complete only six 25 x 5 x 5 m transects or three 50 x 5 x 5 m transects at deeper sites and stay within the no decompression limits. A transect width of 5 metres was selected to account for variability in water clarity. This decision was justified with visibility falling to approximately 4 metres at two sites. Furthermore, a calibration study showed that the observers measurement error for distance estimates increased beyond 5 m. Because measurement error could potentially affect the size of areas censused, it strengthened the case for the selection of a 5 m transect width. No reef fish were collected for voucher specimens. A species list is included in Appendix A2, Table A2.1.

4.2.5. Statistical Analysis

Exploratory data analysis-Algae and fish

The SCAN module of PATN (Belbin, 1993) was used to calculate species richness (ie number of different species recorded at each site) and occurrence of each species, at each site for benthic macroalgae and fish.

For fish only, data collected from diver 1 was used (Dr Euan Harvey). Total mean abundance of fish at each site and of species across all sites was calculated. Overall mean abundance of fish was calculated by summing mean abundances for all species at each site.

Univariate analysis-Fish

Patterns in the numbers of fish observed along large and small transects were analysed separately using analysis of variance (ANOVA). A two-way ANOVA with factors site (random with 20 levels) and diver (random with two levels) was used. Data for the 20 most common fish species was the dependent variable for numbers of fish. Similar analyses were carried on species richness data. Species richness is defined here as the number of different species observed by each diver at a site. Cochrans test was used to test homogeneity of variance among sites.

Multivariate data analysis-Algae and sponges

Species presence/absence data for each site was imported into PATN in relational format (ie. only species presence data) for analysis. Relational format considerably reduced the size of the site x species array by omitting absence records. The DATN module in the PATN software package (Belbin, 1993) generates a site by species matrix from relational data. Spatial patterns in the occurrence of algae species and the % cover of sponges were examined using semi-strong hybrid multi-dimensional scaling (SSH module in PATN). Ordinations were based on a Bray-Curtis dissimilarity matrix and were generated in 3 dimensions.

Multivariate Analysis-Fish

Spatial patterns in the numbers of fish along large and small transects were examined using semi-strong hybrid multi-dimensional scaling (SSH module in PATN). Data used for this analysis was abundance of fish species (as a mean across six replicate transects). A similar analysis was carried out using total abundances of fish species belonging to several size classes.

Ordinations were based on Bray-Curtis dissimilarity matrices and were generated in three dimensions. The PCC module in PATN was used to evaluate which sites most strongly influence spatial patterns observed on the ordinations. Only data collected by diver 1 was used in these analyses.

ANOSIM-Marine algae

Differences in species composition of marine algae between regions, habitats and depths were analysed using multivariate analysis of similarities (ANOSIM). This analysis was carried out using the ANOSIM module in the PRIMER software package (Plymouth Marine Laboratories). Data for all quadrats from all sites, except the sites from the Northern Region (Eagle Bay, Rocky Bay and Bunker Bay), were used. Species only occurring once across all sites were also excluded. Using PRIMER, the ANOSIM analysis is limited by a site x species matrix of up to 125 samples. The analysis was based on a Bray-Curtis similarity matrix constructed from 4th root transformed data. Clarkes R and significant probabilities were determined from 5000 random permutations. Significant probabilities were corrected for the number of one way ANOSIMs performed using the Bonferroni correction. We did this by dividing the significant probabilities, <0.05, <0.01 and <0.001 by the number of tests performed which was equal to 4.

Single one-way ANOSIMs were used to address five hypotheses:

> ***Hypothesis 1:*** Is there a significant difference in assemblages of macroalgae between shallow (<10 m) and deep (10 –20 m) granite reefs.
>
> ***Hypothesis 2:*** Is there a significant difference in assemblages of macroalgae between shallow limestone and shallow granite reefs.
>
> ***Hypothesis 3:*** Is there a significant difference in assemblages of macroalgae between low and high relief granite reefs at deep sites (10-20 m).
>
> ***Hypothesis 4:*** Is there a significant difference in assemblages of macroalgae between low and high relief limestone reefs at shallow sites (<10 m).
>
> ***Hypothesis 5:*** Is there a significant difference in assemblages of macroalgae between low and high relief granite reefs at shallow sites (<10 m).

No ANOSIM analysis was conducted on fish and sponge data due to restrictions on the size of arrays which can be analysed using PRIMER and the methodological difficulties encountered with the fish and sponge analyses.

SIMPER-Marine Algae and Sponges.

Following ANOSIM, a SIMPER analysis was performed to determine what species of macroalgae were responsible for significant differences in assemblages. SIMPER is a shortened name for percentage similarity of assemblages within a category (reef type, depth or relief) versus between categories. SIMPER was also used to determine those sponge taxa that influenced similarities between survey sites.

4.3 RESULTS

4.3.1. Marine Algae

Exploratory data analysis

The most algal species were recorded at Foul Bay inshore, Bunker Bay and Canal Rocks inshore (Figure 2). Between 40 and 50 species of macroalgae were identified at each of these sites. These sites were characterised by granite substrata, shallow depths and lacked a high-biomass canopy of the kelp *Ecklonia radiata*. The canopy in these areas was generally mainly fucalean brown algae, either *Cystophora* spp or *Platythalia spp*. A kelp canopy was also not present at Eagle Bay and Rocky Bay. Kelp was found in at least one quadrat at all other sites. Windmills and Hamelin Island were the only sites where less than 20 algal species were recorded. Approximately 75.5% of algal species occurred at five or less locations during the survey.

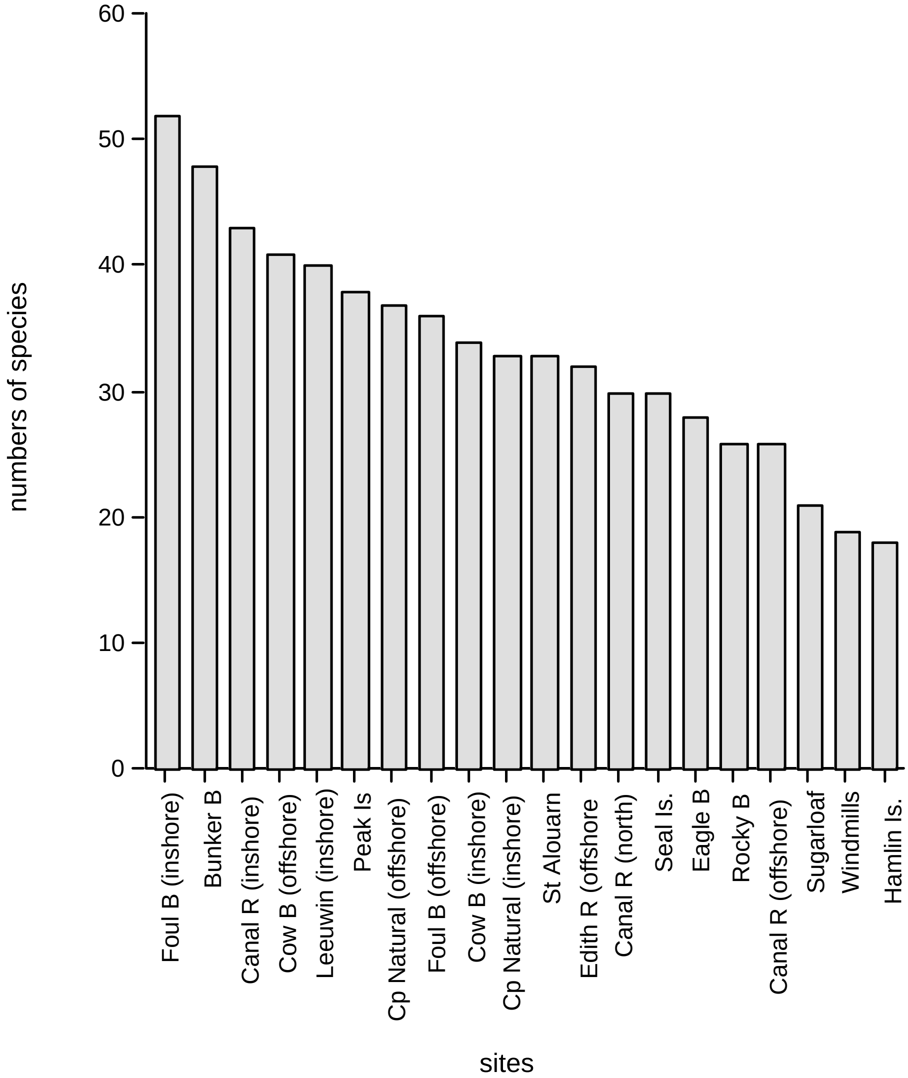

Figure 2. Numbers of taxa of marine algae recorded at 20 sites between Geographe Bay and Flinders Bay in south Western Australia.

Six taxa occurred at least 15 locations (Figure 3). Of these, three were coralline algae (Corallinales, Rhodophyta). The numbers of taxa represented by the crustose coralline group is not know, however as many as twelve species were identified beneath kelp understorey at Rottnest Island (Sim and Townsend 1999).

Of the 20 most commonly occurring species, six were coralline algae (Crustose corallines, *Halipilon roseum, Amphiroa anceps, Metamastophora flabellata, Metagoniolithon radiatum, Jania pulchella, Rhodopeltus australis*, Figure 3). Other abundant species included *Zonaria turneriana* and *Lobophora varians* (Phaeophyta). Juveniles of *Scytothalia dorycarpa* and *Ecklonia radiata* were also common components of the understorey (Figure 3).

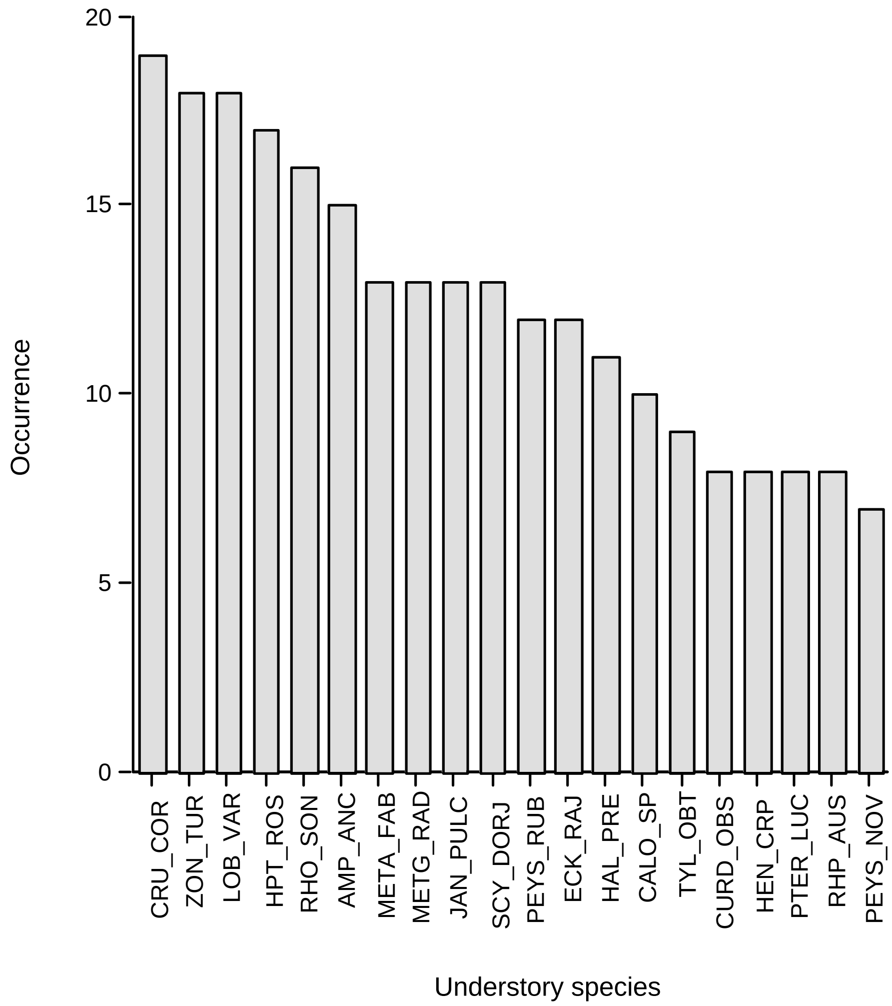

Figure 3 Occurrence of the 20 most common understorey species of marine algae recorded at 20 sites between Geographe Bay and Flinders Bay in south Western Australia.

Ecklonia radiata and *Scytothalia dorycarpa* were the only canopy-forming species, which occurred at greater than 50% of the survey sites (Figure 4). Other common canopy species were *Platythalia angustifolia* and *Cystophora racemosa*. Most canopy-forming species occurred infrequently (<25% of locations, Figure 4) often in mixed species canopies.

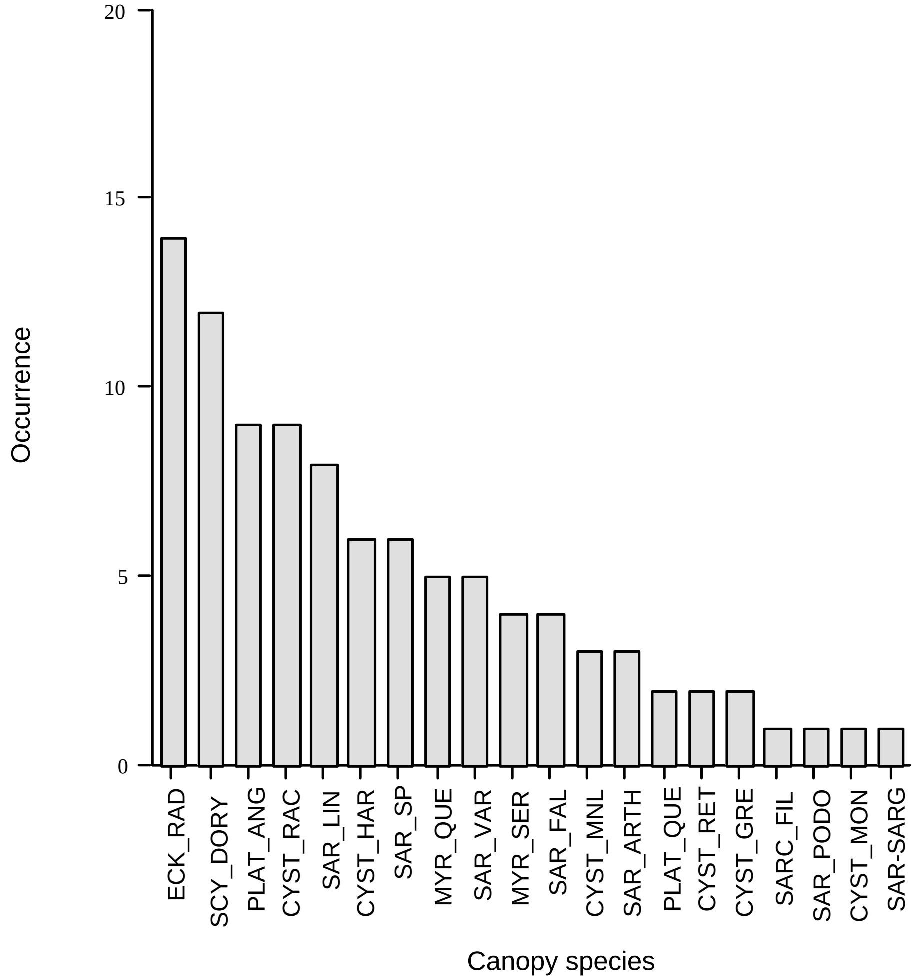

Figure 4. Occurrence of the 20 most common canopy-forming species of marine algae recorded at 20 sites between Geographe Bay and Flinders Bay in south Western Australia.

