National Environmental Research Program

MARINE BIODIVERSITY hub

Application of NERP Biodiversity Hub survey methodology to Geographe Commonwealth Marine Reserve – final report

Theme 1, Project 2 - Analysis of Approaches for Monitoring Biodiversity in Commonwealth Waters (December 2016)

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Important Disclaimer

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EXECUTIVE SUMMARY

This report provides a summary of the design and analysis of the survey undertaken in Geographe Commonwealth Marine Reserve (CMR) from December 2014 to May 2015. The report summarises data collected by previous field studies in Geographe Bay on the distribution and characteristics of key habitat types (seagrasses, corals, rocky reefs and soft sediments), and the benthic invertebrate and vertebrate communities associated with them. This information was taken into consideration when developing the survey objectives and methodology. The survey design applies some of the techniques developed by Theme 1 (Monitoring and Report) of the Marine Biodiversity Hub, funded by the Australian Government's National Environmental Research Program. The survey was designed to answer three objectives developed in conjunction with Parks Australia:

- Estimate the proportion of major habitat types (soft sediment, seagrass and reef) and associated confidence intervals across the CMR, and by Zone (Inside/Outside Marine National Park).
- Quantitatively document the fish assemblages within the CMR, allowing the examination of the spatial distribution of fish assemblages across the reserve. As reef is expected to form a small proportion of the habitat in the CMR, yet be highly productive, information on known reef areas should be obtained where possible and used to ensure reef habitat is adequately represented.
- Quantitatively document the macrofaunal assemblages within the CMR, with particular emphasis on areas dominated by seagrass.

These survey objectives relate only to a single time point (a snapshot of Geographe CMR). We chose to use Baited Remote Underwater Stereo-Video systems (Stereo-BRUVs), with an additional rear-facing camera to simultaneously collect habitat information and relative abundance and length data of demersal fishes. We subsequently used an Autonomous Underwater Vehicle (AUV), deployed in select locations to document information on the macrofaunal seagrass. The samples were selected and the analyses reported based on the current zoning arrangements, noting these are under review.

The report summarises the implementation of the survey, preliminary data analysis and results. The results show that the majority of Geographe CMR seafloor is covered by unconsolidated sediments, deposited over older clay layers and limestone formations. These limestone formations tend to be long and narrow, creating bands of hard substrate surrounded by unconsolidated sediments.

Inside the Marine Park Zones approximately 40% of the area is reef or mixed reef and sand, while in the combined Multiple Use and Special Use Zones

approximately 20% of the sites fall into these categories. These estimates are much higher than were expected based on past knowledge of these areas. It was known that near-shore sandy substrate had extensive seagrass beds. These seagrass beds were previously thought to extend into deeper waters in a very patchy fashion. We now know, however, that there are some areas of extensive seagrass cover in the deeper waters of the CMR. We estimate 54% of the CMR outside the Marine National Park Zones contain seagrass and 73% in the Zones. Furthermore almost half of the sites in the Marine National Park had dense (>50%) seagrass coverage.

We recorded 8086 fish from 148 species using stereo BRUVs. The composition of the fish assemblages differed significantly between substratum and biota types. In particular there was separation between samples on sand with no vegetation, samples with sand and seagrass and samples with reef and algae. The species found in the greatest numbers were *Coris auricularis* (mean = 6.9), *Neatypus obliquus* (2.7*), Parequula melbournensis* (5.5), *Pempheris klunzingeri* (3.8), *Pseudocaranx spp* (8.6) and *Trachurus novaezelandiae* (4.9).

The Geographe CMR project has provided a suitable baseline for monitoring this CMR. Some additional work that would improve the understanding of the CMR and surrounds and utility of future monitoring include:

- *Analysing the existing BRUV data in conjunction with supplementary data*. Following the completion of the BRUVs field work undertaken for this project, Curtin University visited an additional 150 sites concentrated in the shallow areas towards the east of the CMR and the inshore areas outside of the CMR. Analysis of this data in conjunction with the existing dataset would allow comparisons between in and outside of the CMR. Curtin University also collected footage from extended stereo-video tows travelling from the coastline out to the CMR (approximately 23 m depth). This footage would provide a better understanding of the changes in the fish and macroalgal assemblages with distance from the shoreline.

- *Considering long-term monitoring*. This project has provided a baseline for monitoring, but we have not yet considered how to build on this baseline to create a long-term monitoring program, for example, a rotating panel design. The master sample provides a foundation for incorporating information collected in future surveys in a statistically valid and efficient way.

- *Collecting multibeam*. There is some existing lidar data in the eastern inshore area overlapping the CMR. However, it would be beneficial to collect multibeam in some areas to start building a map of the CMR, with particular focus on offshore areas that are not covered by the existing lidar dataset. This will enable greater understanding of the function and significance of deepwater habitats.

- *Fine scale analysis of AUV imagery*. The AUV fieldwork and data analysis were completed under very tight time frames due to equipment failure and the limited time the AUV was available. For this reason the full geo-referenced imagery was not available at the time of project completion. Once this becomes available it would be beneficial to undertake final scale analysis of the AUV imagery using methods employed for other CMRs. This will give an assemblage level benchmark of key habitats inside and outside of Marine National Park Zones.

1. INTRODUCTION

1.1 Background

Geographe Commonwealth Marine Reserve (CMR) lies within and adjacent to Geographe Bay south of Perth, Western Australia, and has a depth range of 15 to 70 m. The Geographe CMR borders Western Australia's Ngari Capes Marine Park which protects the coastal waters between Geographe Bay and Augusta. The CMR is approximately 977 kms^2 and consists of Marine National Park Zone (IUCN Category II – 36 km^2), Special Purpose Zone (IUCN VI – 650 km^2) and Multiple Use Zone (IUCN Category VI -291 km^2)(Figure 1). This zoning is currently under review.

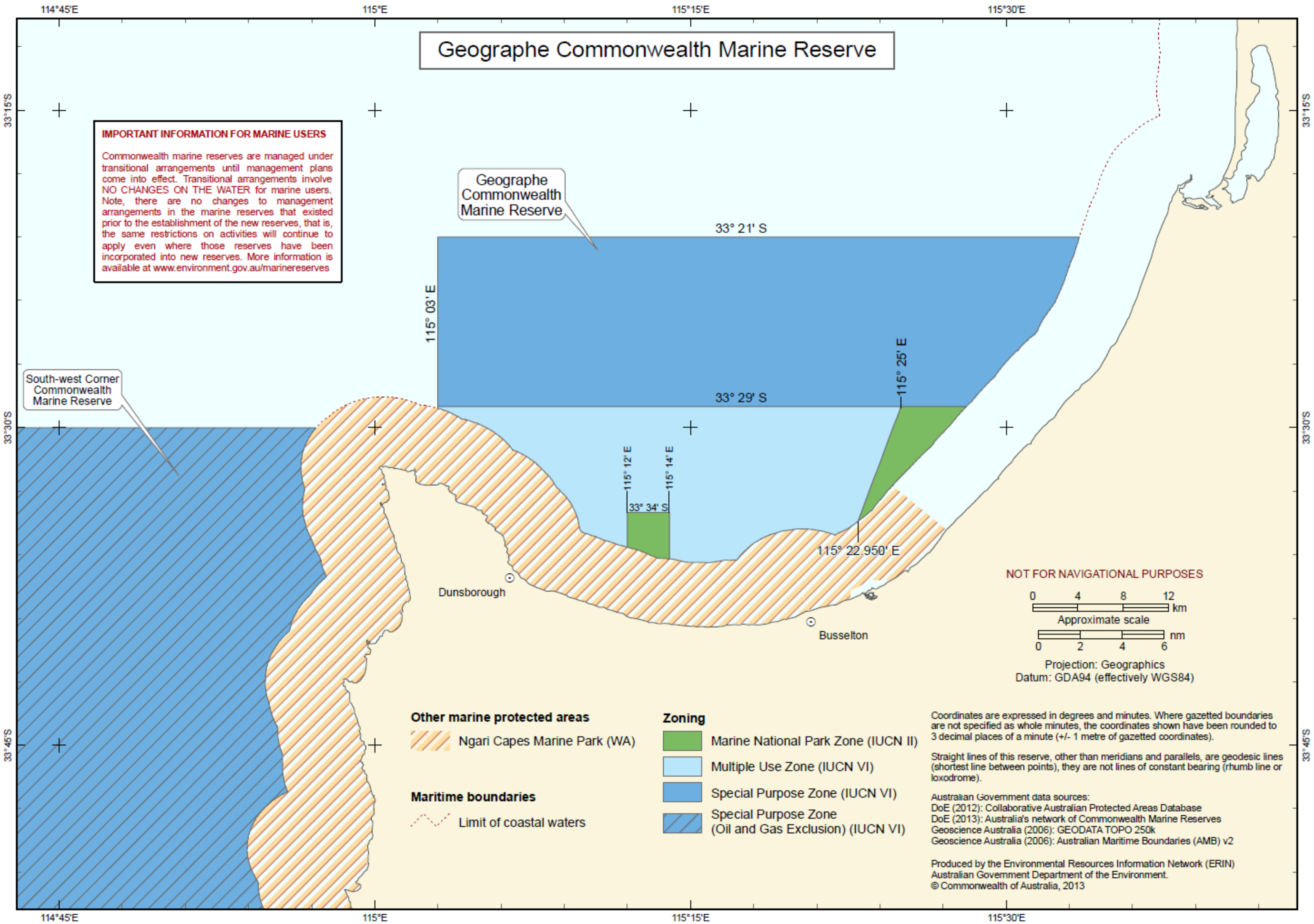

Figure 1 Location and zonation of the Geographe Commonwealth Marine Reserve, noting that zoning may change with review.

The reserve is an area of high benthic productivity and high biodiversity that provides habitat for threatened and migratory seabirds, the humpback whale and blue whale, and the Western rock lobster. Tropical and temperate seagrass species account for the majority of the benthic primary production in the area and provide important nursery habitat for many species. The Department of the Environment recognises that more information is needed to establish a monitoring program for the reserve, including collating all existing data.

The 2008 Marine Futures National Heritage Trust (NHT) II project (Radford et al. 2008) and the seagrass habitat benchmarking of Barnes et al. (2008) collected data that intersects the Geographe CMR boundaries. The NHT II mapping of Geographe Bay captures the southern central part of the reserve and the seagrass habitat benchmarking exercise includes sites that provide assessments of habitat distribution (seagrass, reef), biomass of seagrasses and epiphytes, abundance of sessile invertebrates and fish and baseline data on light, temperature and nutrients.

The marine reserve network was established to protect and maintain Australia's marine biodiversity (DONP 2013). To measure the performance of the CMR network against its stated objectives, and implement management plans, the Australian Government requires the capacity to undertake targeted, cost-effective and sustained data collection. This project aims to assist the Government in working towards this, and in particular to develop a baseline for future monitoring of the Geographe CMR.

1.2 Project objectives

The project has three main objectives:

1. Collate existing information on the distribution and characteristics of key habitat types (seagrasses, corals, rocky reefs and soft sediments), and the benthic invertebrate and benthic vertebrate communities associated with them, in Geographe Bay.

2. In consultation with Parks Australia, use the information collected in Objective 1 to design a statistically robust survey of the CMR to meet the objectives of Parks Australia, building on the baseline survey methodologies developed by Theme 1 of the National Environmental Research Programme (NERP) Marine Biodiversity Hub.

3. Implement the survey, undertake preliminary data analysis and present a summary of results.

1.3 Report structure

The remainder of this report is structured as follows;

- Chapter 2 starts with a summary of the study area. The main objective of this Chapter is to provide a spatially-explicit description of data available within the Geographe CMR. The intention of this exercise is to determine the existing knowledge base for the CMR which will then be used to target field sampling to spatially extend and augment existing knowledge.
- Chapter 3 outlines the survey design starting with the monitoring objectives and principles of survey design. This chapter then describes the details of the selection of survey sites, methodology and field work protocols.
- Chapter 4 describes the results of the analysis of the data collected during the surveys and relates the results to the survey objectives
- Chapter provides a brief discussion about the analysis and design of the survey and recommendations for future work conclude the report.

2. STUDY AREA AND EXISTING DATA

2.1 Study area

Geographe Bay is located in south-west of Western Australia, approximately 200 km south of Perth. It is a wide embayment facing north, extending from Cape Naturaliste in the west to Bunbury in the north-east. The bay is a shallow water marine environment that is unusually protected by the Cape from the prominent south-west swells. The depth gradient is low along the eastern and southern portions of the bay (average of 1.6 m per km to 30 m water depth), and increases rapidly to the western most edge at Cape Naturaliste (22.5 m per km over 30 m water depth). The majority of seafloor is covered by unconsolidated sediments, deposited over older clay layers and limestone formations which are exposed at the surface in various positions throughout the bay. These limestone formations tend to be long and narrow, creating bands of hard substrate surrounded by unconsolidated sediments. The nearshore sandy substrate is colonised by extensive seagrass beds, which patchily extend into deeper water as far as sufficient light is available for photosynthesis. Prior to this survey these seagrass beds were thought to be restricted to the nearshore environment but we now know this to be untrue (Section4).