Multivariate analysis

The ordination of algal species presence/absence showed regional differences in the composition of algal assemblages (Figure 5). Three shallow inshore sites north of Cape Naturaliste (Eagle Bay, Bunker Bay and Rocky Bay) were dissimilar to the remaining 17 sites. The strength of this pattern is reflected in a low stress value of 0.109. Similarities among these three northern sites included the absence of a canopy of *Ecklonia radiata* and unique suites of species that drive the observed patterns. Spatial relationships among the remaining 17 sites on the ordination space did not clearly separate on habitat, reef morphology or depth of the sites (Figure 5). This indicates some homogeneity in the composition of algal assemblages in the study region, or that factors other than those measured here influence the composition of algal assemblages.

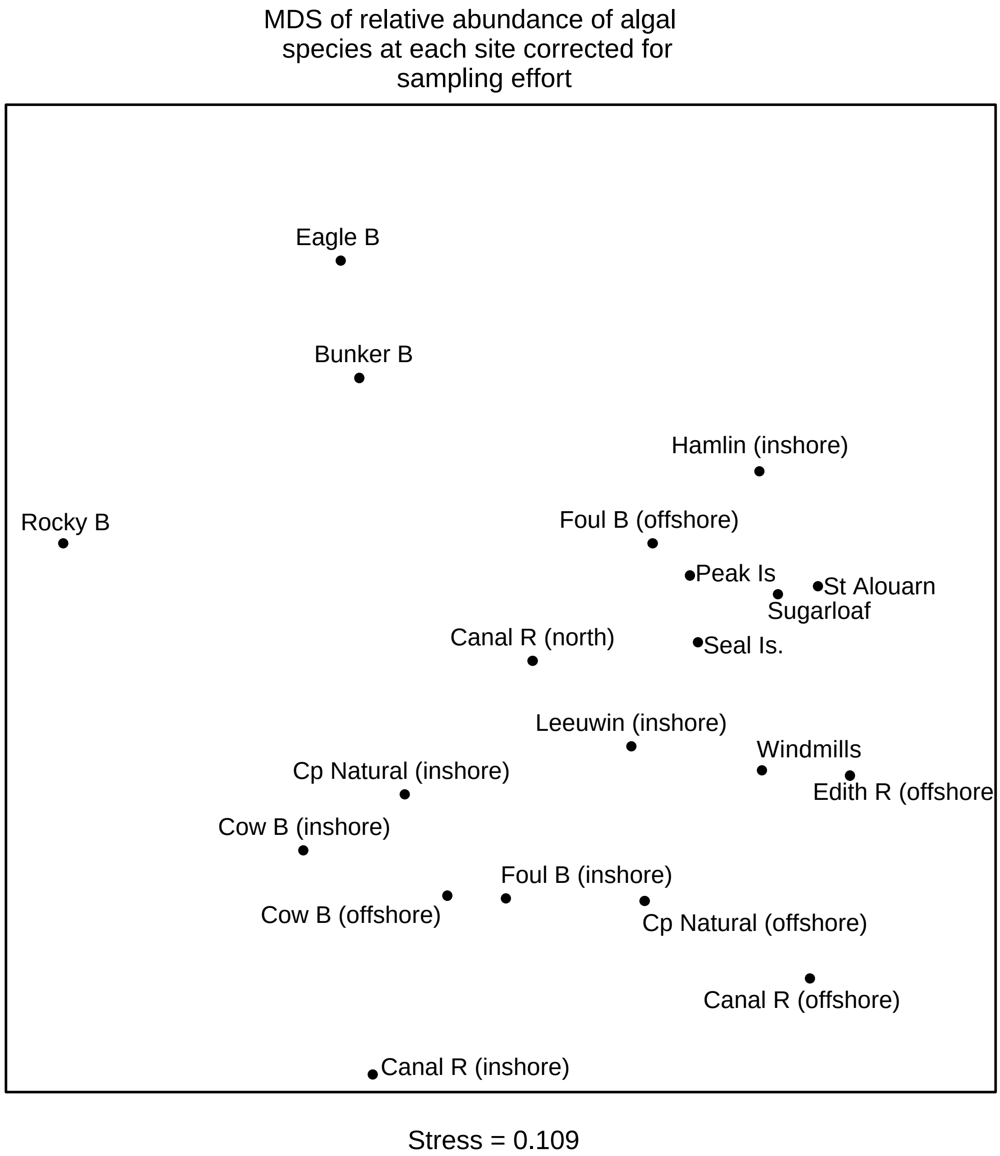

Figure 5. Ordination of 20 sites between Geographe Bay and Flinders Bay in south Western Australia based on mean abundance of 154 algae taxa.

The results of one way ANOSIMs used to test Hypotheses 1 to 5 are shown in Table 3. There were significant differences in macroalgae assemblages between shallow and deep granite (Hypothesis 1) and limestone and granite reefs in shallow waters (Hypothesis 2). Whether a reef was high (>2 m) or low (< 2 m) relief apparently did not significantly influence structure of macroalgae assemblages on deep granite (Hypothesis 3) and shallow limestone (Hypothesis 4) reefs.

The low numbers of reefs sampled influenced this outcome and our application of a Bonferroni Correction to significant probabilities because we resampled our data for each of the one way ANOSIMs and so incurred an experiment-wise error rate. Most shallow granite reefs were low relief boulder fields, and the effect of relief was not able to be tested (Hypothesis 5).

Table 3. Results of one way ANOSIMs testing influence of reef type (limestone, granite), depth (<10 m, 10 – 20 m) and relief (>2 m, <2 m) on macroalgae assemblages. Bonferroni correction applied to p values. * = <0.0125 (<0.05), ** = 0.0025 (<0.01), * = 0.00025 (<0.001).**

HABITAT	Clarkes R	p value	significance
Granite Shallow vs Deep	0.476	0	***
Shallow Limestone vs Granite	0.458	0	***
Relief (Deep Granite) Low vs High Relief	0.101	0.031	Not Significant
Relief (Shallow Limestone) Low vs High Relief	0.288	0.020	Not Significant
Relief (Deep Granite) Low vs High Relief	Data incomplete		

A SIMPER analysis indicated that for deep granite and shallow limestone reefs, few species characterised algal assemblages whereas for shallow granite reefs many species and high species turnover characterised alga assemblages. For deep granite reefs, the canopy brown algae, *Ecklonia radiata* and *Scytothalia dorycarpa* and the understorey red alga *Rhodopeltis australis* characterised the algal assemblage. For shallow limestone reefs, the canopy brown algae, *Ecklonia radiata* and the understorey coralline algae *Amphiroa anceps* and *Jania pulchella* and other red algae *Callophillis* sp. and *Pterocladia lucida* characterised the algae assemblage. For shallow granite reefs, many species equally characterise the algal assemblage. The main canopy brown algae were *Cystophora harveyii*, *C. racemosa*, *Platythalia angustifolia* and *Sargassum varians.*

4.3.2. Sponges and Ascidians

Multivariate analysis

Little clear pattern between the location of survey sites and their distribution on the non-metric MDS indicating species turnover was high between sites, even when they were juxtaposed. SIMPER analyses indicated little similarity between sites within geographical regions, on granite versus limestone reef, and shallow (<10 m) versus deep sites (10-20 m). Sites seemed to be as different within any of these strata as between strata. There was also high species turnover between replicates within sites, and sites were characterised by many species with equally small percentage contributions. Species that were influential were *Clathrina sp1*, *Mycale sp1* and *Echinoclathria.*

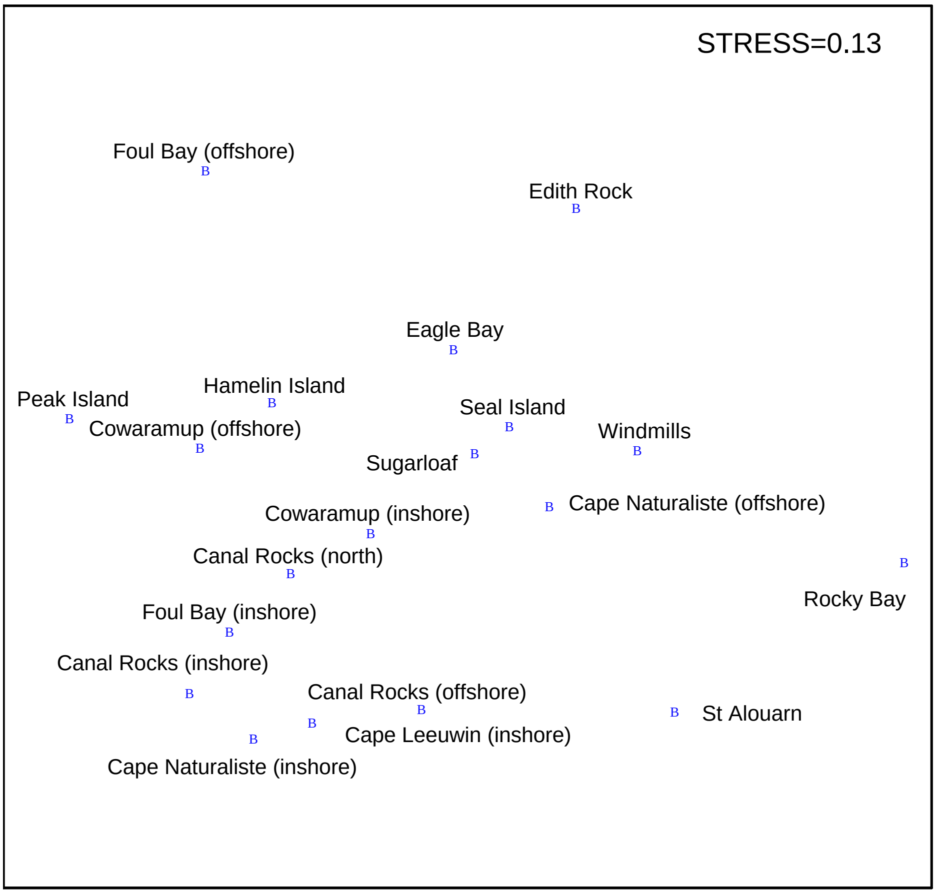

Figure 6. Ordination of 19 sites between Geographe Bay and Flinders Bay in south Western Australia based on mean abundance of sponge species.

4.3.3. Fish

Univariate analysis

Mean fish density per transect for the 20 sites were low for both observers with between two and 3.5 fish observed per transect for large transects and 0.1 to 1.2 fish per transect for small transects. Diver 1 recorded greater numbers of fish on large and small transects compared to diver 2 (Figure 7) suggesting differences in counting fish between observers *in situ* was larger than observed differences between sites.

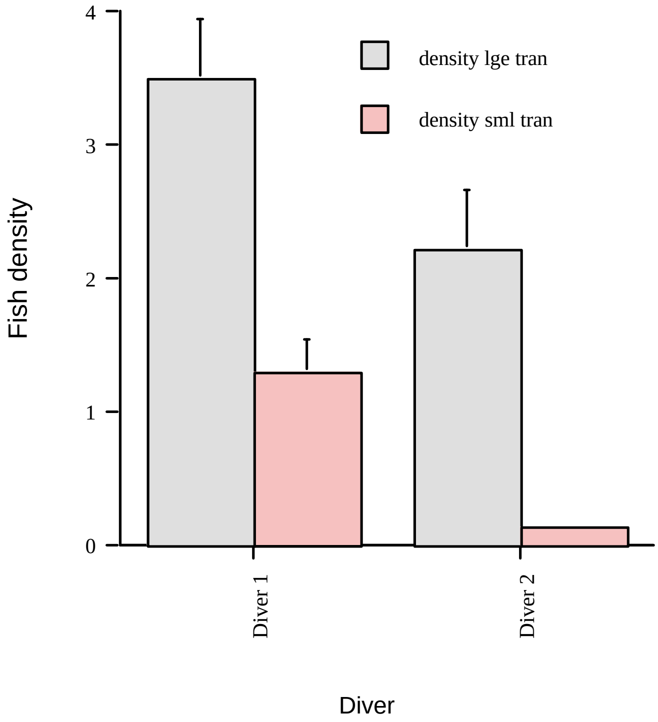

Figure 7. Mean relative abundance of fish recorded at 20 sites between Geographe Bay and Flinders Bay, by two observers on SCUBA along large and small transects.

The mean number of fish species recorded at sites varied from two to six species between large and small transects and between divers. The mean number of fish species recorded in small transects at sites was significantly different between sites, between divers and the interaction between sites and divers (Table 4). ANOVAs for fish densities for both small and large transects and species richness for large transects were not done because of heterogeneous variances even after transformation. Diver 1 recorded on average two more species of fish for both large and small transects (Figure 8). Similarly two more species per site was recorded in large versus small transects for both divers.

Diver bias influenced both mean numbers of fish and species richness observed during the survey. For this reason all multivariate analyses were carried out only on diver 1.