Geographe Bay experiences a mixed, micro-tidal, mainly diurnal climate, with a maximum astronomic tidal range of 1.2 m. The daily tidal range varies biannually, with solstice tidal peaks occurring around December–January and June–July, producing a monthly tidal range that is about 20% higher than during equinoctial troughs during February–March and September–October (Fahrner and Pattiaratchi, 1994). South-west swells are refracted around Cape Naturaliste and arrive at different sections of the Western Australian coast with varying heights and angles. Geographe Bay is well protected from these swell waves by Cape Naturaliste, with gradually increasing exposure from south to north (Fahrner and Pattiaratchi, 1994). The swell waves typically have periods of 10 – 14 s and heights (within the bay) of up to 2 m in winter but generally less than 1 m in summer. Wind waves generated by local winds are short-crested with periods of 5 - 10 s. Wave direction is strongly dependent on wind direction. Geographe Bay is well exposed to these waves during north-westerly winter storms or cyclonic events. Wind wave heights can become quite large during winter, but are generally less than 1 m in summer (Fahrner and Pattiaratchi, 1994).

The summaries of available data in this Chapter refer only to data that was available prior to the surveys undertaken as part of this project. The outcomes from our surveys are discussed in later Chapters.

2.2 Bathymetry

There are no high resolution (5 – 15 m grid size) bathymetry data sets available for the full extent of Geographe Bay. The only bathymetry dataset which fully covers all of Geographe Bay is the Australian national bathymetry dataset (resolution: 9 arc seconds or 250 m grid) (Figure 2). In 2009, Fugro LADS Corporation completed the Bathymetry and LiDAR Seabed Survey from Two Rocks to Cape Naturaliste, out to approximately 20 m water depth. The resolution of this dataset is 10 m (grid size) and overlaps with the eastern Marine National Park Zone, southern and eastern portions of the Multiple Use Zone and eastern portion of the Special Use Zone (Figure 3). High resolution bathymetry (3 m grid) produced by the Marine Futures Project (2006) covers the western Marine National Park Zone and a portion of the Multiple Use Zone (Figure 4).

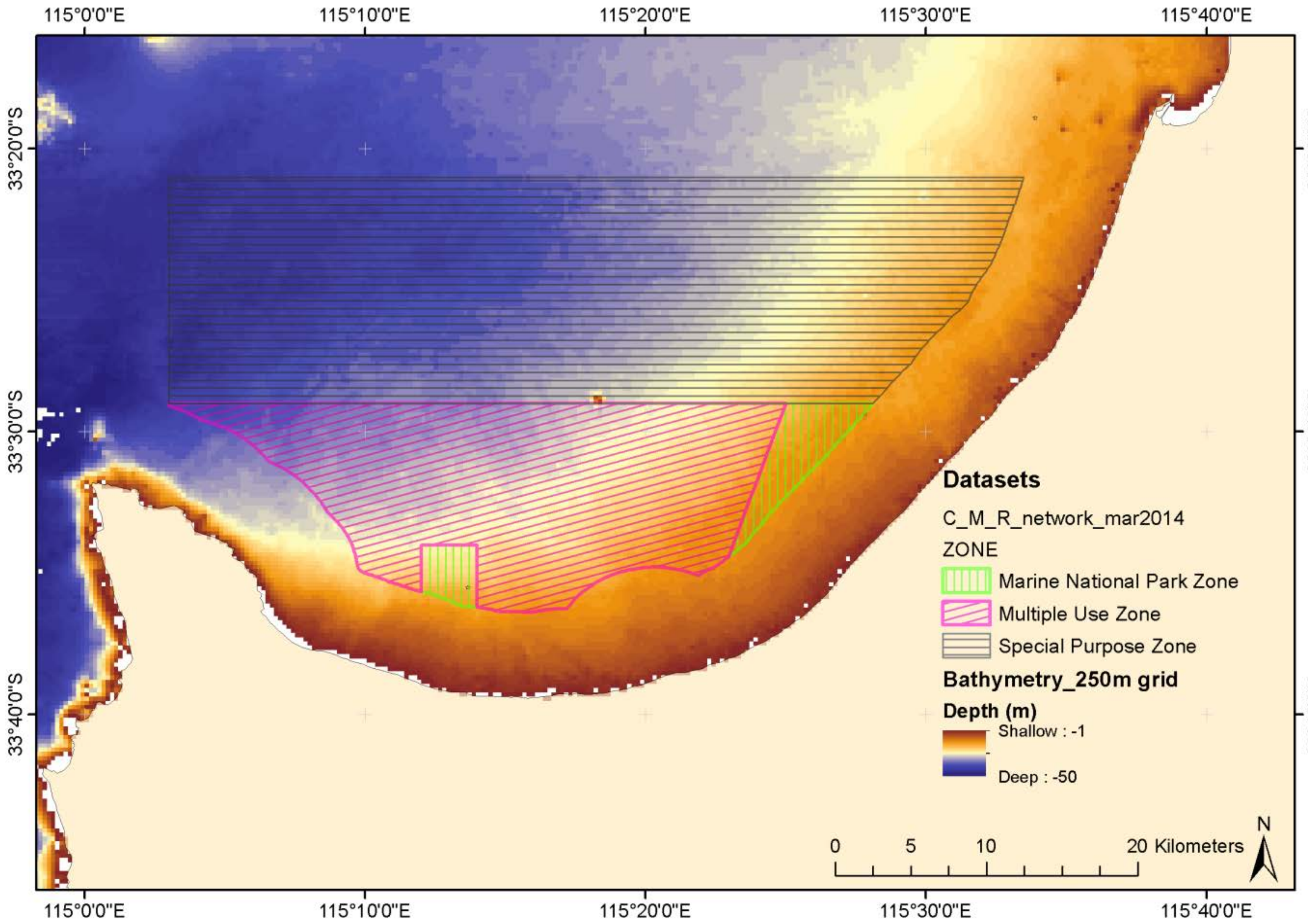

Figure 2 Australian National Bathymetry dataset (Resolution: 9 arc seconds or 250 m)

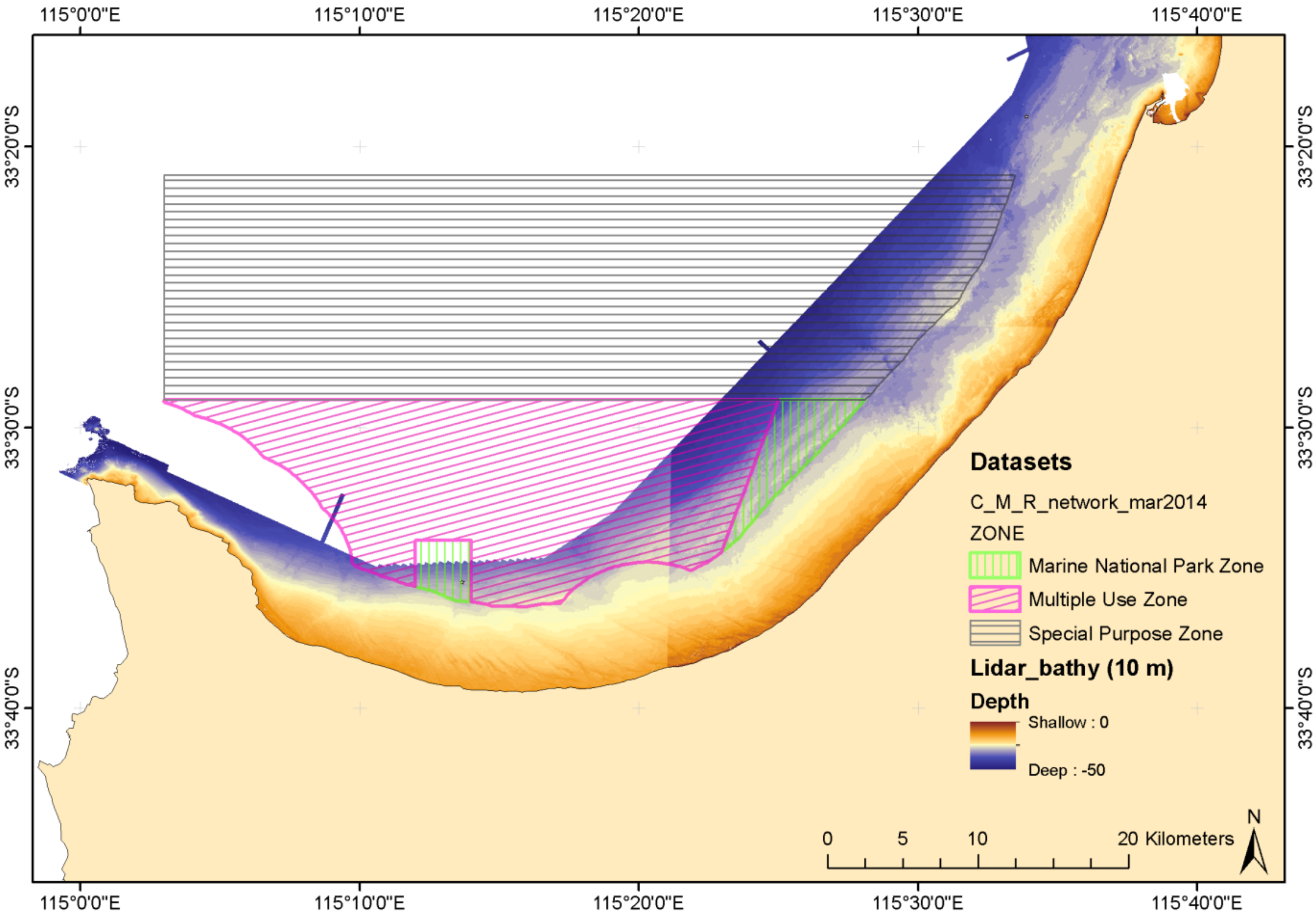

Figure 3 Nearshore bathymetry from the 2009 Fugro Bathymetry and LiDAR Seabed Survey

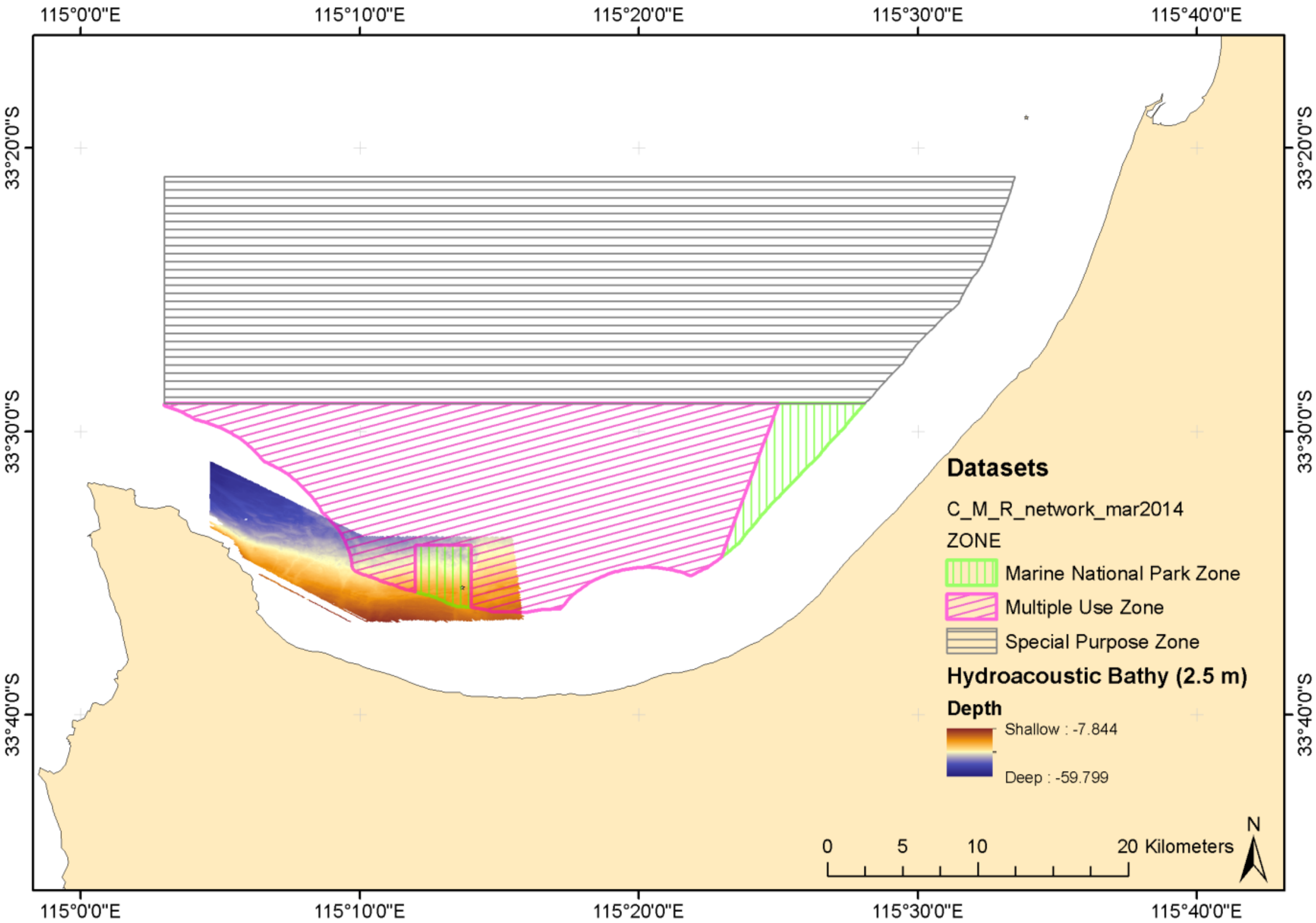

Figure 4 High resolution bathymetry derived from hydroacoustic surveys completed for the Marine Futures project in 2006

2.3 Benthic substrates

The benthic substrate in Geographe Bay is dominated by unconsolidated sediments (sand), with small pockets of rocky reef in various positions throughout the bay. In 1999, towed video was deployed along transects in the north-eastern portion of the bay (south of Bunbury, opposite Dalyellup) in 7-13 m water depths (Figure 5). This survey identified small areas of reef platform and high profile reef, in a mostly sandy matrix. Pockets of hard reef substrate have also been identified in the western portion of the bay, which was mapped during the Marine Futures project (2006) and overlaps with the western Marine National Park Zone and the south-western portion of the Multiple Use Zone (Figure 5). Past seagrass research projects show that the nearshore benthic environment in the southern most portion of the bay is dominated by sandy substrate, colonised by extensive seagrass beds (GEM Report 2007, Westera et al. 2007). Some reef substrates have been identified in the offshore survey areas of the Westera et al. study, overlapping with the southern portion of the Multiple Use Zone (Figure 5).