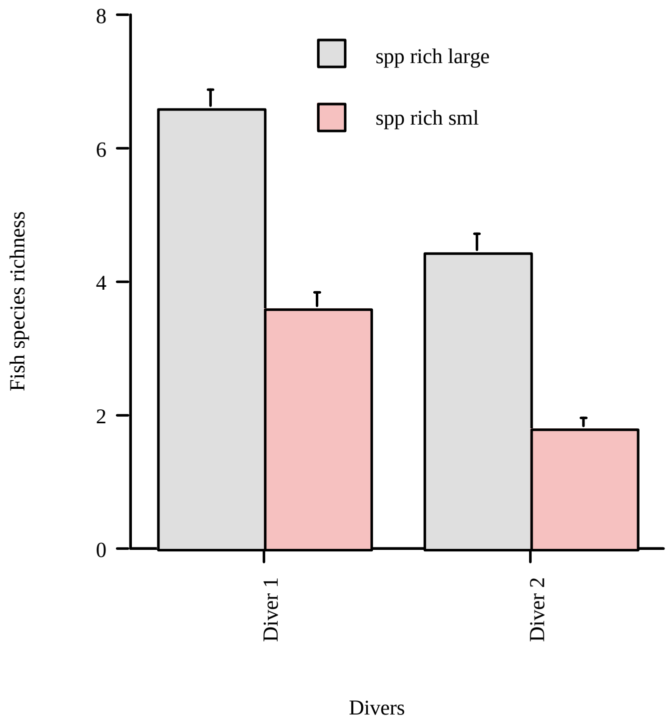

Figure 8. Mean number of fish species recorded at 20 sites between Geographe Bay and Flinders Bay by two observers on SCUBA along large and small transects.

Table 4. Summary for analysis of variance of species richness along small transects. Data log (x+1) transformed.

Source	DF	Mean Squares	*F*-value	*p*-value
Site	19	0.355	2.872	0.0132
Diver	1	3.536	28.59	0.0001
Site x Diver	19	0.124	2.800	0.0002
Error	190	0.044		

Exploratory data analysis

The most fish species were recorded along large transects at exposed offshore sites during the survey (Figure 9). Between 24 and 31 species were recorded at Seal Island, Sugarloaf Rock, Cape Naturaliste (offshore) and Canal Rocks (offshore). Species richness was relatively even across the remaining sites with numbers of species varying between 21 and 12 (Figure 9). Cape Naturaliste and Windmills, both low relief granite sites contained fewest species along large transects.

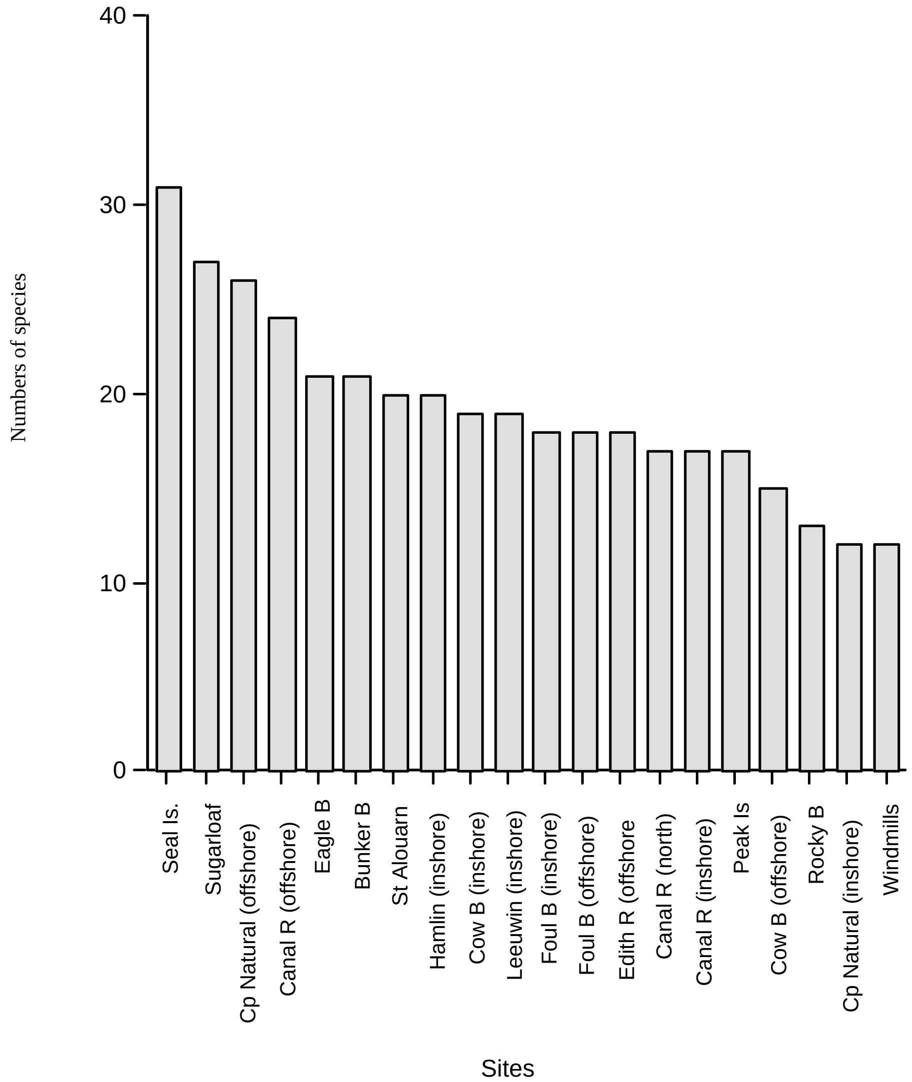

Figure 9. Numbers of species of fish recorded along large transects at 20 sites between Geographe Bay and Flinders Bay in south Western Australia by diver 1.

Patterns of overall mean abundance of fish differed from those for species richness. Most fish were recorded at Peak Island (Figure 10). The relative abundance of fish at each site differed, with few sites sharing similar relative abundance values. The lowest numbers of fish were recorded from the northern shore at Rocky Bay and Cape Naturaliste inshore (Figure 10).

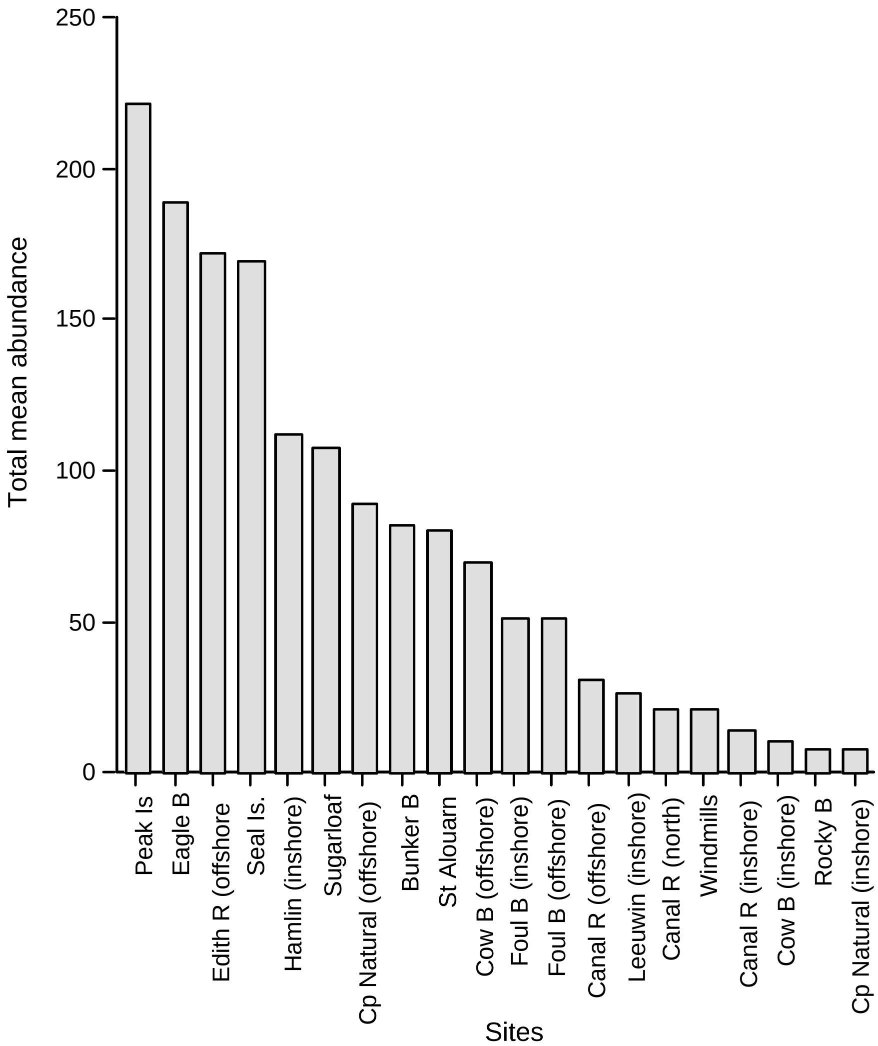

Figure 10. Relative abundance of fish recorded along large transects at 20 sites between Geographe Bay and Flinders Bay in south Western Australia by diver 1. Y-axis values were calculated by summing mean abundances for all fish species at each site.

Three species of fish were considerably more abundant than the other 79 species of fish recorded along large transects (Figure 11). Black headed puller (*Chromis klunzingeri*), Blue lined Hulafish (*Trachinops brauni)* and Noarlunga Hulafish (*T. noarlungae)* were the most common species with total abundances being an order of magnitude greater than most other species (Figure 11). All three species occur in schools.

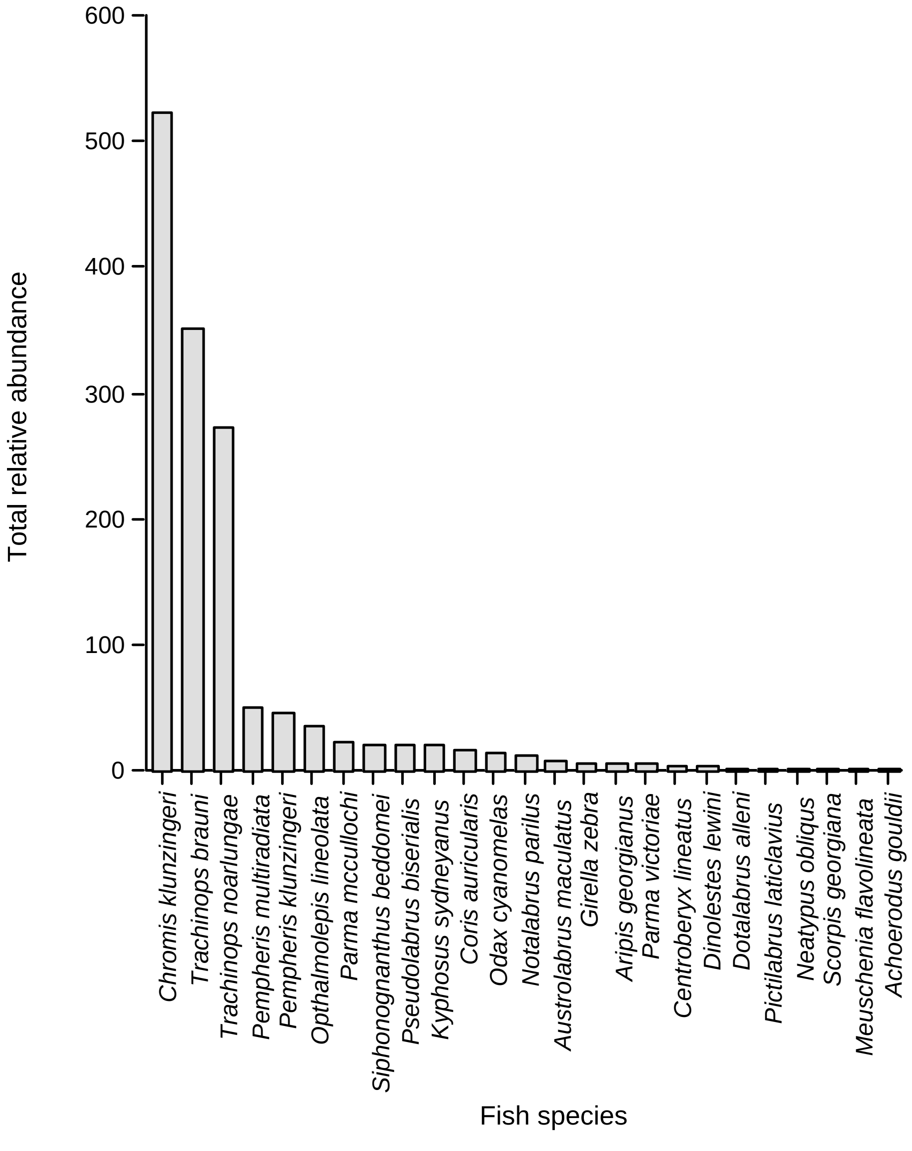

Figure 11. Relative abundance of the twenty most common fish species recorded along large transects at 20 sites between Geographe Bay and Flinders Bay in south Western Australia by diver 1. Y-axis values were calculated by summing mean abundances for each fish species across all sites.

Multivariate analysis

Mean abundance of fish along large transects

Rocky Bay was excluded from the ordination of fish abundance along large transects recorded by diver 1. Low abundances of fish at that site strongly influenced patterns among the remaining 19 sites.

Sites characterised by high relief reefs were generally plotted with high y-vector values in the ordination space (Figure 12). No other clustering relating to geographical location, reef type, relief or depth was reflected in the ordination.