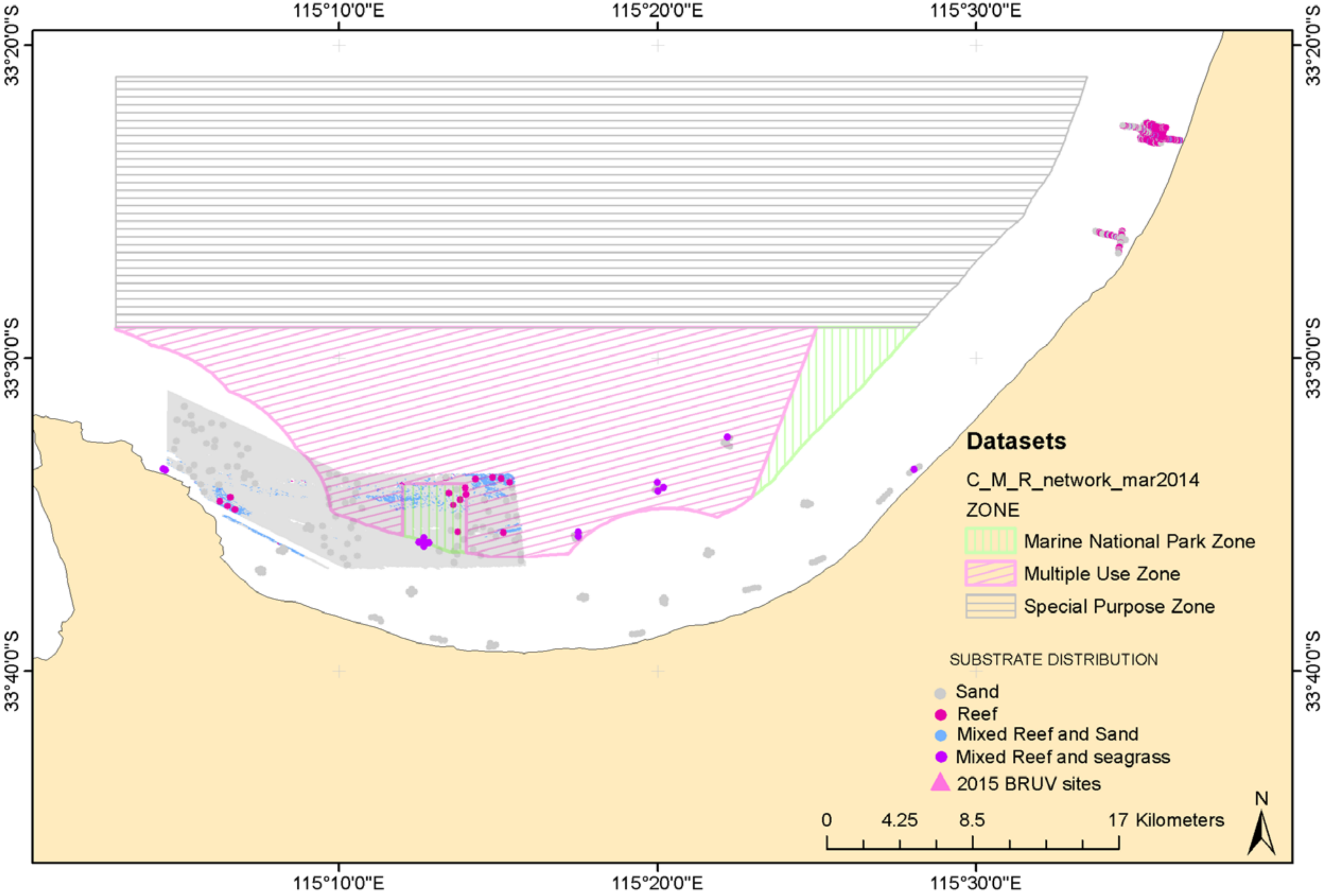

Figure 5 Distribution of benthic substrates inside the Marine National Park and Multiple Use Zones

2.4 Seagrass distribution

Seagrasses in the subtidal region (2 - 4 m) have been well characterised (Walker et al., 1987; McMahon et al., 1997). These shallow water areas are dominated by *Posidonia sinuosa* (60% cover), and the second most common species, *Amphibolis antarctica* is found around the edges of *P. sinuosa* meadows, as well as on limestone outcrops (McMahon and Walker, 1998). The 1999 towed video survey in the north-eastern portion of the bay (south of Bunbury, opposite Dalyellup) in 7-13 m water depths revealed patches of *Amphibolis antacrtica* and *Posidonia angustifolia* as the dominant benthic biota occupying sandy substrates. These transects lie to the east (inshore) of the Special Purpose Zone in the CMR (Figure 6). Aerial photography from 2004 was used to analyse the distribution of *Posidonia* and *Amphibolis* seagrass in nearshore shallow areas (<10 m depth) in the southernmost portion of Geographe Bay (GEM report 2007). Two methods were used to produce a full coverage (with respect to the study region not the CMR) seagrass distribution map, classification accuracies were assessed, and a spatial assessment of classification certainty was also developed. Three quarters (77%) of the study area was shown to be covered by seagrass, equating to 9699 ha. However, this seagrass distribution map does not spatially overlap with the CMR (Figure 6). More recently, tow video and drop camera images in deeper water (15 - 40 m) in the western portion of the field area identified more *Posidonia* and *Amphibolis* patches, as well as patchy distributions *Zostera* and *Halophila* (Marine Futures NHT II Project, 2006, unpublished data).

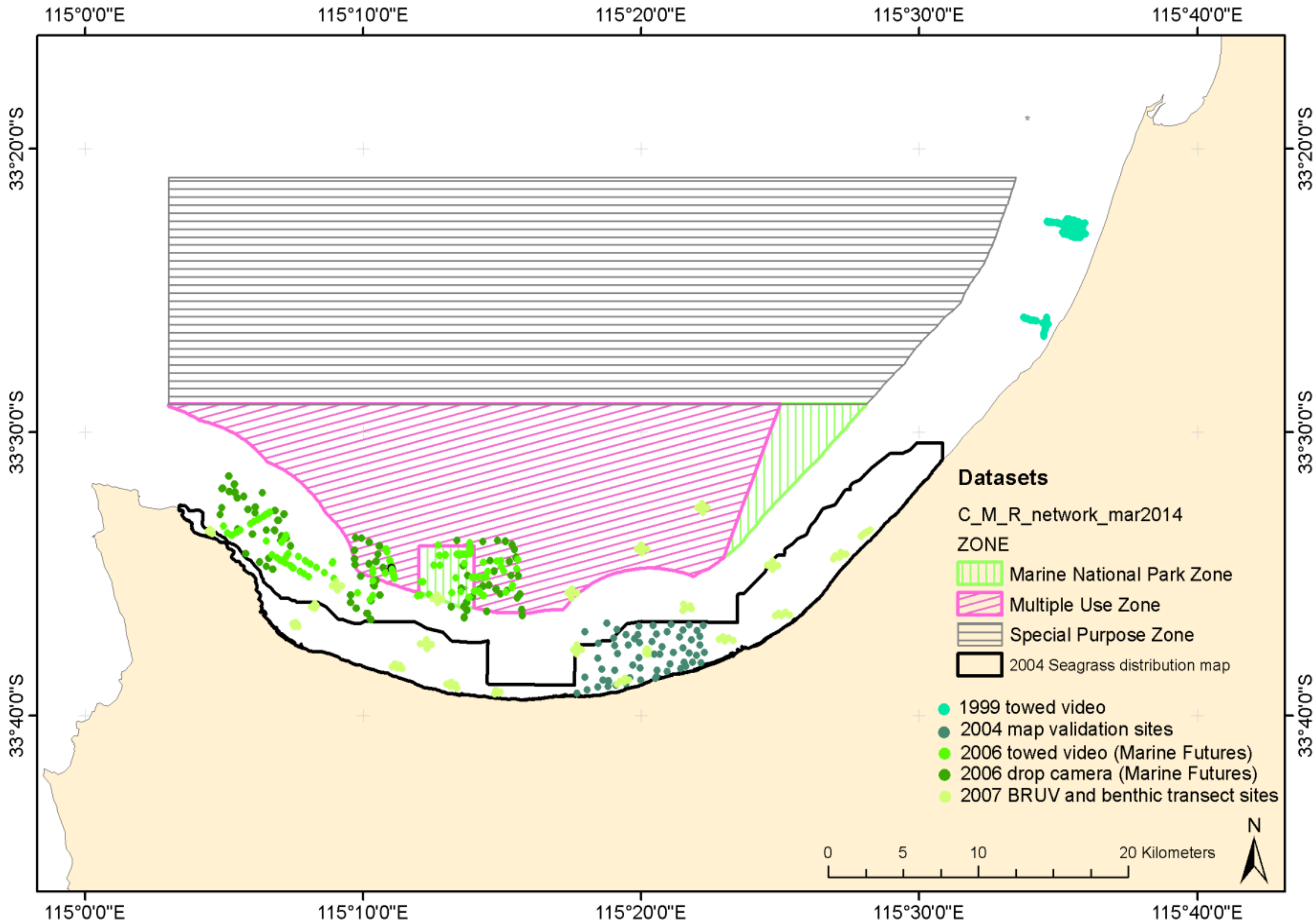

Figure 6 Available data on seagrass distribution in Geographe Bay. Note the site sizes depicted are not to scale, they have been enhanced for visualisation

2.5 Macroalgae distribution

Less than 10 genera of macroalgae have been specifically identified during spatially-explicit camera and diving surveys in Geographe Bay. These include *Caulerpa, Sargassum, Ecklonia, Ulva, Scytothalia, Amphiroa* and *Padina*. In most instances, macroalgae has been classified into colour groups (green, brown, red) or morphology (foliose, encrusting, filamentous). Prior to this survey macroalgae was thought to be mainly found on hard, rocky substrates in the offshore regions of the bay, overlapping the south-western region of the CMR, and along the north-east coast (Figure 7).

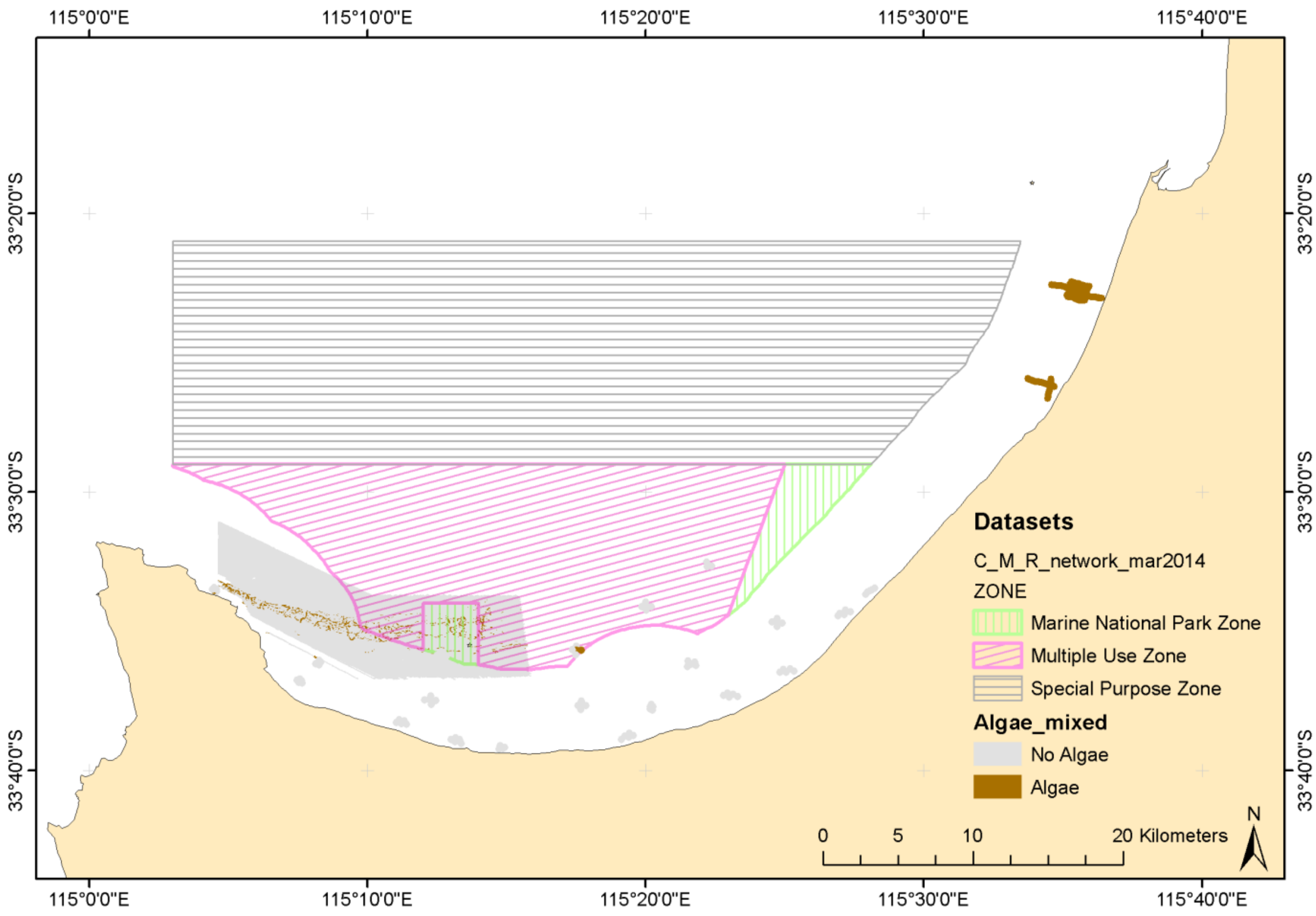

Figure 7 Available data on macroalgae distribution in Geographe Bay

2.6 Invertebrate distribution

The main groups of invertebrates identified from video footage of benthic transects and drop camera samples taken throughout Geographe Bay (prior to this survey) include sponges, ascidians, corals (hard and soft), sea stars, hydroids, bryozoans, gastropods, bivalves and sea urchins. Sponges were more common than all other invertebrate groups. In general, invertebrates were more associated with hard substrates than soft substrates, however, this may be due to the difficultly of seeing other organism in dense seagrass meadows.