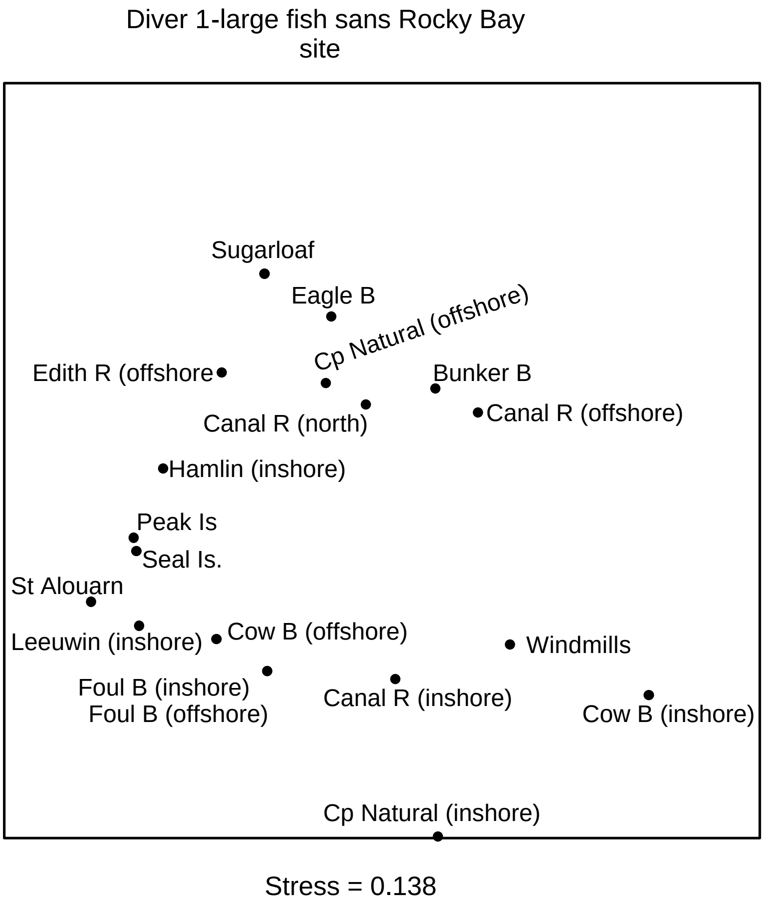

Figure 12. Ordination of relative abundance of fish species recorded along large transects at 19 sites between Geographe Bay and Flinders Bay in south Western Australia by diver 1.

Mean abundance of fish along small transects

The ordination of fish abundance recorded by diver 1 along small transects shows no clustering relating to geographical location, reef type, relief or depth was reflected in the ordination (Figure 13). Two Canal Rocks sites are separated from the main cluster of sites.

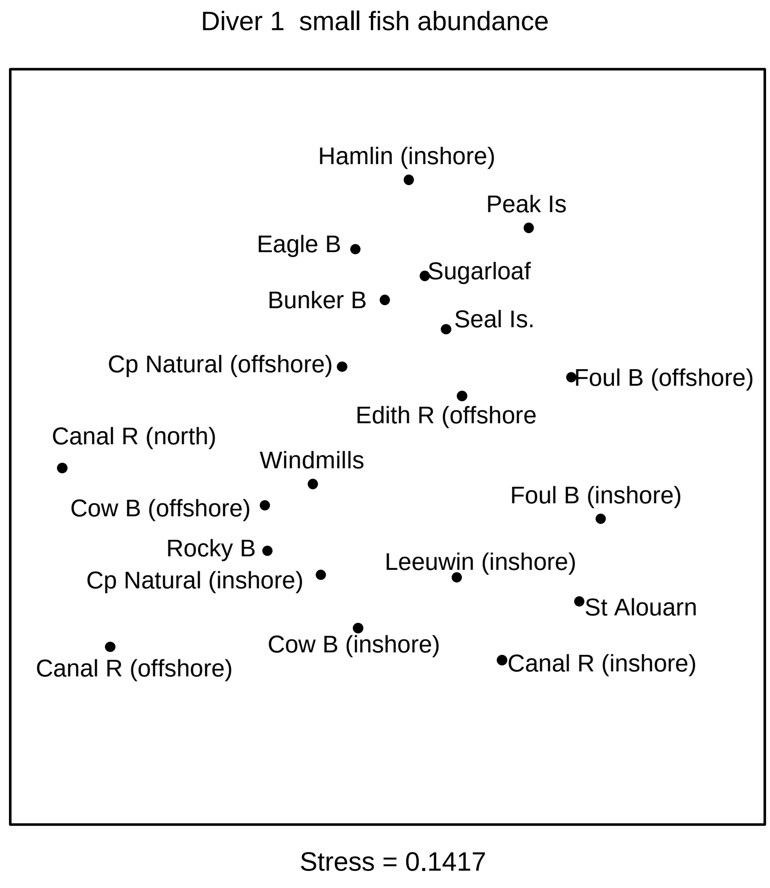

Figure 13. Ordination of relative abundance of fish species recorded along small transects at 20 sites between Geographe Bay and Flinders Bay in south Western Australia by diver 1.

<u>Fish length</u>

The ordination of estimated fish length data collected by diver 1 along large transects shows that Foul Bay inshore and Cape Leeuwin inshore sites were most dissimilar to other sites (Figure 14). Canal Rocks north was also dissimilar from the majority of sites. These sites have relatively low overall fish abundance. Spatial patterns were strongly influenced by seven species (using PCC module in PATN).

Blackhead Pullers 2-4 cm and 4-6 cm were recorded 1799 and 903 times respectively. Other species which strongly influenced patterns included Footballer Sweep 6-8 cm, Maori Wrasse 12-14 cm, McCulloch's Scalyfin 20-25 cm Pencil Whiting 6-8 cm, Victorian Scalyfin 18-20 cm and Zebra Fish 16-18 cm. These species ranged in abundance between 7 and 91 individuals and were found at 4-13 sites.

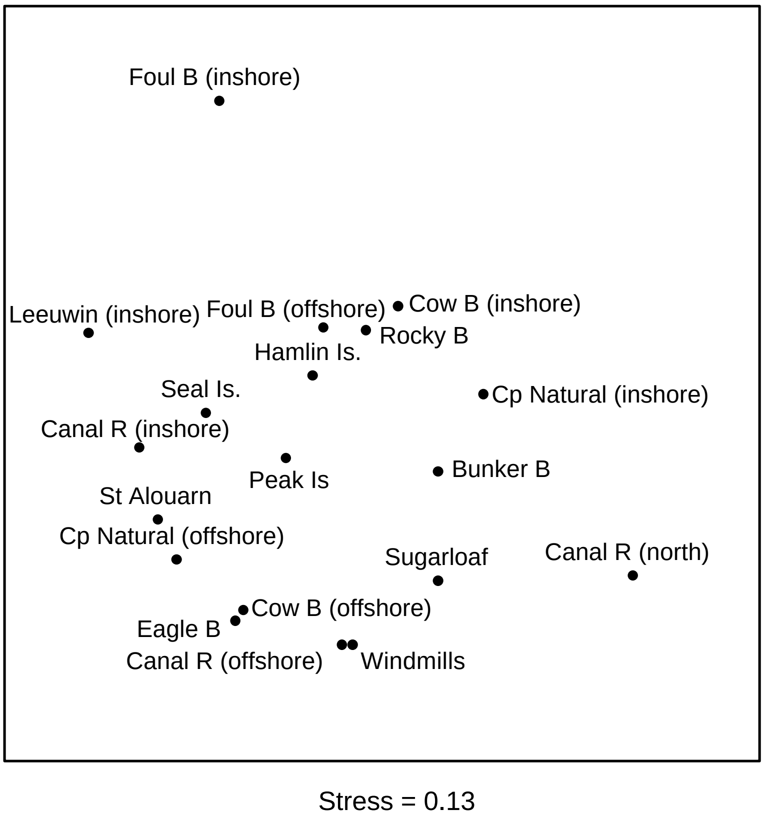

Figure 14. Ordination of length data for fish species recorded at 19 sites between Geographe Bay and Flinders Bay in south Western Australia by diver 1. Edith Rock site was omitted due to missing data.

4.4 DISCUSSION AND OUTCOMES

4.4.1. Algae

Assemblages of marine algae varied across the study region and were significantly different among regions, between granite and limestone reefs and between depths <10 m and 10-20 m. Regional differences were observed between sites on the northern shore of Cape Naturaliste and the western and southern regions of the survey area. This probably reflects different wave exposure regimes, as the northern shore is well protected against prevailing western and southern winds and ocean swells.

Assemblages of marine algae in the study area were species rich with 154 species recorded from the survey. Many species were rare and were surveyed infrequently. Only six algae occurred at >15 survey sites. Approximately 75% of the total species recorded occurred at less than five sites. The most species rich sites did not have kelp canopies. Similarly, from Marmion Marine Park, eighty two taxa of red, brown and green algae were found associated with *Ecklonia radiata* kelp (Phillips *et al*., 1997). Many of these taxa were rare and only 18 occurred in >10% of samples and 13 taxa in 5-10%.

Algal assemblages on granite reef and boulder fields have not previously been characterised in temperate Western Australia. There was a significant difference in algal assemblages on deeper granite reefs offshore versus shallow onshore reefs and boulder fields. The kelp, *Ecklonia radiata* and the large brown alga, *Scytothalia dorycarpa* were the dominant canopy on deeper granite reefs, and occurred in similar biomass. The understorey under these canopies were depauperate, with most smaller foliose and filamentous algae occurring in patches in the canopy. The foliose red algae *Dictymenia sonderi* and the bladed brown alga, *Lobophora variegat*a occurred in patches with little or no kelp canopies. Similarly, in Marmion Marine Park, these species are common in kelp forests in clearings in the canopy and when kelp densities are less than 8 thalli m^{-2} (Kendrick *et al*., 1999).

Shallow granite reef and boulder fields were characterised by species rich canopies of the kelp *Ecklonia radiata* and species of *Sargassum*, *Cystophora*, *Platythalia* and *Scytothalia* and other large brown algae (Womersley, 1987). Understorey assemblages were also more diverse, with high species turnover between replicate quadrats within sites. Similarly, more protected onshore reefs in Marmion Marine Park, near Perth, Western Australia have less biomass of kelp and more diverse assemblages of algae and sessile invertebrates than offshore reefs (Hatcher, 1989).

Limestone reefs had similar dominant understorey species to those observed in Marmion Marine Park, near Perth Western Australia (Phillips *et al*., 1997, Kendrick *et a*l., 1999). *Amphiroa anceps*, *Jania pulchella*, *Callophillis* sp. and *Pterocladia lucida* are abundant understorey species under kelp dominated limestone reefs in the southwest of the study region, from near Hamelin Bay to Augusta. The taxa, *Amphiroa anceps*, *Jania* sp. and *Pterocladia lucida* also characterise understorey species in kelp forests on limestone reefs in Marmion Marine Park (Phillips *et al.*, 1997). The algal assemblages in the study region show similar patterns of species distribution and species turnover with exposure to oceanic swells, to the Marmion Marine Park, near Perth, Western Australia. At Marmion, *Amphiroa anceps* and *Pterocladia lucida* are more common on reefs with medium to high exposure to ocean swells (Kendrick *et al*., 1999).

4.4.2. Sponges and Ascidians

Sponges and ascidians were diverse components of the sessile benthos. They were undersampled in this survey, but show some pattern, suggesting that more research effort should be expended on these groups. Observer bias can be removed through adequate photography and careful sampling of specimens. The present survey had only a single diver collecting sponges and ascidians for most of the sites. Further surveys should include a team of sponge and ascidian researchers.

4.4.3. Reef Fish

Regional spatial patterns of fish abundance and size were not observed during this survey, although offshore sites showed the highest species richness. Species richness at each site ranged from 12-32 species. More species were observed offshore than onshore sites. The most numbers fish along large transects were recorded at Peak Island and the fewest at Cape Naturaliste. A small number of fish species occurred in densities 1-2 orders of magnitude greater than most other species. Some of these species were important in influencing patterns observed on ordinations.

The visual estimation technique is not suitable for biodiversity surveys of this kind. Abundances and species richness of fish were significantly influenced by recorder bias. Future surveys should have less effort expended on fish.

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4.6 APPENDIX A

Appendix A1. Diver calibration for fish survey

INTRODUCTION

Accurate and precise data on the length and abundance of reef fishes is difficult to obtain due to the fishes occupying different habitats and displaying varying behaviour over a range of spatial and temporal scales. Environmental surveys commonly determine the abundance and length frequency of reef fish assemblages using SCUBA divers to count and visually estimate the length of individual reef fish (Jones and Chase, 1975; Harmelin-Vivien and Bouchon-Navaro, 1981; Russ, 1985; Bellwood and Alcala, 1988; Kulibicki, 1989; Samoilys, 1989; Francour, 1991). Visual census techniques have many advantages compared to other sampling techniques, in that they are quantitative, quick, non-destructive and repeatable (English *et al*., 1994). The disadvantages are that the observers undertaking the sampling need to be trained and must have experience to identify, count and estimate the length of reef fish, ad the distance to them accurately (English *et al*., 1994; Harvey and Shortis, 1996; Harvey *et al*. 1999a; 1999b; 1999c).

The level of precision and accuracy associated with visual estimates of length and distance will influence comparisons of data over different temporal or spatial scales in two distinct ways. Firstly, bias in the estimates will make the results of the analysis less reliable. Secondly, any lack of precision in the estimates arising from both sampling error and measurement error will tend to reduce the power of the statistical analysis.

Errors in distance estimates are of great concern as they have the potential to greatly affect the spatial and temporal comparisons of abundance estimates. The majority of researchers do not physically mark the boundary of their sample unit due to time constraints. Therefore observers need to estimate the distance to each fish, in order to decide whether it is inside the sample unit. Harvey *et al.* (1999c) demonstrate that the magnitude of error for estimates of distance made by experienced and novice observers can be substantial. This error may potentially result in an 82% underestimate, or 194% overestimate of the actual area censused by experienced observers and will affect the abundance of fish counted.

Even though calibration procedures are recommended and used by some researchers (GBRMPA, 1979; Bell *et al*., 1985; Polunin and Roberts, 1993; Darwall and Dulvy, 1996), inter-diver variability and diver measurement error may still invalidate comparisons of the changes in the mean length between sites and over time. Consequently, it is important that the level of precision and accuracy of length estimates is stated in reports and publications, and that measurement error is minimised to allow realistic interpretation of the data and comparisons of assemblages or individual species.

Prior to departing on the field survey, the two observers spent one day (19/1/99) undertaking calibrations for fish length and distance.

METHOD

LENGTH ESTIMATES

Seventeen model fish were attached to a weighted 50 m rope which was draped out over the surface of the sea bed. The two observers swam up and down the transect estimating the length of each model as it was encountered. The transect was then shifted to another location where the observers repeated the process. Between dives the vessel operator assisted the observers by determining the level of error so that the observers could correct themselves.

DISTANCE ESTIMATES

The two observers would simply pick a visible feature and estimate the distance to it. The real distance was then measured with a fibreglass tape measure.

RESULTS

LENGTH ESTIMATES

Tables A1 and A2 show the improvement in length estimates with each trial. These trials should be probably repeated during a survey as a cross-check.

Table A1. Error in length estimates for observer 1.

	Trial 1	Trail 2	Trail 3	Trail 4
Mean (cm)	4.40	3.88	-0.94	-1.39
Std dev (cm)	9.20	5.84	5.67	4.45
Standard error (cm)	2.38	1.42	1.42	1.05
Sample size (cm)	15	17	16	18

Table A2. Error in length estimates for observer 2.