Similar to macroalgae, invertebrates in samples taken prior to this survey were mostly found on hard, rocky substrates in the offshore regions of the bay, overlapping the southern western region of the CMR, and along the north-east coast (Figure 9). An in-depth investigation into invertebrates was completed via SCUBA surveys by Westera et al. (2007). In summary, there were five species of coral and one zoanthid, seven species of sea star, one sea urchin and one sea cucumber, twelve species of ascidians, seventy-two sponge specimens collected – identifications to be done by the Western Australian Museum, two large molluscs – the bivalve, *Pinna bicolor* and the marine snail, *Campanile symbolicum*. The preliminary examination of the data suggested very patchy distributions for many of the species and relatively few species that are widespread. Some sponge species may be new to science.

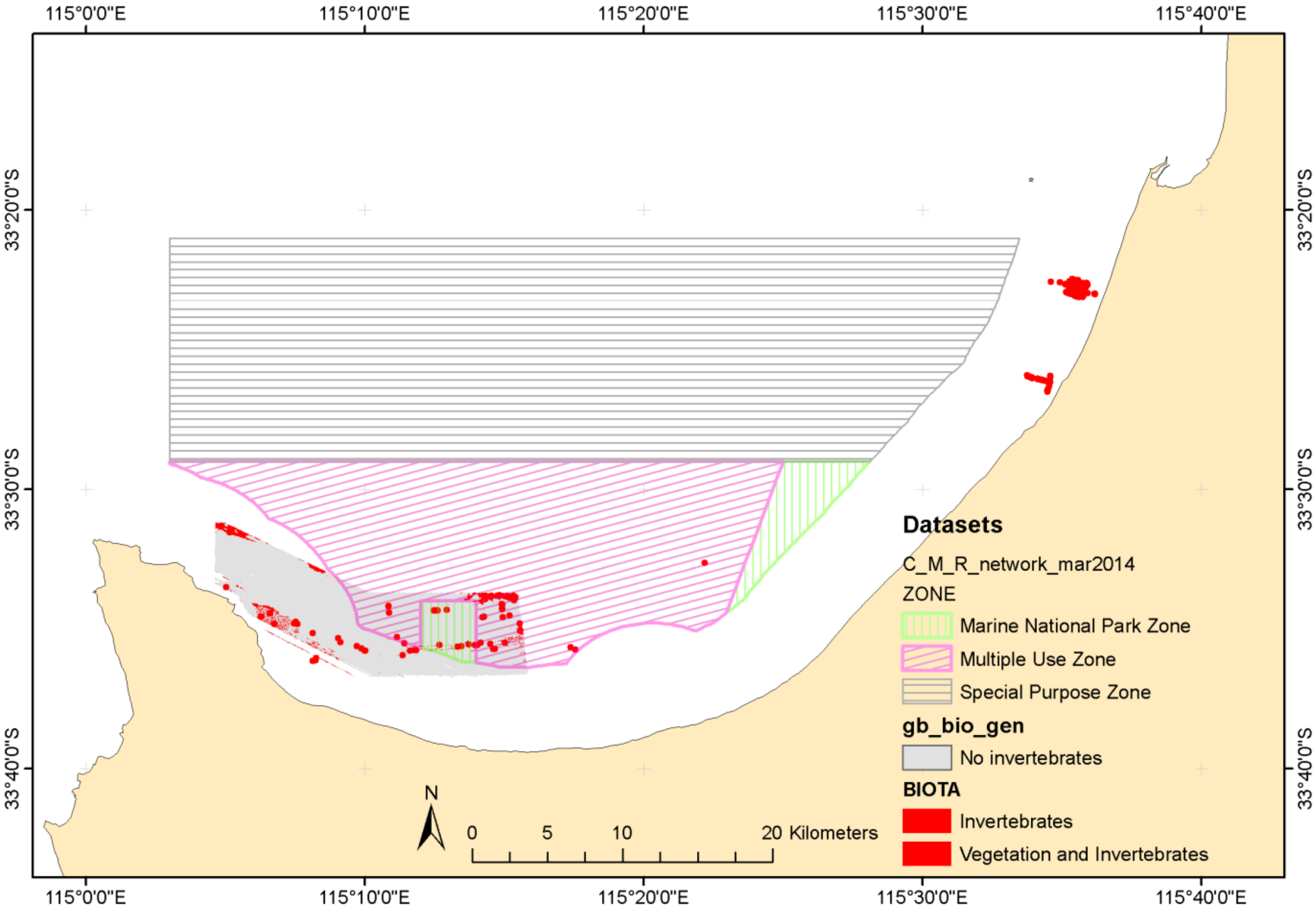

Figure 8 Available data on invertebrate distribution in Geographe Bay. Note the site sizes depicted are not to scale, they have been enhanced for visualisation

2.7 Fish distribution

Seventy six species of fishes from 54 genera and 32 families were recorded on Baited Remote Underwater Stereo-Video systems (Stereo-BRUVs) during the Westera et al. 2007 study in Geographe Bay (Figure 9). Four types of sampling sites were sampled in Geographe Bay based on distance from shore/depth and proximity to drains or estuaries:

1. Near-shore and near to drains or estuaries
2. Near-shore and away from drains
3. Mid-shore
4. Off-shore

The most abundant species were striped trumpeter (*Pelates sexlineatus*), yellowtail scad (*Trachurus novaezelandiae*) and sand trevally (*Pseudocaranx wrightii*) (Westera et al. 2007). In addition one species each of octopus, cuttlefish, squid and crab were also recorded. Species diversity was in general highest in off-shore sites (Table 1, site locations in Figure 10). The Westera et al. (2007) study indicated significant small-scale variation in assemblages and abundances among sites and that there were significant differences in assemblages with distance from shore. In general, striped trumpeter (*Pelates sexlineatus*) were most abundant in near-shore habitats while the western king wrasse (*Coris auricularis*) and maori wrasse (*Ophthalmolepis lineolatus*) were most abundant in off-shore sites.

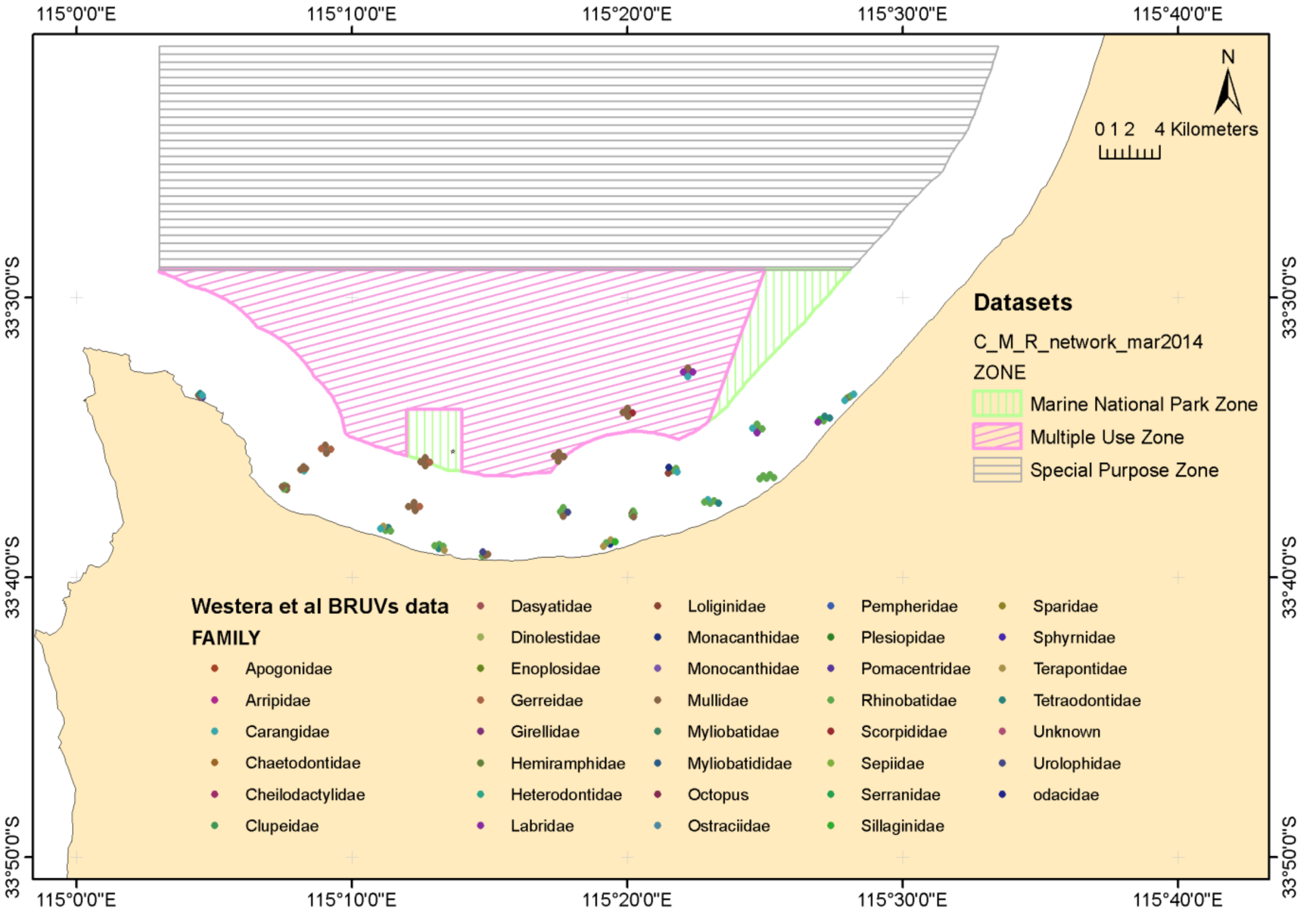

Figure 9 Available data on the distribution of different families of fish in Geographe Bay

Table 1 Measures of diversity of fishes recorded in each type of habitat. Sites were pooled in each habitat type (Westera et al. 2007)

Habitat	Number of species	Simpson measure of fish diversity	Shannon-Weiner measure of fish diversity
Drains near-shore	35	1.943	0.775
Non-drains near-shore	36	2.331	0.859
Mid-shore	35	1.888	0.706
Off-shore	45	2.730	0.931

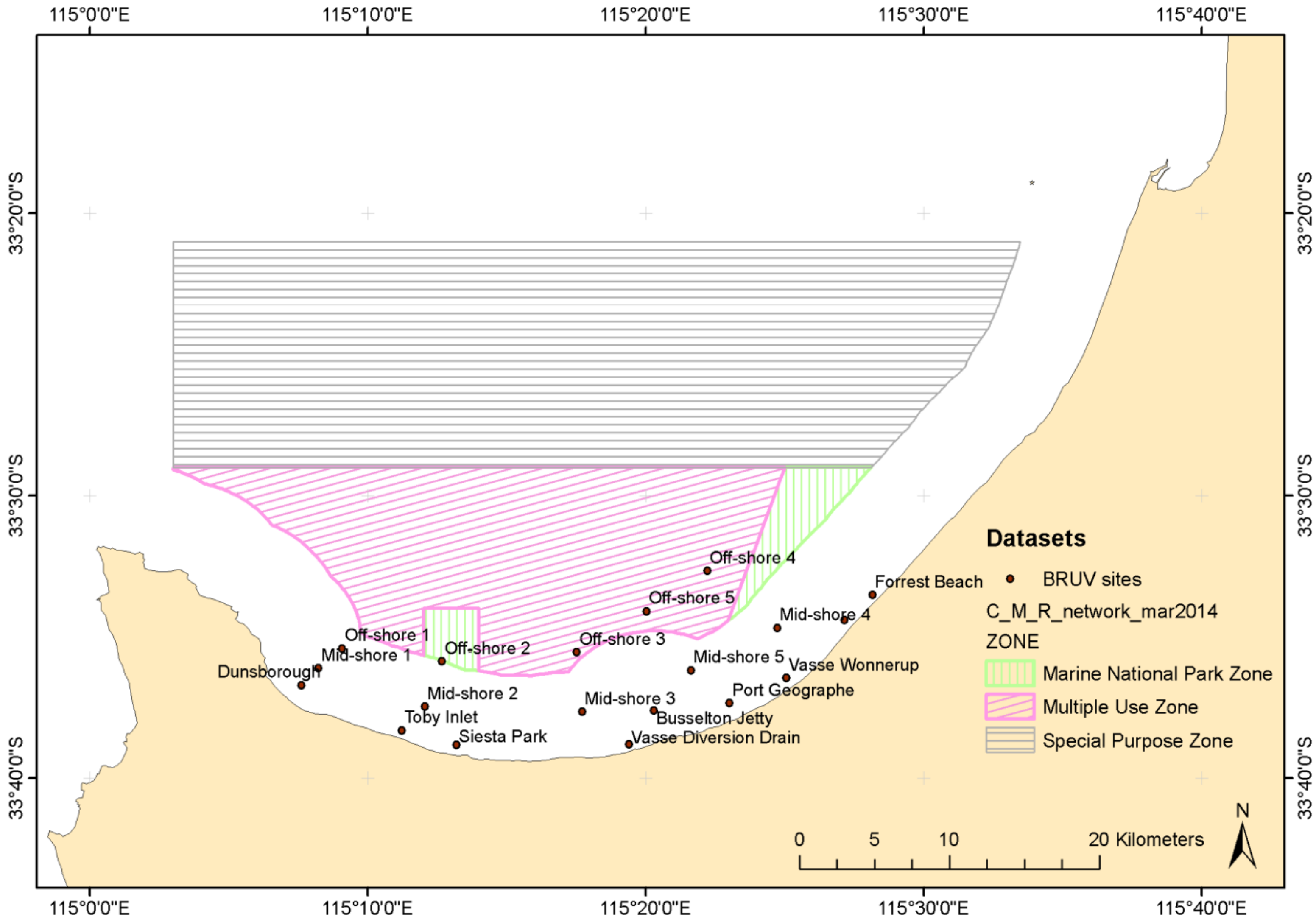

Figure 10 Baited remote underwater video (BRUV sites from Westera et al. 2007 study).

2.8 Aggregation of existing data

Aggregating all existing data in or near Geographe CMR shows that while there are several existing datasets for the eastern Marine National Park Zone there is only LiDAR data available in the western park. Outside of the Marine National Park Zones there is some data in the Multiple Use Zone but nothing in the Special Purpose Zone. This existing knowledge will be built on through the remainder of this report.

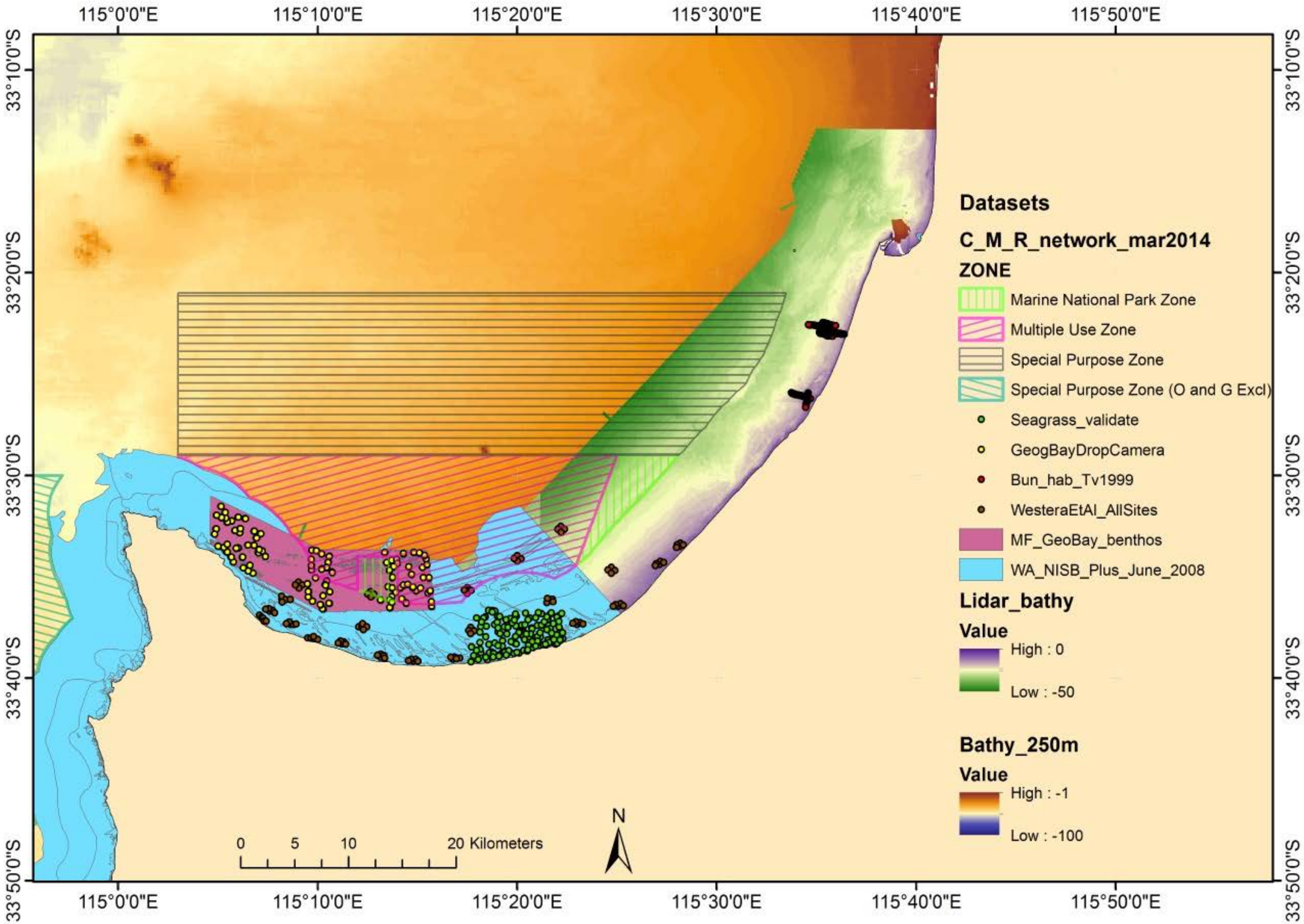

Figure 11 All available existing data in or near Geographe CMR

3. SURVEY DESIGN METHODS AND ANALYSIS

3.1 Objectives

To set up an efficient and effective monitoring program it is critical to have a clear and well-defined set of objectives. The following monitoring objectives were developed in conjunction with Parks Australia:

- Estimate the proportion of major habitat types (soft sediment, seagrass and reef) and associated confidence intervals across the CMR, and broken down by Zone (Inside/Outside Marine National Park).
- Quantitatively document the fish assemblages within the CMR, allowing the examination of the spatial distribution of fish assemblages across the reserve. As reef is expected to form a small proportion of the habitat in the CMR, yet be highly productive, information on known reef areas should be obtained where possible and used to ensure reef habitat is adequately represented.
- Quantitatively document the macrofaunal assemblages within the CMR, with particular emphasis on areas dominated by seagrass.

These monitoring objectives relate only to a single time point, that is, a snapshot of Geographe CMR. We chose to use Baited Remote Underwater Stereo-Video systems (Stereo-BRUVs), with an additional rear-facing camera to simultaneously collect, information on habitat type and the species composition, relative abundance and length of demersal fishes. We subsequently used an Autonomous Underwater Vehicle (AUV) to document information on the macrofaunal seagrass.

3.2 Stereo-BRUVs

The initial step in developing the stereo-BRUVs sample design was to determine the extent of the proposed sampling. While it would have been tempting to restrict stereo-BRUVs sampling to the Marine National Park and Multiple Use Zones, as these areas are shallower and have a reduced travel distance from land (allowing more samples to be collected for a given cost), the survey objectives refer to the entire CMR. In particular we need to make scientifically defensible inferences regarding areas beyond the sites that have been previously sampled (Section 2). As very little current information exists for the Geographe CMR on which to base a sample design, a probabilistic sample design (all sites have a non-zero and known chance of selection) was deemed necessary. This approach provides for CMR-wide inference and allows design and model-based methods to be applied to the resulting monitoring data during any future data analyses. It also provides flexibility for potentially changing future objectives, rather than optimizing the design for a single objective which may then lose its relevance a short-time later. The ability to calculate design-based estimates and associated estimates of precision is critical when there is little existing data for the area which may be used to develop a model. This was explored extensively through the NERP Marine Biodiversity Hub (Lawrence et al. 2015, Hill et al 2015).

It is important to note that experienced field teams are understandably cautious about expending sampling effort in areas with no prior information, particularly if there are parts of the study area that are relatively well known and thereby provide some assurance that sampling effort targeting (for example) sea grass habitat will indeed encounter such habitat. Furthermore, it is not unusual for field teams to infer that reef and seagrass, for example, have a limited distribution in a study area (such as a CMR) based on the limited evidence that is currently available. These issues can lead to concerns that a completely randomized design may risk sufficient representation of target habitats such as seagrass and reefs. To assuage these concerns and guard against the possibility of a truly limited habitat distribution, the probabilistic sample design implemented in Geographe CMR was complemented by some targeted sampling to ensure that key habitats like reef and seagrass were adequately represented.

The most common choices of sample design for environmental programs are simple random sampling and systematic sampling. While these are simple and commonly understood designs, they have some undesirable properties. Simple random samples often result in the sites being clustered together (and conversely large patches without any sites). While systematic sampling overcomes this problem, a design-based variance estimator does not exist. An alternative, spatially-balanced approach, that avoids both of these problems is the Generalised Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). This design was successfully trialed in the Flinders CMR, the Tasman Fracture CMR (via an equivalent spatially balanced approach) and the Houtman-Abrolhos Key Ecological Feature in Theme 1 of the Marine Biodiversity Hub. Using this approach a previously unknown cluster of mixed reef habitat was identified in the Flinders CMR (Hayes et al. 2015). The GRTS methodology ensures sample sites are distributed in a spatially balanced way and is also associated with a local neighbourhood variance estimator that is stable and nearly design unbiased.

There are some additional features of a GRTS design that make it desirable for the Geographe CMR monitoring:

- It is probability based so allows the use of design or model-based estimation techniques
- The reverse hierarchical order of the sample means that it is easy to select a subsample or additional samples that also have good spatial properties.
- It is possible to “oversample” at the time of the survey design and use the selected additional sites for future monitoring regimes

- Stratification and unequal probability of selection are well catered for

A sample design is classed as stratified if the area to be sampled is partitioned into mutually exclusive and exhaustive strata and sample selection occurs independently within each strata. Stratification will result in a reduction of the variance of an estimate if the units within strata are homogenous. However, it can result in increased variance estimates if the strata are not related to the response variable. Stratification may also be used if different sample selection methods or probabilities are to be used in different areas. The following strata were created for Geographe CMR:

- Marine National Park Zone
- Multiple Use and Special Use Zones combined

3.2.1 Sample selection

We selected a GRTS master sample (an overly large sample) using the *spsurvey* package in R (Kincaid and Olsen 2012), rather than a realistic sample size specific to this study, so that should sampling take place in the future the points would be pre-determined thus avoiding ad hoc sampling on each new occasion. From the master sample 40 BRUV sites were selected across the two Marine National Park Zones and 110 sites across the Multiple Use and Special Use Zones (Figure 12). This led to the sites in the Marine National Park Zones being closer than those outside, to ensure that there was adequate representation from these two important areas. It is important to note that the GRTS design is flexible and does not depend on these two areas being Marine National Park Zones in the future.