	Trial 1	Trial 2	Trial 3
Mean (cm)	2.09	-2.69	-0.63
Std dev (cm)	5.54	3.30	3.65
Standard error (cm)	1.67	0.92	0.84
Sample size (cm)	11	13	19

The accuracy and precision of estimation of distance underwater are shown in Table A3.

Table A3: Distance accuracy and precision for diver 1 and diver 2.

Observer	1	2
Mean (m)	0.27	-0.04
Std dev (m)	0.48	0.40
Standard error (m)	0.11	0.09
Sample size (m)	19	19

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Appendix A2. Species lists

Table A2.1 Fish of the Geographe Bay-Capes-Hardy Inlet region, WA Australia

Species of fish observed during survey and identified by Dr Euan Harvey, Dept. of Botany, The University of Western Australia.

Species	Common name
Acanthaluteres spilomelanurus	Bridled Leatherjacket
Acanthistius pardalotus	Western Leopard
Achoerodus gouldii	Western blue Groper
Anoplocapros amygdaloides	Western smooth Boxfish
Anoplocapros lenticularis	White barred Boxfish
Aplodactylus westralis	Western sea Carp
Apogon ruepellii	Gobbleguts
Apogon victoriae	Red striped Cardinal fish
Aracana aurita	Shaw's Cowfish
Aracana ornata	Ornate Cowfish
Arothron hisipidus	Stars and stripes Toadfish
Arripis georgianus	Tommy ruff
Aulopus purpurissatus	Sargeant Baker
Austrolabrus maculatus	Black spotted Wrasse
Bigener brownii	Spiny Tailed Leatherjacket
Bodianus frenchi	Western Foxfish
Brachaluteres jacksonia	Pygmy Leatherjacket
Centroberyx lineatus	Swallowtail
Cheilodactylus rubrolabiatus	Red lipped Morwong
Cheilodactylus gibbosus	Western crested Morwong
Cheilodactylus nigripes	Magpie Perch
Chelmonops curiosus	Western Talma
Chromis klunzingeri	Black Headed Puller
Chrysophrys auratus	Snapper
Contusus brevicaudus	Prickly Toadfish
Coris auricularis	Western King Wrasse
Dactylophora nigricans	Dusky Morwong
Dasyatis brevicaudata	Smooth Stingray
Dasyatis thetidis	Black Stingray
Dinolestes lewini	Long finned pike
Diodon nicthemerus	Globe fish
Dotalabrus alleni	Little rainbow Wrasse
Dotalabrus aurantiacus	Pretty polly Wrasse
Enoplosus armatus	Old Wife
Epenephelus rivulatus	Chinaman cod
Epinephelides armatus	Breaksea cod
Eubalichthys bucephalus	Black Reef Leatherjacket
Eubalichthys mosaicus	Mosaic Leatherjacket
Eupetrichthys angustipes	Snakeskin Wrasse
Gerres subfasciatus	Roach
Girella tephraeops	Western rock Blackfish
Girella zebra	Zebra fish
Glaucosoma hebracium	Jewfish
Halichoeres brownfieldi	Brownfields Wrasse
Heterodontus portusjackson	Port Jackson shark
Kyphosus cornelii	Western Buffalo Bream
Kyphosus sydneyanus	Silver Drummer
Lotella rhacinus	Beardie
Meuschenia flavolineata	Yellow striped Leatherjacket

Species	Common name
Meuschenia freycineti	Six spined Leatherjacket
Meuschenia galii	Blue lined Leatherjacket
Meuschenia hippocrepis	Horseshoe Leatherjacket
Microcanthus strigatus	Stripey
Myliobatis australis	Eagle ray
Neatypus obliquus	Footballer Sweep
Nelusetta ayraudi	Chinaman Leatherjacket
Nemadactylus valenciennes	Queen Snapper
Neoodax balteatus	Little weed Whiting
Notalabrus parilus	Brown spotted Wrasse
Odax acroptilus	Rainbow fish
Odax cyanomelas	Herring Cale
Omegophora armilla	Ringed Toadfish
Omegophora cyanopunctata	Blue spotted Toadfish
Ophthalmolepis lineolata	Maori Wrasse
Orectolobus maculatus	Spotted Wobbegong
Orectolobus sp	Western wobbegong
Othos dentex	Harlequin fish
Paraplesiops meleagris	Western Blue devil
Parascyllium variolatum	Varied Catshark
Parequula melbournensis	Silverbelly
Parma mccullochi	McCulloch's Scalyfin
Parma occidentalis	Western Scalyfin
Parma victoriae	Victorian Sclayfin
Parupeneus signatus	Black spotted Goatfish
Pelates sexlineatus	Striped Trumpeter
Pelsartia humeralis	Sea Trumpeter
Pempheris klunzingeri	Rough Bullseye
Pempheris multiradiata	Common Bullseye
Penicipelta vittiger	Toothbrush Leatherjacket
Pictilabrus laticlavius	Senator Wrasse
Pictilabrus sp.	False senator Wrasse
Plectorinchus flavomaculatus	Gold spotted sweetlips
Pseudocaranx dentex	Skipjack Trevally
Pseudocaranx wrighti	Sand Trevally
PseuDOLAbrus biserialis	Red banded Wrasse
Pseudophycis barbata	Bearded Cod
Rhabdosargus sarba	Tarwhine
Sallaginoides punctata	King George Whiting
Schuettea woodwardi	Woodwards Pomfret
Scobinichthys granulatus	Rough Leatherjacket
Scorpis aequipinnis	Sea Sweep
Scorpis georgiana	Banded Sweep
Sillago maculata	Trumpter Whiting
Siphonognathus beddomei	Pencil Weed Whiting
Siphonognathus caninus	Sharp nosed Whiting
Sphyraena obtusata	Striped sea pike
Tilodon sexfasciatum	Moonlighter
Torquener pleurogramma	Banded Toadfish
Trachichthys australis	Roughy
Trachinops brauni	Blue lined Hulafish
Trachinops noarlungae	Noarlunga Hulafish
Trachurus declivis	Jack Mackerel
Trachurus novaezelandiae	Yellowtail Mackerel
Trygonoptera mucosa	Western Stingaree
Trygonoptera ovalis	Striped Stingaree
Trygonoptera personata	Masked Stingaree
Upeneichthys lineatus	Blue lined Goatfish
Upeneichthys vlamingii	Blue spotted Goatfish
Urolophus circularis	Circular Stingaree
Urolophus paucimaculatus	Sparsely spotted Stingaree

Table A2.2 Algae and seagrasses of the Geographe Bay-Capes-Hardy Inlet region, WA Australia

Species of algae and seagrasses identified by:
Dr John Huisman (Murdoch University) and Dr Gary Kendrick (University of Western Australia).

Species	Species
Acanthophora dendroides	*Acrocarpa robusta*
Acrocarpa sp	*Adelophyton sp*
Amphibolis griffthii	*Amphiroa anceps*
Amphiroa gracilis	*Antithamnion hanowioides*
Apjohnia laetevirens	*Areschougia sp*
Aserococcus bullosus	*Botryocladia sonderi*
Callophycus harveyanus	*Callophycus oppositifolius*
Callophycus sp	*Callophyllus sp*
Carpopeltis elata	*Carpopeltis sp*
Carpopeltis spongeaplexus	*Caulerpa brownii*
Caulerpa flexilis	*Caulerpa germinata*
Caulerpa hedleyi	*Caulerpa longifolia*
Caulerpa obscura	*Caulerpa simpliciuscula*
Ceramium sp	*Champia compressa*
Champia sp	*Cladisiphon sp*
Claviclonium ovatum	*Caulocystis uvifera*
Codium sp	*Codium spongiosum*
Ceoloclonium sp	*Colpomenia sp*
Craspedocarpus sp	*Crustose corallines*
Curdiea obesa	*Cutleria multifida*
Cutleria sp nov	*Cystoseira trinodis*
Cystoseira grevillei	*Cystophora harveyi*
Cystophora monilifera	*Cystophora moniliformis*
Cystophora pectinata	*Cystophora racemosa*
Cystophora retorta	*Cystophora sp1*
Cystophora sp2	*Dasyclonium incisum*
Dasyphylla priessi	*Dasya sp*
Dictyopteris australis	*Dictyopteris muelleri*
Dictyopteris plageogramma	*Delisea pulchra*
Dictyota naevosa	*Dictyota sp*
Dilophus fastigiatus	*Dilophus sp*
Dictyosphaeria sericea	*Dictymenia sonderi*
Dictymenia tridens	*Echinothamnion hystrix*
Echinothamnion mallardiae	*Ecklonia radiata with multiple holdfasts*
Ecklonia radiata	*Epiphloea bullosa*
Erythroclonium sonderi	*Erythroclonium minuta*
Euptilocladia spongeosa	*Euptilocladia articulata*
Galaxaura marginata	*Gloiosaccion brownii*
Glossophora nigricans	*Gracilaria preissiana*
Griffithsia sp	*Griffithsia teges*
Halimeda cuneata	*Halopteris sp*
Haloplegma preissii	*Haloplegma sp2*
Haraldiophyllum erosum	*Hennedya crispa*
Heterosiphonia crassipes	*Heterosiphonia muelleri*
Hemineura frondosa	*Haliptilon roseum*
Hyroclathrus clathratus	*Hypoglossum sp*
Hypnea ramentacea	*Hypnea sp*
Jania pulchella	*Jania sp*
Kuetzingia canaliculata	*Laurencia brongniartii*
Laurencia cruciata	*Laurencia elata*
Laurencia filiformis	*Laurencia sp1*
Laurencia sp2	*Lobospira bicuspidata*
Lobophora variegata	*Melobesia sp*
Metamastophora flabellata	*Metagoniolithon radiatum*
Metagoniolithon stelliferum	*Myriodesma quercifolia*
Myriodesma serelata	*Myriodesma sp*
Pachydictyon sp	*Padina sp*

Species	Species
Peyssonnelia novae-hollandiae	*Peyssonnelia rubra*
Peyssonnelia sp	*Phaecelocarpus sp*
Platyhalia angustifolia	*Platyhalia quercifolia*
Plocamium cartilagineum	*Plocamium mertensii*
Plocamium preissianum	*Polysiphonia sp*
Psilothalia sp	*Pterocladia capillacea*
Pterocladia lucida	*Pterocladia rectangularis*
Pterocladia sp	*Rhipiliopsis robusta*
Rhodymenia sonderi	*Rhodopeltis australis*
Sargassum sub-genus sargassum	*Sarconema filiforme*
Sargassum sub-genus arthrophycus	*Sargassum fallax*
Sargassum linearifolium	*Sargassum pinnate species*
Sargassum podocanthum	*Sargassum sp*
Sargassum spinuligerum	*Sargassum tristichum*
Sargassum varians	*Scaberia agardhii*
Scinaia sp	*Scytothalia dorycarpa*
Sporochnus sp	*Spyridia dasyoides*
Thalassodendron pachyrhizum	*Thuretia quersifolia*
Tylotus obtusatus	*Vidalia spiralis*
Zonaria sp	*Zonaria turneriana*

Table A2.3 Sponges of the Geographe Bay-Capes-Hardy Inlet region, WA Australia

Sponges identified from the study area by Kevin Bancroft (CALM Marine Conservation Branch and Dr Jane Fromont (Western Australian Museum).

Order	Family	Genus	Species
Class Calcarea			Calc Sp 1
Class Calcarea			Calc Sp 2
Class Calcarea			Calc Sp 3
Class Calcarea			Calc Sp 4
Class Calcarea			Calc Sp 5
Class Calcarea			Calc Sp 6
Class Calcarea			Calc Sp 7
Class Calcarea			Calc Sp 8
Class Calcarea			Calc Sp 9
Class Calcarea			Calc Sp 11
Class Calcarea			Calc Sp 12
Class Calcarea			Calc Sp 13
Class Calcarea			Calc Sp 14
Class Calcarea			Calc Sp 12
Class Calcarea			Calc Sp 15
Class Calcarea			Calc Sp 16
Class Calcarea			Calc Sp 17
Class Calcarea			Calc Sp 18
Class Calcarea			Calc Sp 19
Clathrinida	Clathrinidae	*Clathrina*	*Clathrina* Sp
Dendroceratida	Dysideidae		Dysideidae Sp 1
Dictyoceratida			Dictyoceratida Sp 1
Dictyoceratida			Dictyoceratida Sp 2
Dictyoceratida	Irciniidae		Irciniidae Sp 1
Dictyoceratida	Spongiidae		Spongiidae Sp 1
Dictyoceratida	Spongiidae		Spongiidae Sp 3
Dictyoceratida	Spongiidae		Spongiidae Sp 5
Dictyoceratida	Spongiidae		Spongiidae Sp 6
Dictyoceratida	Spongiidae		Spongiidae Sp 3
Dictyoceratida	Spongiidae		Spongiidae Sp 7
Dictyoceratida	Spongiidae		Spongiidae Sp 8
Dictyoceratida	Spongiidae		Spongiidae Sp 9
Dictyoceratida	Spongiidae	*Hippospongia*	*Hippospongia* Sp 1
Dictyoceratida	Spongiidae	*Phyllospongia*	*Phyllospongia* Sp 1
Dictyoceratida	Spongiidae	*Strepsichordaia*	*Strepsichordaia* Sp 10
Dictyoceratida	Irciniidae	*Thorectandra*	*Thorectandra* Sp 1
Halichondrida			Halichondrida Sp 1
Halichondrida			Halichondrida Sp 2
Halichondrida	Axinellidae		Axinellidae Sp 1
Halichondrida	Axinellidae		Axinellidae Sp 2
Halichondrida	Axinellidae		Axinellidae Sp 3
Halichondrida	Axinellidae		Axinellidae Sp 5
Halichondrida	Axinellidae		Axinellidae Sp 6
Halichondrida	Axinellidae		Axinellidae Sp 7
Halichondrida	Axinellidae		Axinellidae Sp 8
Halichondrida	Axinellidae		Axinellidae Sp 9
Halichondrida	Axinellidae		Axinellidae Sp 10
Halichondrida	Axinellidae		Axinellidae Sp 12
Halichondrida	Axinellidae		Axinellidae Sp 13
Halichondrida	Axinellidae		Axinellidae Sp 14
Halichondrida	Axinellidae	*Cymbastela*	*Cymbastela* Sp 1
Halichondrida	Axinellidae	*Cymbastela*	*Cymbastela* Sp 2
Haplosclerida			Haplosclerida Sp 1
Haplosclerida			Haplosclerida Sp 2
Haplosclerida	Callyspongidae	*Callyspongia*	*Callyspongia* Sp 1
Haplosclerida	Callyspongidae	*Callyspongia*	*Callyspongia* Sp 2

Order	Family	Genus	Species
Haplosclerida	Callyspongidae	*Callyspongia*	*Callyspongia* Sp 3
Poecilosclerida	Microcionidae		Microcionidae Sp 1
Poecilosclerida	Microcionidae		Microcionidae Sp 2
Poecilosclerida	Microcionidae		Microcionidae Sp 3
Poecilosclerida	Microcionidae		Microcionidae Sp 5
Poecilosclerida	Microcionidae		Microcionidae Sp 7
Poecilosclerida	Microcionidae		Microcionidae Sp 8
Poecilosclerida	Microcionidae		Microcionidae Sp 13
Poecilosclerida	Microcionidae		Microcionidae Sp 15
Poecilosclerida	Microcionidae		Microcionidae Sp 16
Poecilosclerida	Microcionidae	*Clathria*	*Clathria styloprothesis*
Poecilosclerida	Microcionidae	*Clathria*	*Clathria* Sp 2
Poecilosclerida	Microcionidae	*Clathria*	*Clathria* Sp 3
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 1
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 2
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 3
Poecilosclerida	Microcionidae	*Echinoclathria (Holopsamma)*	*Echinoclathria (Holopsamma)* Sp 4
Poecilosclerida	Raspailiidae	*Echinodictyum*	*Echinodictyum* Sp 1
Poecilosclerida	Mycalidae	*Mycale*	*Mycale* Sp 1
Poecilosclerida	Mycalidae	*Mycale*	*Mycale* Sp 2
Poecilosclerida	Myxillidae	*Iotrochota*	*Iotrochota* Sp 1
Poecilosclerida	Myxillidae	*Iotrochota*	*Iotrochota* Sp 2
Poecilosclerida	Myxillidae	*Iotrochota*	*Iotrochota* Sp 3
Poecilosclerida	Tedanidae		Tedanidae Sp 1
Poecilosclerida	Tedanidae		Tedanidae Sp 2
Verongida	Aplysinidae		Aplysinidae Sp 1
Verongida	Aplysinidae		Aplysinidae Sp
Homosclerophorida	Plakinidae		Plakinidae Sp 1
Homosclerophorida	Plakinidae		Plakinidae Sp 2
Astrophorida			Astrophorida Sp 1
Astrophorida			Astrophorida Sp 2
Astrophorida			Astrophorida Sp 3
Astrophorida			Astrophorida Sp 4
Astrophorida			Astrophorida Sp 5
Astrophorida			Astrophorida Sp 6
Astrophorida	Anchoriniidae		Anchoriniidae Sp 1
Astrophorida	Anchoriniidae		Anchoriniidae Sp 2
Astrophorida	Anchoriniidae		Anchoriniidae Sp 3
Astrophorida	Geodiidae	*Geodia*	*Geodia* Sp 1
Astrophorida	Geodiidae	*Geodia*	*Geodia* Sp 2
Hadromerida			Hadromerida Sp 1
Hadromerida			Hadromerida Sp 2
Hadromerida			Hadromerida Sp 3
Hadromerida	Chondrillidae	*Chondrilla*	*Chondrilla australiensis*
Hadromerida	Latrunculiidae		Latrunculiidae Sp1
Hadromerida	Polymastidae	*Polymastia*	*Polymastia* Sp 1
Hadromerida	Polymastidae	*Polymastia*	*Polymastia* Sp 2
Hadromerida	Spirostrellidae		Spirostrellidae Sp 1
Hadromerida	Suberitidae	*Caulospongia*	*Caulospongia* Sp 1
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 1
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 2
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 3
Hadromerida	Tethyidae	*Tethya*	*Tethya* Sp 4
Lithistida			Lithistida Sp 1

Table A2.4 Ascidians of the Geographe Bay-Capes-Hardy Inlet region, WA Australia

Identified by Dr Laura J. Stocker from the Institute for Science and Technology Policy, Murdoch University, WA 6163
E-mail: stocker@central.murdoch.edu.au

FAMILY CLAVELINIDAE
Genus *Clavelina*
Clavelina cylindrica
Clavelina moluccensis

Genus Neptheis
Neptheis fascicularis

FAMILY PYCNOCLAVELLIDAE
Genus *Euclavella*
Euclavella claviformis

FAMILY HOLOZOIDAE
Genus *Distaplia*
Distaplia pallida

FAMILY POLYCITORIDAE
Genus *Eudistoma*
Eudistoma maculosum

Genus *Polycitor*
Polycitor nubilus

FAMILY RITTERELLIDAE
Genus *Ritterella*
Ritterella sigillinoides

FAMILY PSEUDODISTOMIDAE
Genus *Pseudodistoma*
Pseudodistoma australe
Pseudodistoma candens
Pseudodistoma sp. CC1

FAMILY POLYCLINIDAE
Genus *Aplidiopsis*
Aplidiopsis mammillata

Genus *Sydneiodes*
Sydneiodes tamaramae

Genus *Synoicum*
Synoicum sacculum

Genus *Aplidium*
Aplidium altarium
Aplidium benhami
Aplidium clivosum
Aplidium cratiferum
Aplidium filiforme
Aplidium petrosum
Aplidium rubricollum
Aplidium triggsense
Aplidium sp. CC1
Aplidium sp. CC2
Aplidium sp. CC3

Family Didemnidae
Genus *Didemnum*
Didemnum albidum
Didemnum sp. CC1
Didemnum sp. CC2
Didemnum sp. CC3
Didemnum sp. CC4
Didemnum sp. CC5 (candidum?)
Didemnum sp. CC6 (augusti?)
Didemnum sp. CC7

Genus *Leptoclinides*
Leptoclinides sp. CC1
Leptoclinides sp. CC2
Leptoclinides sp. CC3
Leptoclinides sp CC4 (c.f. Leptoclinides sp 4, P. Kott, 1997)

Genus *Polysyncraton*
Polysyncraton aspiculatum

FAMILY PEROPHORIDAE
Genus *Perophora*
Perophora hutchisoni
Perophora multiclathrata

FAMILY STYELIDAE
Genus *Cnemidocarpa*
Cnemidocarpa sp. CC1 (pedata?)

Genus *Oculinaria*
Oculinaria australia

Genus *Botrylloides*
Botrylloides leachi

FAMILY PYURIDAE
Genus *Pyura*
Pyura gibbosa

5 PART B: INTERTIDAL HABITATS

Prepared by

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5.1 INTRODUCTION

The topography of the area between Geographe Bay/Cape Naturaliste to Cape Leeuwin/ Augusta, Hardy Inlet, is complex, with a range of rock types from granites and gneiss, aeolianite limestone and sandy beaches creating a variety of different habitats (Marine Parks and Reserves Selection Working Group, 1994). The shoreline from Cape Naturaliste to Cape Leeuwin covers approximately 100 km. The area defined as intertidal is not large due to the small tidal range (less than one metre), and hydrostatic effects, often overridden by the prevailing onshore wind waves and oceanic swells (Hodgkin and Di Lollo, 1956). The intertidal areas are of interest because of the close proximity of different basement rocks with quite different microhabitats and the potential for high human impact because of their relative accessibility.

Our role in this survey was to quantitatively survey the intertidal areas along this stretch of coastline, providing baseline information that could be used for long-term monitoring before and after marine reserve implementation and identifying areas requiring more comprehensive study in the future.

5.2 METHODS

Intertidal habitats between Dunsborough in the west of Geographe Bay around Cape Naturaliste southwards to Cape Leeuwin and Augusta were surveyed from 30 January to 6 February, 1999. The area was divided into three regions:

- North – from Dunsborough around Cape Naturaliste to Sugar Loaf Rock;
- West – from Canal Rocks to Gnarabup, and;
- South – from Hamelin Bay south around Cape Leeuwin to Augusta.

These regions were the same as used by the subtidal survey. We visited as much of the coastline within these regions as time and accessibility would allow. Time constraints limited the survey to areas accessible by roads and tracks and excluded areas that could be accessed only by extensive walking forays along the coast. Onshore winds, rising swells overriding the predicted low tides limited sampling to the high intertidal on the exposed areas.

At each locality we made note of the major rock types, slope aspect, extent and exposure. We also viewed aerial photographs (DOLA 1994a; 1994b; 1996) to help characterise the area (Appendix B1). A full description of all locations and habitat types is presented in Appendix B2. Where and when conditions permitted access, the fauna in the high intertidal was sampled by recording the types and numbers of the conspicuous fauna within 0.25 m^2 quadrats. A total of 24 sites were sampled in this way (Appendix B2 & B3). Two main habitat types were apparent: boulder fields (20 sites) and horizontal limestone platform (four sites). In the boulder fields, between 14 and 30 quadrats were placed haphazardly, the number depending upon the extent of the site. On platforms, up to 20 quadrats were placed more or less systematically along up to four transects parallel to the shore. Each site was classified as either exposed or sheltered based on prevalent conditions.

In addition to the fauna, the dominant algal types and any seagrasses in the intertidal were noted and/or collected. Algae were more abundant in the subtidal areas. Algal species growing between 5 and 25 m depth were sampled in the complimentary and more comprehensive subtidal survey.

The fauna was differentiated in the field, with limited collections made for later identification using Shepherd and Thomas (1982), Wells and Bryce (1986), Wilson (1994), and Edgar (1997). Rather than produce a comprehensive species list, this study aimed to examine gross similarities between regions and sites within regions, with precise species identification possibly forming part of a later more extensive survey.

Multivariate analysis of the data was conducted using the PRIMER software package (Plymouth Marine Laboratory). Species abundance was summed over all quadrats examined at each site and those species occurring as single individuals at a single site were then removed from the data set. The remaining species assemblages were examined for general patterns by ordination in two dimensions using non-metric multi-dimensional scaling based on Bray-Curtis similarity coefficients following fourth root transformation of the data. Differences between assemblages in boulder fields and on limestone platforms were assessed by one-way Analysis of Similarities or ANOSIM (Clarke and Warwick, 1994) and, for boulder field sites, the effect of region and exposure was tested by two-way ANOSIM. ANOSIM procedures were also based on Bray-Curtis similarity coefficients and run through 5000 random permutations to assess the significance of any differences.

5.3 RESULTS

5.3.1. Habitats

The coastline consists of repeated sequences of granite and gneiss headlands, small limestone outcrops and sandy beaches (Appendix B1). The entire coastline is exposed to oceanic swells and NNW trending rock outcrops (Canal Rocks, Cowaramup, Cape Mentelle) form the only bays of any size.

Immediately to the east of Cape Naturaliste the intertidal areas are narrow, located on small rocky outcrops of granite interspersed with small sandy beaches. The wireweed seagrass *Amphibolis antarctica* grows patchily at the lower tide level. Off shore the water depth is shallow (<2 m), with mobile unvegetated sand, with seagrasses found further offshore. At Dunsborough the rocky shoreline gives way to the long sandy beach of Geographe Bay, with vast seagrass meadows.

Limestone outcrops are found from Cape Naturaliste southwards. These are generally small and narrow (10-20 m width) interspersed with small sandy beaches and follow the line of the dune behind. The incessant onshore waves move across the reef and sand may be trapped in depressions or amongst algae. The largest limestone platforms are found at Yallingup, Cowaramup, Gnarabup, surrounding Hamelin Island and the islands off Cosy Corner.

Granite and gneiss outcrops with steep slopes to seawards usually abut deeper waters, with a small intertidal area subjected to oceanic swells (Sugarloaf Rock, Canal Rocks, North Point Cowaramup, Cape Freycinet and Cape Leeuwin). Large "gutters" and fissures between granite boulders create more protected habitats (Canal Rocks, Quarry and Ringbolt Bay Cape Leeuwin) which often accumulate large amounts of wrack. In more protected areas, granites form boulder fields (Smiths Beach, Canal Rock Beach) and may lie on a on limestone basement or may be incorporated into the limestone matrix (Cowaramup and Moses Rock).

The sandy beaches are often exposed to incoming swell and the coarse sands highly mobile. Wrack accumulations on in the protected areas of sandy beaches create habitat for worms and insects.

5.3.2. Algae

Depressions, gutters and edges of some of the intertidal platforms contained a number algal and seagrass species. Turf, predominantly *Jania* sp., was common on limestone platforms and often trapped sand forming a microhabitat for polycheate worms. Depressions in the rock surface with stable sand communities eg. Cowaramup Bay contained the small seagrass *Heterozostera tasmanica*. *Sargassum* sp. and *Cystophora harveyi* often formed dense stands in rock pools on platforms (Moses Rock and Gnarabup). At the level of low spring tide, the seagrass *Amphibolis antarctica* was found growing on rocks and sand (Cowaramup). In slightly deeper water (0.5 m) immediately offshore, a number of other seagrass species *Amphibolis griffithii, Posidonia angustifolia*, *P. sinuosa*, *Thallassodendron pachyrizhum* and *Halophila ovalis* were also found. One collection of algae from the northern side of Cowaramup Bay, made adjacent to the boat ramp in the low intertidal, a zone exposed at extreme spring tides, resulted in 27 species and serves as an indication of the high diversity of species in this area (Table 5).

Table 5. Algae and seagrasses collected in the low intertidal at Cowaramup Bay (adjacent to site CI).

Species
Acrocarpa robusta
Amphiroa anceps
Amphibolis antarctica
Caulerpa brownii
Cladophora sp.
Codium spongiosum
Colpomenia sp
Crustose corallines
Cystophora harveyi
Dictyota sp.
Dictyosphaeria sericea
Ecklonia radiata adults
Halimeda cuneata
Haliptilon roseum
Hypnea sp
Jania sp
Laurencia cf majiculum
Lobophora variegata
Metagoniolithon radiatum
Metagoniolithon stelliferum
Neogoniolithon sp.
Pachydictyon sp
Sargassum arthrophycus
Scaberia agardhii
Sphacelaria
Zonaria turneriana

5.3.3. Fauna

The intertidal fauna consisted predominantly of molluscs with good numbers of crustaceans and cnidarians, and occasional echinoderms, sponges and fish (Appendix B4). The most common and ubiquitous species were the pulmonate limpet *Siphonaria jeanae*, the acmaeid limpet *Patelloida alticostata*, the trochid *Austrocochlea rudis* and the nerite *Nerita atramentosa.* Other notable species included the serpulid *Galeolaria caespitosa*, the chiton *Clavarhizoma hirtosa* and the whelk *Thais orbita.* All other species were in much smaller numbers and more patchily distributed. These included the larger gastropods *Haliotus roei*, *Turbo pulcher* and *T. torquata*.