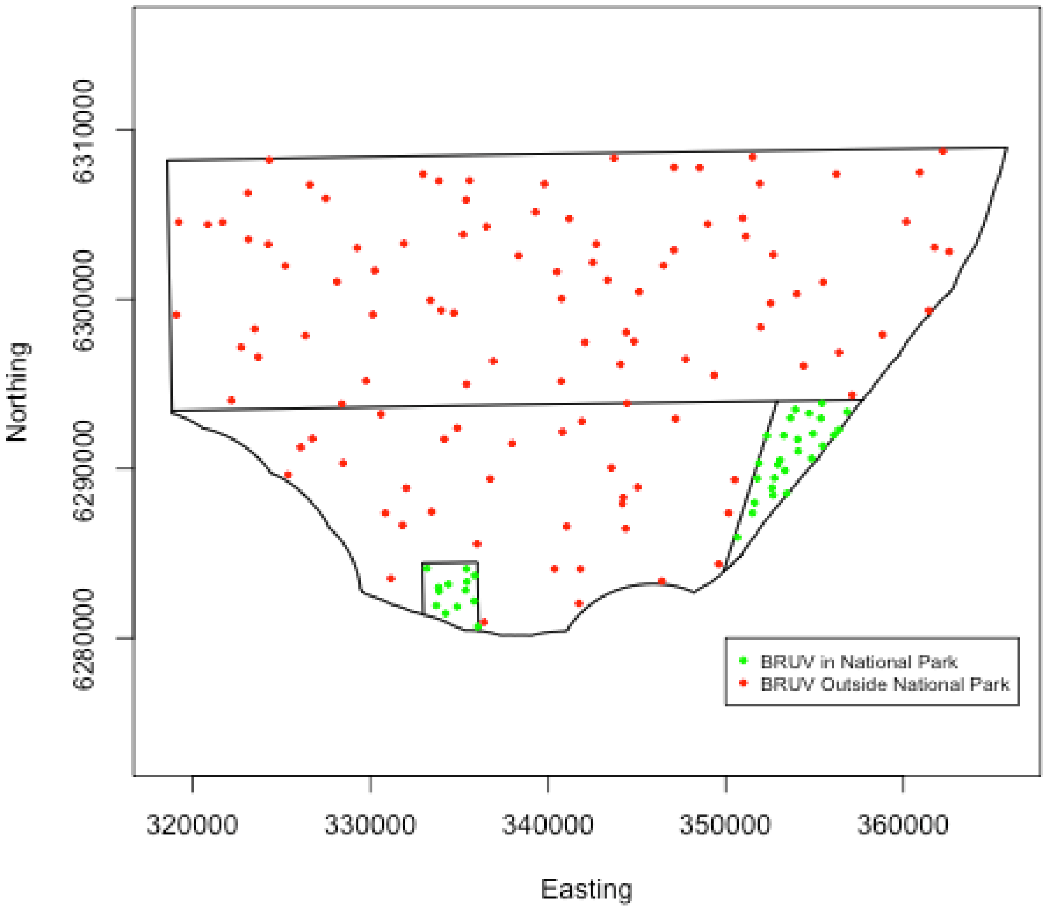

Figure 12 BRUV locations selected using GRTS: 40 sites inside National Park and 110 sites outside National Park

In addition to the sites selected using GRTS the field crew dropped an additional 40-50 BRUVs targeting reef/seagrass habitat. A set of guidance parameters were developed by the project team to ensure not all of these targeted BRUVs were in the same location, namely:

- 10 drops per depth strata (4 strata in total) should be selected for the purpose of targeting reef
- If a particular strata does not have enough reef for 10 targeted drops then extra drops (to a maximum of 15) should be moved to the adjacent strata
- Drops should be separated by as much distance as possible (this will depend on how much reef is encountered in each strata and the geographic spread)

In addition to the sites described above (GRTS and targeted) a further set of sites were sampled in the inshore areas of the CMR and also between the coast and the CMR boundary. This data collection was funded by Curtin University. As the sites were selected using a combination of GRTS and other selection methodologies and the time frames for this report were very tight we have not analysed them in this report. However they will be analysed in conjunction with the data described in this report at a later date.

3.2.2 Data collection, processing and storage

Stereo-BRUVs are a fishery-independent, non-destructive sampling technique developed and first deployed in Western Australia (Harvey et al. 2007, 2013). Stereo-BRUVs are a sampling method which can collect data in a standardized manner for a broad range of species

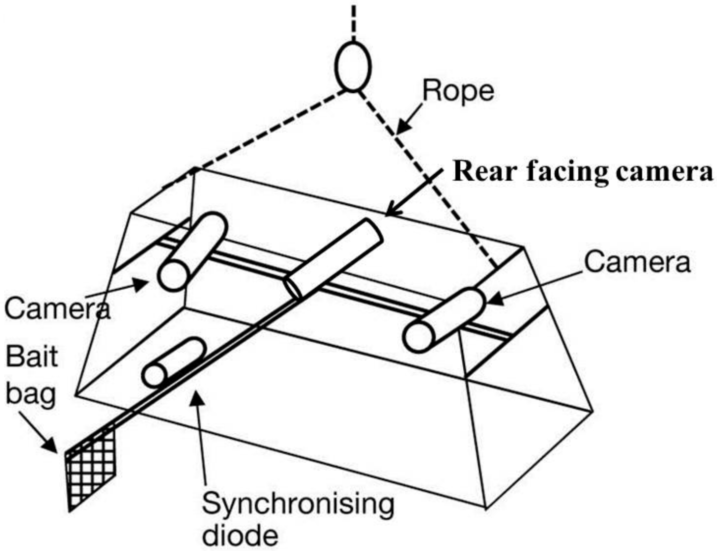

Figure 13 Diagram of a stereo-BRUV system used throughout the fieldwork

Cappo et al. 2003, 2004, 2007, Harvey et al. 2007, Langois et al. 2010, Watson et al. 2005, 2009, 2010). The cameras were inwardly converged at 8 degrees to gain a maximum field of view (Harvey et al., 2002, 2010). We used 800-1000 g of crushed pilchards (Sardinops sagax) in a mesh basket suspended 1.2 m in front of the two cameras to attract fish to the system. A third underwater camera and housing was attached to the rear of the BRUV frame and used in combination with the front facing cameras to classify habitat.

The baited remote underwater stereo-video systems (stereo-BRUVs) were deployed from the Fishing Vessel Hannah Lee between 9th and 15th of December 2014. The stereo BRUVs were lowered to the seafloor using a rope and recovered after a soak time of one hour using a hydraulic craypot winch.

We used Elecard Converter Studio (www.elecard.com) video conversion software to convert video recordings from MT2S to AVI format prior to importing the imagery into image analysis software. The program CAL (SeaGIS Pty. Ltd.) was used to calibrate stereo-BRUVs before and after completion of the field work in order to make accurate measurements of sampling area and fish length (SeaGIS, 2011). This process is described by Harvey and Shortis (1995, 1998) and Shortis and Harvey (1998).

The software 'EventMeasure Stereo' (SeaGIS Pty. Ltd.) was used to keep record of the time when a species was seen on the video and the numbers of individuals. We also used this software to measure length of individual fish and determine their distance from the camera. To avoid repeat counts of individual fishes continuously re-entering the field of view, the maximum number of individuals of the same species appearing at the same time (MaxN) was used as a relative abundance measure. MaxN is a conservative estimate of abundance in high-density areas (Cappo et al., 2003, Cappo et al., 2004, Harvey et al., 2007).

In addition to counts of the relative abundance we also collected information from the video images on the characteristics of the benthic community including the major biota (Seagrass, Algae, Sessile Invertebrate) and the substratum (Reef or Sand). A macro developed in Excel was used as a platform to broadly classify habitats (Figure 14). Substrate was categorised as either hard (reef/rock), soft (sediment) or mixed, with options to further describe the structure/texture of these components. Dominant biota was categorised as algae, seagrass or sessile invertebrates, with the option to further describe the biota according to CATAMI classifications (algae and inverts) or by genus (seagrass). Estimation of percent cover was also recorded for each of the broad substrate (0 - <25%, 25 - < 50%, 50 - <75%, 75 – 100%) and biota categories (Trace <1%, Sparse 1 - 10%, Low >10 – 25%, Medium >25 – 50%, Dense >50 – 75%, Very dense >75%).

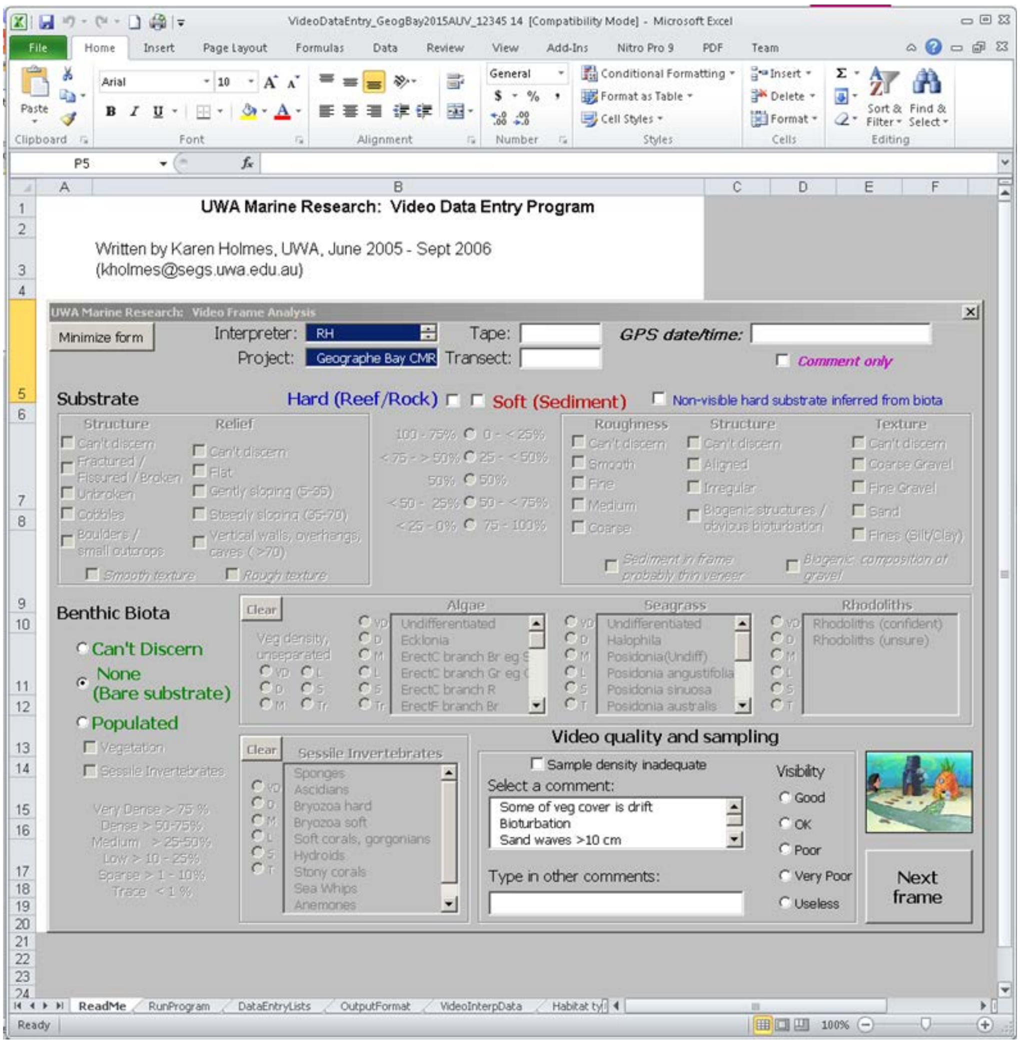

Figure 14 Excel Macro used to classify imagery

The data is stored on IVEC (portal.ivec.org) and the metadata on AODN (portal.aodn.org.au).

3.2.3 Statistical analysis

Major habitat types

Design-based estimates of proportion of the CMR represented by each Substratum (Reef, Mixed, Sand) and Biota (Seagrass and Algae) were calculated using the *spsurvey* package in the R statistical program. These results are based on only those sites selected using GRTS (not the targeted sites) with scoreable videos. Prior to performing the estimation, the survey first-order inclusion probabilities were adjusted to account for the change in the number of sites actually visited and scored compared to those selected (because we purposefully selected more sites than could feasibly be visited). The GRTS design-based estimates of population characteristics are based on the continuous population analog to the Horvitz-Thompson estimator (Stevens and

Olsen 2003). The associated local neighbourhood variance estimator that is built into the *spsurvey* package has been shown to be stable and approximately unbiased under a range of simulation scenarios (Stevens and Olsen 2003).

Fish assemblages

The MaxN for each species was summed over adults and juveniles within stereo BRUVs samples. Published literature has documented that fish assemblages vary with substratum and biota (Harvey et al. 2013) so we used a two-way non-parametric multivariate analysis of variance (PERMANOVA, Anderson 2001, Anderson and Robinson 2003, Anderson et al. 2008) to test for differences in the fish assemblages by Substratum (3 factors; Sand, Reef, Mixed; fixed) and Biota (3 factors; Seagrass, Algae, None; fixed). As depth is also known to vary, depth was used as a covariate in the analysis. MaxN values were square-root transformed and we used a Bray Curtis dissimilarity matrix (Anderson 2006). For each term in the analysis we computed 9999 permutations of the raw data units to obtain *p* values.

To visually compare the fish assemblages sampled by stereo-BRUVs, plots of the principal coordinates were constructed from a constrained Canonical Analysis of Principal Coordinates (CAP, Anderson and Robinson 2003, Anderson and Willis 2003). We used the substratum and biota combined as a factor for the final CAP. We used Spearman rank correlation R values greater than 0.5 or less than -0.5 to identify species influencing the pattern observed in the CAP plot (Anderson et al. 2008).

We were interested in examining how the fish assemblage structure was influenced by the measured environmental variables Depth (continuous variable in metres), Substratum (listed as the presence or absence of sand and reef, or mixed reef and sand), Biota (listed as the presence or absence of vegetation, algae, seagrass and sessile invertebrates). Depth was measured from the depth sounder at the time a stereo-BRUV system was deployed from the vessel. We also categorized the biota (vegetation, seagrass, algae and sessile invertebrates) and the substratum (Sand or Reef) from the video imagery so that we were classifying these variables from the video imagery rather than the habitat maps on which the sample plan was developed. Relationships between fish assemblage data and environmental variables were assessed using Distance Based Linear Models (DISTLM; Legendre and Anderson 1999; McArdle and Anderson 2001) in the computer program PRIMER-E+ (Anderson et al. 2008). Analyses were conducted on a Bray Curtis dissimilarity data matrix. The BEST selection procedure was employed, with all possible models being fitted. The AIC (Akaike Information Criterion) model selection criterion (Chambers and Hastie 1993) was used to select the final model.

Single Species

We tested for differences in the relative abundance of dominant species (identified with a Pearson correlation greater than 0.5 or less than -0.5), the total number of individual fish (abundance) and the number of species (richness) sampled by stereo-BRUVs in two ways. Secondly, we used permutational analysis of variance (PERMANOVA ; Anderson and Millar, 2004) in the same two-factor model described above (9999 permutations), but with a Euclidean distance resemblance matrix (Anderson and Millar 2004, Anderson et al. 2008) on untransformed data. Pair-wise tests were conducted where appropriate and significant terms or interactions plotted.

3.3 AUV

An emerging technique for sampling the seafloor involves combining underwater imagery with Autonomous Underwater Vehicles (AUVs) platforms. AUVs combine many of the strengths of other remote surveying methods including being non-extractive and spatially explicit, with the added bonus of having an extensive depth range, ability to cover extensive sample areas and greater capability of navigating complex reef habitats.

A seafloor survey in Geographe Bay was conducted using the state-of-the-art '*Iver'* Autonomous Underwater Vehicle (AUV) (Figure 15). The submersible is equipped with a full suite of oceanographic instruments, including a high-resolution stereo camera pair and strobes, multibeam sonar, depth, conductivity and temperature sensors, Doppler Velocity Log (DVL) including a compass with integrated roll and pitch sensors, Ultra Short Baseline Acoustic Positioning System (USBL) and forward looking obstacle avoidance sonar. The 'flight path' for each AUV dive can be precisely pre-programmed with a range of sampling designs, depending on the purpose of the survey.

Figure 15 Photograph of the *'Iver'* Autonomous Underwater Vehicle prior to diving to the seafloor (Photo credit: Kim Royce).

3.3.1 Sample selection

As the AUV was available for a limited time (5 days including calibration) the sampling locations were selected according to priority areas identified by the project team, considering the survey objectives, in conjunction with Parks Australia.

The priority areas are mapped in Figure 16 and described below. It is important to note that these sites were selected by hand, so unlike the GRTS sites, the sites have not been selected in an unbiased way and are not considered representative of the entire CMR. Instead, the survey was designed to target key habitats (reef and seagrass) inside and outside the Geographe Bay National Parks, and in deep water (20 – 50 m) for fine-scale benchmarking of assemblages within key habitats and future monitoring purposes. The AUV was consistently flown approximately 2 m above the seafloor along transects that followed an elongated grid design (Hill et al. 2014). These grids were between 0.6 and 3km lengths depending on the locations, priority and distances between identified sites.

The 15 sampling locations selected outlined according to priorities were:

- Priority 1: 4 *x* inside Marine National Park Zones and 4 *x* outside Marine National Park Zones – locations outside are similar depth and habitat to inside (Figure 17 and Figure 18)
- Priority 2: 4 *x* Deep water (offshore) seagrass and reef (Figure 19)
- Priority 3: 3 *x* Deep water (offshore) seagrass (Figure 16)