Multi-dimensional scaling in two dimensions produced a separation with the acceptable Stress of 0.15. The resulting plot showed a clumping of boulder field sites with limestone platforms scattered around them (Figure 15). Only one platform fell within the boulder fields grouping, and this was the platform underlying the boulder field Moses Rock. This discrimination between boulder fields and limestone platforms was based on the presence of limpets, primarily *Siphonaria jeanae*, which were very abundant in the boulder fields. Additionally, there was a suite of species, primarily gastropods, including *Pyrene bidentata*, *T. torquata*, *Campanile symbolicum*, *Aplysia* spp., and echinoderms (Appendix B4) which were only found on the platforms, although in very low numbers.

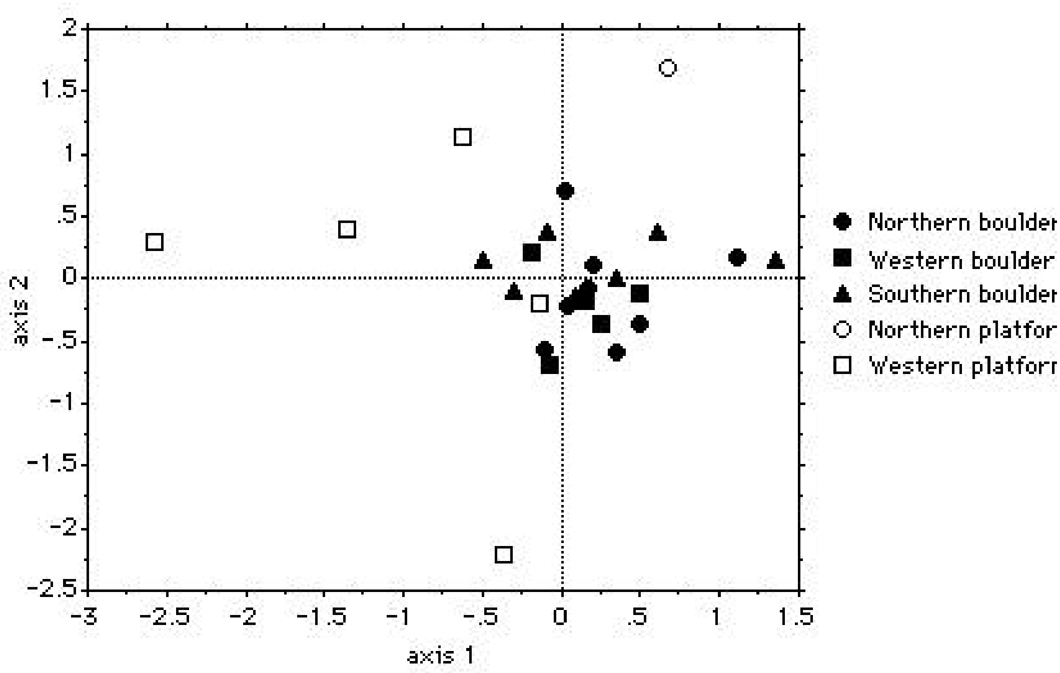

Figure 15. Ordination of faunal assemblages in boulder fields and on platforms by non-metric multi-dimensional scaling (Stress = 0.15).

The assemblages in boulder fields and on platforms were significantly different by one-way ANOSIM (Appendix 5). The tight clustering of boulder field sites is indicative of the high similarity of their fauna (Figure 15). Within boulder field sites there was no significant separation by either region or exposure. The limestone platforms did not group closely (Figure 15). The most unique site was Prevelly, which was larger in extent, topographically diverse with a higher number of microhabitats consequently supporting a larger and more diverse fauna.

5.4 DISCUSSION

The high intertidal fauna sampled in this survey had a low diversity, species that are commonly found along the south-west coast (Wells and Bryce, 1986; Wilson, 1994). Our analysis showed clearly that the limestone platforms had a quite different faunal assemblage to that of the granitic boulder fields. Assemblages in the boulder fields were similar across all three regions, however the assemblages on limestone platforms differed both from that of the boulder fields and from each other.

The difference between the fauna of limestone and granitic areas can be explained by differences in their microtopography. Granites have relatively smooth surfaces in comparison to limestone areas, which have an irregular outline and surface. Pools in the platform may contain seagrass and algae with an associated fauna of small grazing organisms (Edgar, 1990; Jernakoff *et al*., 1996; Hutchings *et al*., 1991) occasionally sampled by our quadrats. In some cases, rocks, boulders and sand may overlay the platform, creating additional habitat. This degree of habitat diversification varied markedly among platforms accounting for the marked differences in the fauna from different platforms.

5.5 LIMITATIONS OF THE STUDY

This method of sampling by haphazardly placed quadrats has provided an adequate basis for a general site description, but very few species were recorded in this survey. This does not reflect the high diversity of species in the area. Many more species were seen at each site than were recorded within the quadrats.

Collections made by other groups such as the Western Australian Museum and The Western Australian Shell Club testify to the rich invertebrate fauna along this coastline (Marine Parks and Reserves Selection Working Group, 1994). Our observations agree with the comment Marine Parks and Reserves Selection Working Group (1994) that the cryptic invertebrate fauna exhibits the greatest species diversity on these rocky shores.

5.6 PRESSURES PRESENT AND FUTURE

The exposed coast affords some protection to intertidal marine habitats as access is limited to mild conditions with small swells and low tides. There are few well developed platforms in this area and most are easily accessible from the shore making the larger fauna such as the abalone *Haliotis roei* and the turban shells *Turbo pulcher* and *T. torquata*, particularly at risk. Accessible intertidal areas such as the limestone platforms of Yallingup, Kilcarnup, and Prevelly are also likely to be disturbed by people walking on them to collect rock lobster pots and abalone. The collection of these species, although subject to bag limits, will increase with the growing population and the impact of reducing these populations on the overall community structure has not been investigated, but may be significant.

There are increasing numbers of people visiting these areas, and it can be expected that pressure on invertebrates that are not targeted at this time, will increase. Such species include the black nerite (*Nerita atramentosa)*, the giant limpet (*Patella laticostata)*, small limpets (*Siphonaria jeanie* and *Pateloida alticostata*), the giant barnacle (*Austrobalanus nigrescens)* and sea urchins. The Marine Parks and Reserves Selection Working Group (1994) highlighted that shell collectors target the endemic species of Cypraea found in this area. These are not truly intertidal species but are accessible in many areas during Spring tides when the boulders they shelter under are exposed. Collection of these cryptic species such as *Notocypraea* sp. also disturbs the habitats. There is evidence in sandy areas where wrack accumulates such as the small beaches around Cape Leeuwin digging for 'bait worms" at the high tide level may at times disturb the base of dunes. The extent of this activity should be monitored in future surveys.

It can be expected that the nutrient loads in the numerous small freshwater steams and seeps will increase as urbanisation of the areas grows. These may have some impact on the intertidal areas in protected areas such as Cowaramup Bay, and Prevelly and Kilcarnup. However in many areas the high water movement experienced on this exposed coast will disperse nutrients.

5.7 CONCLUSIONS

The intertidal areas between Dunsborough and Augusta appear at this point in time to generally be in good condition with high abundances of some species of fauna recorded in this survey. It is recommended that more comprehensive surveys are needed to adequately sample the algae and the more cryptic fauna, a greater knowledge of which would be essential for any future monitoring program.

Despite the apparent health of the intertidal areas in this region, some habitats appear particularly vulnerable and it is recommended that the limestone platforms are afforded special protection because of their accessibility.

5.8 ACKNOWLEDGEMENTS

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5.10 APPENDIX B

Appendix B1. Serial number of aerial photographs of locations included in this survey

LOCATION	Photograph
Cape Naturaliste. Bunker Bay, Eagle Bay,	5016-7, 5022-5 (DOLA, 1994a)
Dunsborough	5063-5 (DOLA, 1994a)
Yallingup to Cape Naturaliste	5257-61 (DOLA, 1994b)
Canal Rocks, Smiths Beach, Yallingup	5252-6 (DOLA, 1994b)
Cape Clairault/ Injidup	5238 (DOLA, 1994b)
Moses Rock to Quininup Falls	5244-7(DOLA, 1994b)
Cowaramup Point and Bay	5237-5241 (DOLA, 1994b)
Ellen Brook	5234-6 (DOLA, 1994b)
Prevelly to Cape Mentelle	5229- 5232 (DOLA, 1994b)
Marmaduke Point / Gnarabup	5229-31 (DOLA 1994b), 5022-3 (DOLA 1996)
Fishing Place / Redgate	5027, 5022 (DOLA 1994b)
Cape Freycinet/ Conto Springs	5070 (DOLA, 1996), 5223 (DOLA, 1994)
North Point/ Boranup	5074 & 5116 (DOLA, 1996) also 5116-5220 (DOLA, 1994b)
Hamelin Bay	5119 (DOLA, 1996)
Cosy Corner	5162/3 (DOLA, 1996)
Augusta	5197 (DOLA, 1996)
Leeuwin (1929) 1: 100000	7/10/96 RUN 9 5183-5202

Appendix B2. Description of intertidal areas on rock outcrops, headlands and limestone platforms

Geographe Bay-Cape-Hardy Inlet region. Locations where quantitative samples were collected indicated in Bold Type.

Location	Landward aspect	Type & extent platform	Notable Biota	Exposure
DUNSBOROUGH / EAGLE BAY	Granite outcrops and boulder along sweeping bays,	limited, small limestone at Eagle Bay		North east aspect, protected from westerly swells refracted around cape. Exposed to north along shallow Geographe Bay
ROCKY POINT	Limestone cliff	granite boulders		sheltered
CAPE PIQUET		granite boulders		sheltered
GANNET ROCK		granite boulders		sheltered
BUNKERS BAY				
CAPE NATURALISTE	Granite headland, eroding dune behind	narrow limestone		exposed to west and north
SUGAR LOAF / YALLINGUP	High consolidated dunes narrow limestone reefs at base; Sugarloaf large granitic dome forming small headland	narrow		exposed to west
YALLINGUP	small granite headland with limestone platform to north	relatively large, with pools	Fisheries Protected Area	exposed
SMITHS BEACH	Small granite headland to south, limestone headland to north	small limestone platform in of middle bay	Limestone with turf binding sand	north facing exposed, but with wide relatively sandy bay dissipating swell

Location	Landward aspect	Type & extent platform	Notable Biota	Exposure
CANAL ROCKS	Granite headland on west canal between north south trending rocks; landward consolidated dune, eroding cave face	narrow limestone with sand in middle of the bay		western side headland exposed; forming north opening bay relatively sheltered with *Posidonia* sp.
CAPE CLAIRULT / INJIDUP	Granite headland?			exposed headland, protecting sandy bay with northerly aspect
MOSES ROCK	Steep limestone cliff area to south appears to be similar	granite boulders lying on a narrow limestone reef with central gutter parallel to beach	bare rock with coralline algae and small amount turf; *Galeolaria* at limestone granite boulders interface	exposed
COWARAMUP	High headlands North granite, South consolidated dune. interrupted, narrow limestone reef south to Ellensbrook	variable limestone platform, wider to south of point, depressions in platform with sand accumulations Rounded granites and angualr metamorphic rocks embedded on limetone platofrm or forming shallow subtidal boulder field	algal turf binding sand and seagrass *H. tasmanica* in sand filled depressions	northerly aspect protected from westerly swells,
ELLENSBROOK	Limestone reefs extensive to south	river water enters sea at granite boulder area with limestone platform		
CAPE MENTELLE / KILCARNUP	Extensive limestone reef at point			north side point WNW facing swells refracted around point
PREVELLY / MARGARET RIVER	Limestone outcrops and islets at sealevel, Consolidated dune with limestone outcrops			exposed to westerly swells, dissipated in embayments by reefs and minor changes in aspect
GNARABUP POINT	Consolidated dune, eroded at sealevel forming wide reef	extensive limestone to south of Pt with classic notch and storm ramp, broken to north deep holes, gutters with high diversity algal sp, raised lip to seaward; subtidal reefs at entrance to bay	extent platform, variable topography giving a high diversity of microhabitats	exposed but variable degree of protection due to width platform

Location	Landward aspect	Type & extent platform	Notable Biota	Exposure
ARMADUKE POINT	unconsolidated dune moderate height, granite rocky point, limestone outcrop (3m)	small limestone platform at base of dune, large granite boulders to sea and on platform		exposed
REDGATE / WRECK GEORGETTE	granite boulder outcrops along sandy beach line, unconsolidated dunes behind beach			exposed
THE FISHING PLACE	small bay surrounded by granite? headlands			
CAPE FREYCINET / CONTOS SPRINGS	Cape, massive granite boulders to west; high consolidated dune above sandy beach			exposed
NORTH POINT / BORANUP	Appear similar to Cosy Corner? granite headland			
HAMELIN BAY / WHITE CLIFF POINT	headland high consolidate dune with exposed duricrust, long sweeping beach to north backed by extensive dunes some with blowouts	Hamelin Is. limestone with small platform and extensive limestone reefs; to seaward granite islands, extensive *P. angustifolia/sinuosa* meadows, flora in bay not investigated		
FOUL BAY	high consolidated dune exposed cave formation; granite headland to south, wide sandy beach between headlands	small platform with storm bench (10m) at base of dune, granites and metamorphic within limestone; accumulations of T*urbo intercostalis*, *Turbo torquatus*, *Thais orbita*, urchin *Phyllocanthus* spines in crevices; fossil corals at lower part of limestone outcrop	low turf on platform, narrow linear cracks, very regular surface	some protection from swells, very turbid waters, no large invertebrates due to regular topography; bird midden? with broken *Turbo*, *Lampus*, *Haliotis*, *Thais*, urchins, crabs, recent with gull droppings
COSY CORNER / KNOBBY HEAD	consolidated dunes around high granite domes; offshore limestone islands and reef platforms granites trending SW	limestone reef to east, outcropping on beach and offshore	seagrass *A. antarctica* off sandy bay aerial photos indicate large sand sheets offshore	exposed to SW; some protection due to offshore islands and reefs
SKIPPY ROCK	off shore granite boulder protecting small beach, exposed limestone cliff			protected with accumulations of wrack

Location	Landward aspect	Type & extent platform	Notable Biota	Exposure
QUARRY BEACH	consolidated dune with exposed caves and seepage areas forming tufa over granite/gneiss			moderately exposed to west
WATERWHEEL	granite/gneiss boulders forming headlands with small coarse orange sandy beach between			exposed
RINGBOLT BAY	linear rocky boulder outcrops of granite, gneiss with quartzite intrusions to sea, gutters between outcrops			exposed, some islands and reefs off shore
DISABLED ACCESS / POINT MATTHEW	sandy beach to east, granite and gneissic rocks to west		giant limpets at most exposed point	exposed
BARRACK POINT / GRANNY'S POOL	High dunes over granite boulders		small beaches between rocky outcrops, accumulations of seagrass and *A. antarctica* stem balls. *P. coriacea* pericarps	exposed, boulders form protected pool
BARRACK POINT/ STORM BAY/FLINDERS BAY / AUGUSTA	rocky point, small sandy beach rocks 20m offshore with diverse algal assemblages and seagrass *A. antartica*	granite, Gneiss and schist boulder field on narrow sand covered limestone platform, boulders seaward edge	algal turf and sand binding rocks to pavement *Serpulorbis* on rocks	easterly aspect, moderately exposed to swells

Appendix B3. Details of all sites sampled between Dunsborough and Augusta

	Code	Region	Quadrats	Latitude	Longitude	Description
Boulder fields						
Pt Picquet	PP	North	30	33°34'00"S	115°05'00"E	sheltered sites, facing NE into Geographe Bay, with a narrow
Gannet Rock	GR	North	30	33°34'30"S	115°05'30"E	intertidal area (2m wide) of small granite boulders on sand
Rocky Pt. East	RE	North	30	33°33'00"S	115°03'30"E	sheltered, facing E into Geographe Bay, intertidal 3-5m wide
Rocky Pt. West	RW	North	30	33°33'00"S	115°03'15"E	more exposed, facing NNE, with steep drop into sand
Sugarloaf Rock 1	S1	North	30	33°33'30"S	115°00'10"E	exposed, facing N, large boulders, intertidal 10m wide
Sugarloaf Rock 2	S2	North	30	33°33'30"S	115°00'10"E	sheltered behind Sugarloaf Rock, facing NW, intertidal narrower
Cape Naturalist East	CE	North	30	33°32'00"S	115°00'30"E	just east of Cape, relatively sheltered, facing N, 5m intertidal
Cape Naturalist South	CS	North	15	33°32'30"S	115°00'30"E	high energy, facing W, boulder field separated from shore by sand
Canal Rocks	CR	West	30	33°40'10"S	115°00'30"E	sheltered, facing W, in lee of Canal Rocks
Smith's Beach	SB	West	15	33°39'30"S	115°00'30"E	high energy, exposed, large sloping boulders dropping steeply
Cowarumup (outer)	CO	West	30	33°51'40"S	114°59'10"E	exposed headland, east end of bay, facing NW, intertidal 5m wide
Cowarumup (inner)	CI	West	30	33°51'40"S	114°59'10"E	sheltered, facing S into east end of bay, extensive intertidal
Prevelly boulders	PS	West	30	33°59'30"S	114°59'30"E	exposed headland, south of Gnarabup, facing SW
Foul Bay	FB	South	20	34°14'30"S	115°03'00"E	exposed headland in extensive bay, facing W, narrow steep shore

	Code	Region	Quadrats	Latitude	Longitude	Description
Flinders Bay	FL	South	20	34°20'30"S	115°10'30"E	sheltered, facing east within bay, wide intertidal (20m)
Granny's Pool	GB	South	20	34°20'40"S	115°10'30"E	sheltered, facing ESE, still within Flinders Bay
Fishing Ramp	FR	South	20	34°21'40"S	115°09'20"E	exposed, facing SE at entrance to Flinders Bay
Ringbolt Bay	RB	South	20	33°22'00"S	115°08'40"E	exposed, facing SW on headland
Waterwheel	WW	South	20	34°22'00"S	115°08'30"E	sheltered gutters
Quarry Bay	QB	South	20	34°21'40"S	115°08'30"E	sheltered, on south shore of W facing bay, facing N
Limestone platforms						
Cape Naturaliste	CN	North	20	33°32'30"S	115°00'30"E	exposed, small, sand covered platform, some emergent boulders
Moses Rock (platform)	MP	West	20	33°35'00"S	114°59'30"E	exposed, low platform behind fringing rocks
Moses Rock (boulders)	MB	West	20	33°35'00"S	114°59'30"E	exposed boulders on inner platform
Cowarumup (platform)	CP	West	45	33°51'55"S	114°59'00"E	sheltered platform facing N, 20m wide
Cowarumup (boulders)	CB	West	15	33°51'55"S	114°59'00"E	sheltered boulders on inner platform
Prevelly limestone	PP	West	80	33°58'50"S	114°59'30"E	exposed platform, extensive, 50+m wide

Appendix B4. Site totals of all species found in 0.25 m^2 quadrats at all sites sampled between Dunsborough and Augusta

Habitat								**BOULDER FIELDS**													**LIMESTONE PLATFORMS**				
Region	North								West					South							North			West	
Site	PT	GR	RE	RW	S1	S2	CE	CS	CR	SB	CO	CI	PS	FB	FL	GP	FR	RB	WW	QB	CP	MP	MB	CP	CB PP
No of quadrats	30	30	30	30	30	30	30	15	30	15	30	30	30	20	20	20	20	20	20	20	20	20	20	45	15 80
Phylum Porifera																									
Tethya sp.																		1							
other sponge spp					1													1							
Phylum Cnidaria Class Anthozoa																									
Order Actinaria																									
Brown Anemone	6			1			2	1		4						2				1					1
Green Anemone	1						1								2										
White Anemone			1					1													2				1
Actinia tenebrosa							1			5										1					
?Isanemone sp.								7		1										2					11
Order Zooanthida																									
Isaurus cliftoni																								1	

Habitat											BOULDER FIELDS										LIMESTONE PLATFORMS				
Region				North							West					South					North			West	
Site	PT	GR	RE	RW	S1	S2	CE	CS	CR	SB	CO	CI	PS	FB	FL	GP	FR	RB	WW	QB	CP	MP	MB	CP	CB PP
No of quadrats	30	30	30	30	30	30	30	15	30	15	30	30	30	20	20	20	20	20	20	20	20	20	20	45	15 80
Order Scleractinia																									
brain coral					3	5																			
Phylum Mollusca Class Polyplecophora																									
Clavarhizoma hirtosa	4	23		3	56	9	26	86	1	87	20	54	24	90	1	1	1	43	25	3	2		4		34
Chiton sp2												2													
Chiton sp3																									3
Phylum Mollusca Class Gastropoda SubClass Prosobranchia																									
Family Acmaeidae																									
Patelloida alticostata	196	22	10	156	117	229	235	75	115	81	145	204	152	77	116	31	90	24	73	34		51	89	66	21 16
Limpet spp	12	14	73	110	90	139	261	143	128	195	201	150	210	444	64	31	68	60	276	87	10	129	139	96	99 3
Family Patellidae																									
Patella laticostata					1		1			2															
Phylum Mollusca Class Gastropoda SubClass Prosobranchia																									
Family Neritidae																									
Nerita atrementosa	58	106	181	210	154	120	213		13	228	231	125	106		86	199	15	12	51	114	2	1	256		3 2

Habitat											**BOULDER FIELDS**										**LIMESTONE PLATFORMS**					
Region				North						West						South					North			West		
Site	PT	GR	RE	RW	S1	S2	CE	CS	CR	SB	CO	CI	PS	FB	FL	GP	FR	RB	WW	QB	CP	MP	MB	CP	CB	PP
No of quadrats	30	30	30	30	30	30	30	15	30	15	30	30	30	20	20	20	20	20	20	20	20	20	20	45	15	80
Family Haliotidae																										
Haliotis roei	3				1		3				6	19														12
Family Fissurellidae																										
Amblychilepas nigrita																								1		
Scutus antipodes															1									1		
Family Trochidae																										
Austrocochlea rudis	48	305	175	131	312	352	82	32	184	76	411	285	264	13	115	225	42	55	160	111	32	279	684		99	108
Notogibbula priceissiana					5				1			1				3			2					3		
Cantharidus pulcherrimus					1							1				2				1				3		
Trochid spp.																1		1								
Stomatella auricula																				4				18	6	
Family Turbinidae																										
Turbo pulcher					1						1	1														6
Turbo torquata																										3
Family Campanilidae																										
Campanile symbolicum																								5	1	1

Habitat	BOULDER FIELDS																				LIMESTONE PLATFORMS					
Region	North								West					South							North		West			
Site	PT	GR	RE	RW	S1	S2	CE	CS	CR	SB	CO	CI	PS	FB	FL	GP	FR	RB	WW	QB	CP	MP	MB	CP	CB	PP
No of quadrats	30	30	30	30	30	30	30	15	30	15	30	30	30	20	20	20	20	20	20	20	20	20	20	45	15	80
Family Littorinidae																										
Littorina unifasciata			21										1	1						2						
Family Muricidae																										
Thais orbita	5	4		5	10	3	8	5	3	4	10	3	8		1	4	1	4	3	2		1	1	2		4
Cronia avellana																			1							
Phylum Mollusca Class Gastropoda SubClass Prosobranchia																										
Family Buccinidae																										
Cominella tasmanica																						1		4		
Family Vermetidae																										
Serpulorbis cf sipho															2											
Family Columbellidae																										
Pyrene bidentata												4											2	1	3	11
Family Costellariidae																										
Vexillum marrowi																						1				1
Family Conidae																										
Conus anemone					1						1															

Habitat	BOULDER FIELDS																				LIMESTONE PLATFORMS					
Region	North								West					South							North			West		
Site	PT	GR	RE	RW	S1	S2	CE	CS	CR	SB	CO	CI	PS	FB	FL	GP	FR	RB	WW	QB	CP	MP	MB	CP	PP	CB
No of quadrats	30	30	30	30	30	30	30	15	30	15	30	30	30	20	20	20	20	20	20	20	20	20	20	45	80	15
Phylum Mollusca Class Gastropoda SubClass Opisthobrachia Order Anaspida Family Aplysiidae																										
Aplysia oculifera																									1	
Aplysia dactylomela																									1	
Order Nudibranchia																										
undetermined spp									1																1	
Phylum Mollusca Class Gastropoda SubClass Pulmonata																										
Siphonaria jeanae	138	281	228	599	802	888	1298	454	207	457	1331	908	533	1419	148	65	8352	1041	473	441	228	6	395	196		58
Phylum Mollusca Class Bivalvia																										
Septifer bilocularis	1											1												1		
?Lucinid sp																								1		1
Xenostrobus pulex																										3
Phylum Mollusca Class Cephalopoda																										
Octopus sp																		1						1		
Phylum Annelida Class Polychaeta																										
Sabellid sp											1															
Galeolaria sp	P	P	P	P	P	P	P		P	P	P	P	P		P	P	P	P	P	P			P		P	P

Habitat	BOULDER FIELDS																				LIMESTONE PLATFORMS				
Region	North								West					South							North			West	
Site	PT	GR	RE	RW	S1	S2	CE	CS	CR	SB	CO	CI	PS	FB	FL	GP	FR	RB	WW	QB	CP	MP	MB	CP	CB PP
No of quadrats	30	30	30	30	30	30	30	15	30	15	30	30	30	20	20	20	20	20	20	20	20	20	20	45	15 80
Phylum Arthropoda SubPhylum Crustacea Order Cirripedia																									
Austromegabalanus		1					1	4		1				1											
undetermined sp.			37	22							2	1		1			9			1					
Order Decapoda																									
Brachyuran spp	7	3		2				2				1	3	3			6	2	3	1			2		
Paguroid sp					4	2						2	1						1				1	2	
Palaemonid sp									1							1				1			7	1	13 1
Phylum Echinodermata Class Asteroidea																									
Coscinasterias muricata																								3	
Phylum Echinodermata Class Ophiuroidea																									
undetermined sp.																								10	1
Phylum Echinodermata Class Echinoidea																									
Heliocidaris erythrogramma																								1	1
Phylum Echinodermata Class Holothuroidea																									
undetermined sp.																								1	

Habitat												**BOULDER FIELDS**									**LIMESTONE PLATFORMS**				
Region				North						West						South					North			West	
Site	PT	GR	RE	RW	S1	S2	CE	CS	CR	SB	CO	CI	PS	FB	FL	GP	FR	RB	WW	QB	CP	MP	MB	CP	CB	PP
No of quadrats	30	30	30	30	30	30	30	15	30	15	30	30	30	20	20	20	20	20	20	20	20	20	20	45	15	80
Phylum Chordata Class Teleosteii																										
Blenniid spp	3	3			1	3						2	4					1	3	1			4			6
Number of species	14	11	9	11	18	11	14	11	11	13	13	19	12	9	11	13	10	14	13	18	6	8	13	22	14	22

Appendix B5. Results of Analysis of Similarity (ANOSIM)

a) ONE-WAY ANOSIM:

assemblages in boulders fields compared with those on limestone platforms

GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R): 0.663

Number of permutations: 5000 (RANDOM SAMPLE FROM APPROX 2.302D+05)
Number of permuted statistics greater than or equal to global R: 1

Significance level of sample statistic: 0.0%
A significant difference between boulder field and platform fauna

b) TWO-WAY CROSSED ANOSIM:

within boulder fields, testing for differences in assemblages by region and exposure

i) TESTS FOR DIFFERENCES BETWEEN region GROUPS

(averaged across all exposure groups)

GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R): -0.044

Number of permutations: 5000 (RANDOM SAMPLE FROM APPROX 1.940D+06)
Number of permuted statistics greater than or equal to global R: 3124

Significance level of sample statistic: 62.5%
No significant difference among regions

ii) TESTS FOR DIFFERENCES BETWEEN exposure GROUPS

(averaged across all region groups)

GLOBAL TEST
~~~~~~~~~~~
Sample statistic (Global R): 0.162

Number of permutations: 5000 (RANDOM SAMPLE FROM 19600)
Number of permuted statistics greater than or equal to global R: 498

Significance level of sample statistic: 10.0%
No significant difference between exposure groups
~~~~~~~~~~~