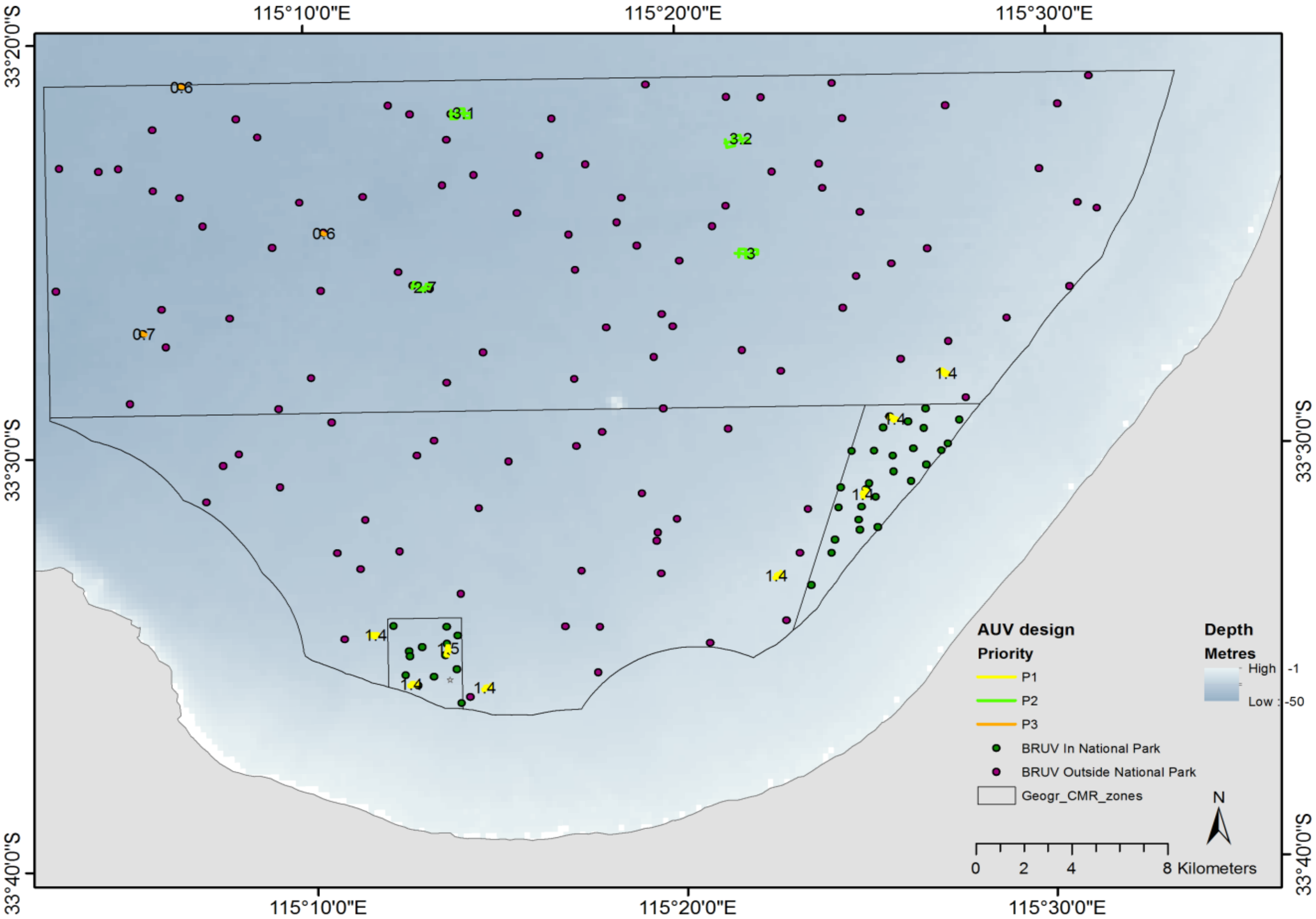

Figure 16 AUV sampling locations in Geographe CMR

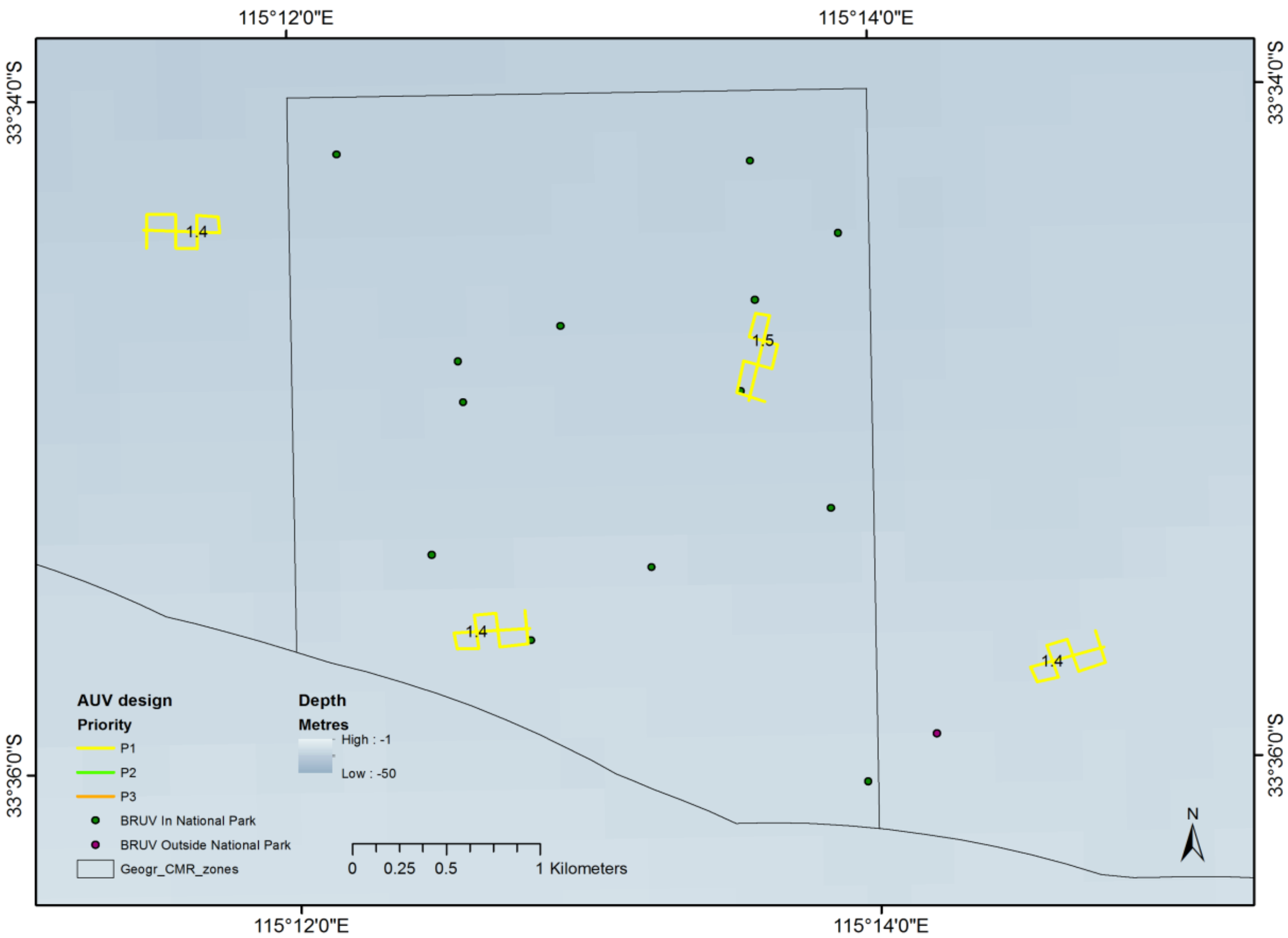

Figure 17 AUV sampling locations inside and outside western National Park

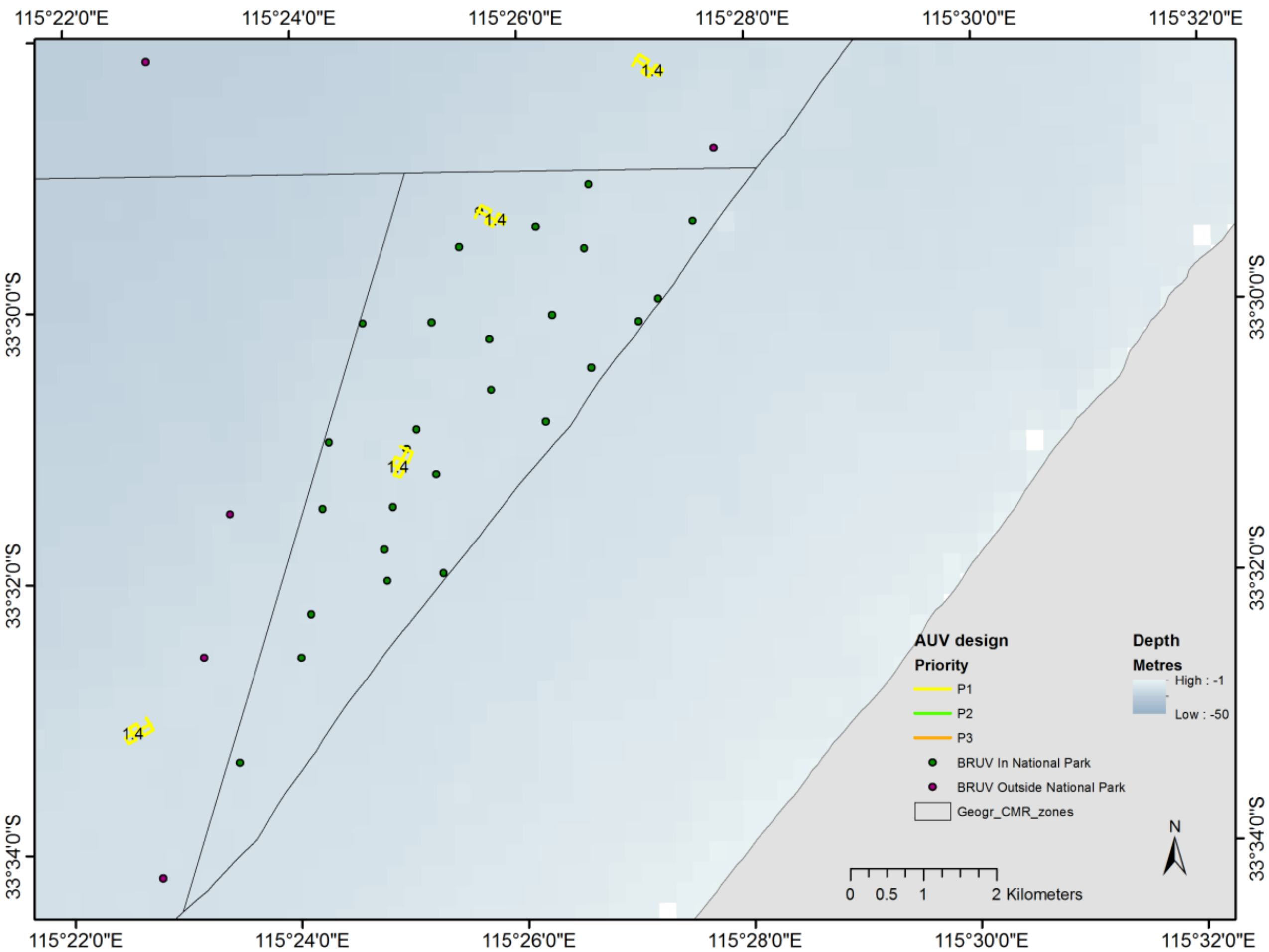

Figure 18 AUV sampling locations inside and outside eastern National Park

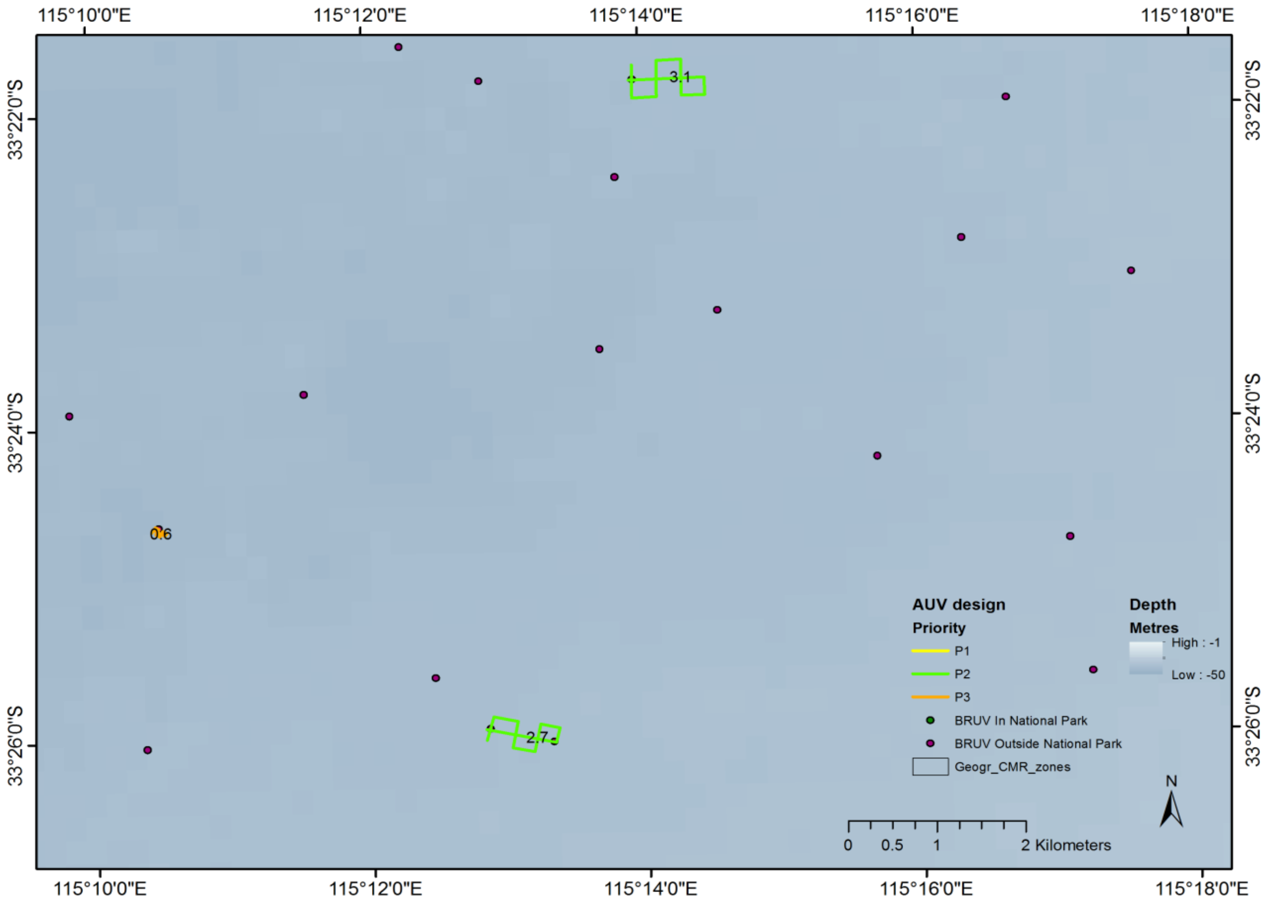

Figure 19 A subset of AUV sampling locations in deeper water

3.3.2 Data collection

Between 2000 and 12000 high-resolution images (each capturing approximately 2 x 1.5 m of seabed) were collected at each site, depending on the length of the transect. Every 100th image (approximately 1%) along the transect was scored (Hill et al. 2014) using a Macro developed in Excel to classify habitats (Figure 14). Substrate was categorised as either hard (reef/rock), soft (sediment) or mixed, with options to further describe the structure/texture of these components. Dominant biota was categorised as algae, seagrass or sessile invertebrates, with the option to further describe the biota according to CATAMI classifications (algae and inverts) or by genus (seagrass). Estimation of percent cover was also recorded for each of the broad substrate and biota categories.

As the AUV data was collected towards the end of the project there was insufficient time to undertake the fine-scale scoring protocol developed under the NERP Marine Biodiversity Hub. This will be completed and analysed as a priority in the near future.

The full, geo-referenced dataset from the AUV survey is still being processed with intentions of storing it on Squidle (http://squidle.acfr.usyd.edu.au/).

3.3.3 Statistical analysis

Given the limited time available to analyse the AUV data, the AUV images were only scored according to basic habitat categories (sand, reef, mixed) and the presence/absence of seagrass, algae, sponges and coral. The exact geographic location of each image was also unavailable so the images were grouped at the area level when presenting the summary information for each of the biota categories. More detailed, geo-referenced data will be available at a later date.

4. RESULTS

4.1 BRUVs

4.1.1 GRTS sites

The results in this subsection are based only on the 129 BRUV sites that were selected using GRTS that resulted in scoreable video footage (the remaining sites were either missed in the field, incorrectly located or resulted in an upward facing camera or failed in the field preventing the habitat from being scored). The estimates in this section can be considered an unbiased representation of the CMR. Sites with at least 75% reef were classified as Reef while sites with less than 75% reef were classified as Mixed even if only a small amount of reef was present.

The GRTS habitat estimates (Table 2) show that approximately 6% of sites in the Marine National Park Zones have at least 75% reef and 39% of sites with at least a small amount of reef (Reef + Mixed). Outside the Marine National Park Zone 1% of sites are largely reef with 19% containing some reef.

	Sand	Reef	Mixed
In Marine National Park Zone	0.606 (0.454,0.759)	0.061 (0.000,0.128)	0.333 (0.193,0.473)
Outside Marine National Park Zone	0.802 (0.736,0.869)	0.010 (0.000,0.027)	0.177 (0.114,0.241)

Table 2 Proportion of GRTS sites and 95% confidence intervals (in brackets) falling into each habitat category

The locations of the Reef, Sand and Mixed sites are plotted in Figure 20. The presence of reef is spread fairly well through the entire CMR with a concentration of sites in and around the eastern Marine National Park Zone.

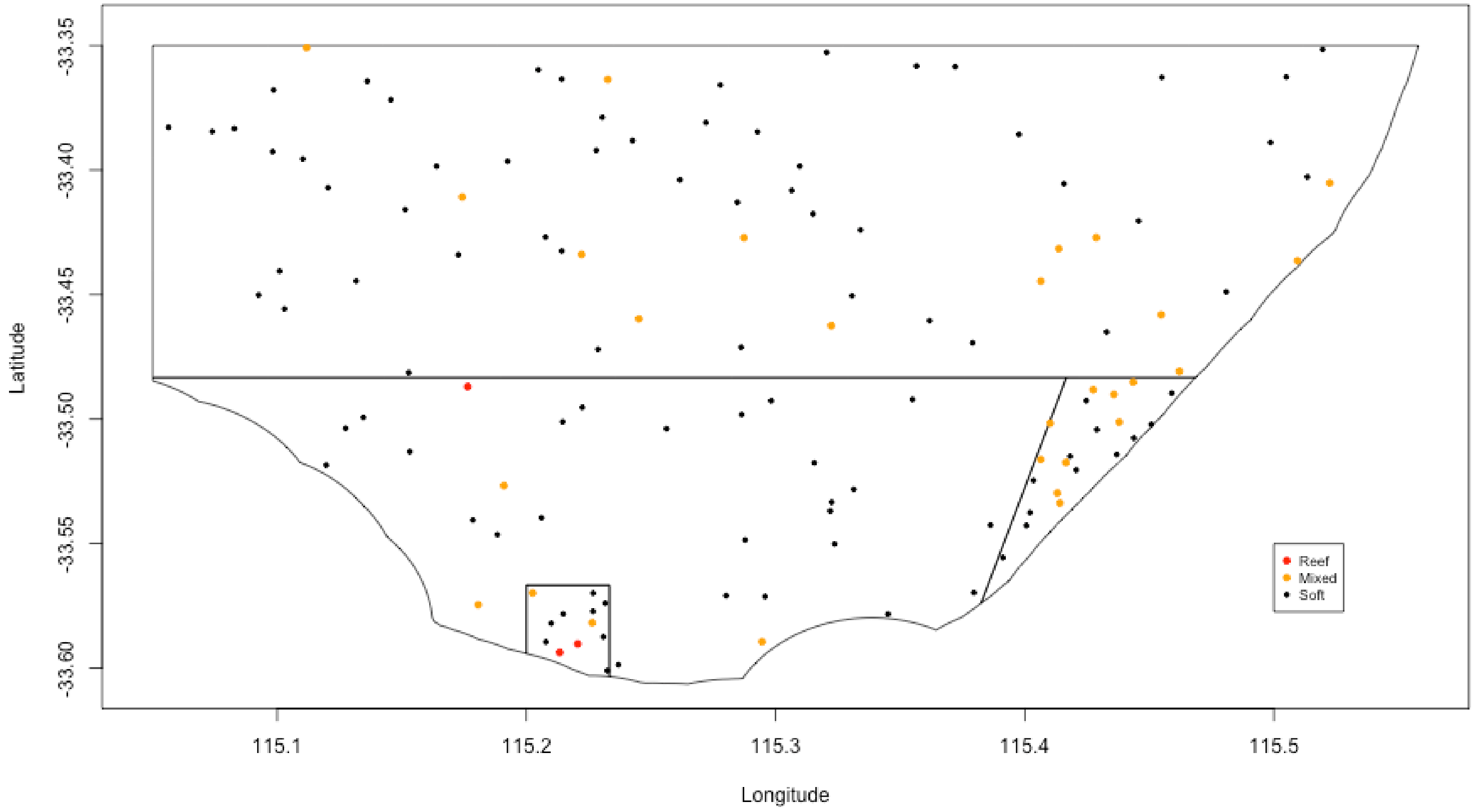

Figure 20 GRTS sites classified into Reef, Mixed and Soft (Sand)

Sites were scored according to the percent coverage of seagrass (None 0%), Trace 0-1%, Sparse 1 - 10%, Low >10 – 25%, Medium >25 – 50%, Dense >50 – 75%, Very dense >75%). Table 3 shows a breakdown of the results by category. At least sparse cover of seagrass was found at 54% of sites (95% confidence interval 47-62%) outside the Marine National Park Zones and 73% (95% confidence interval 60-87%) in the Zones. In particular, almost half of the sites in the Marine National Park had dense (>50% cover) seagrass coverage. Dominant seagrass species were *Amphibolis antarctica*, *Posidonia sinuosa* and *Posidonia coriacea.* Other seagrass species included *Amphibolis griffithii, Posidonia australis, Posidonia angustifolia, Halophila ovalis, Thalassdendron pachyrhizum* and *Zostera* spp.

Percent cover	Outside Marine National Park Zones	Inside Marine National Park Zones
0 (None)	43 (45%)	8 (24%)
0-1 (Trace)	1 (1%)	1 (3%)
1-10 (Sparse)	4 (4%)	1 (3%)
11-25 (Low)	11 (11%)	4 (12%)
26-50 (Medium)	12 (13%)	4 (12%)
51-75 (Dense)	16 (17%)	10 (29%)
>75 (Very dense)	9 (9%)	6 (18%)

Table 3 Number of sites falling into each of the seagrass percent cover categories. The percentage of sites in and outside of the Marine National Park Zones falling into each category is listed in brackets.

Figure 21 shows sites with seagrass present. Seagrass is extensive through the whole CMR with the exception of the north west corner.

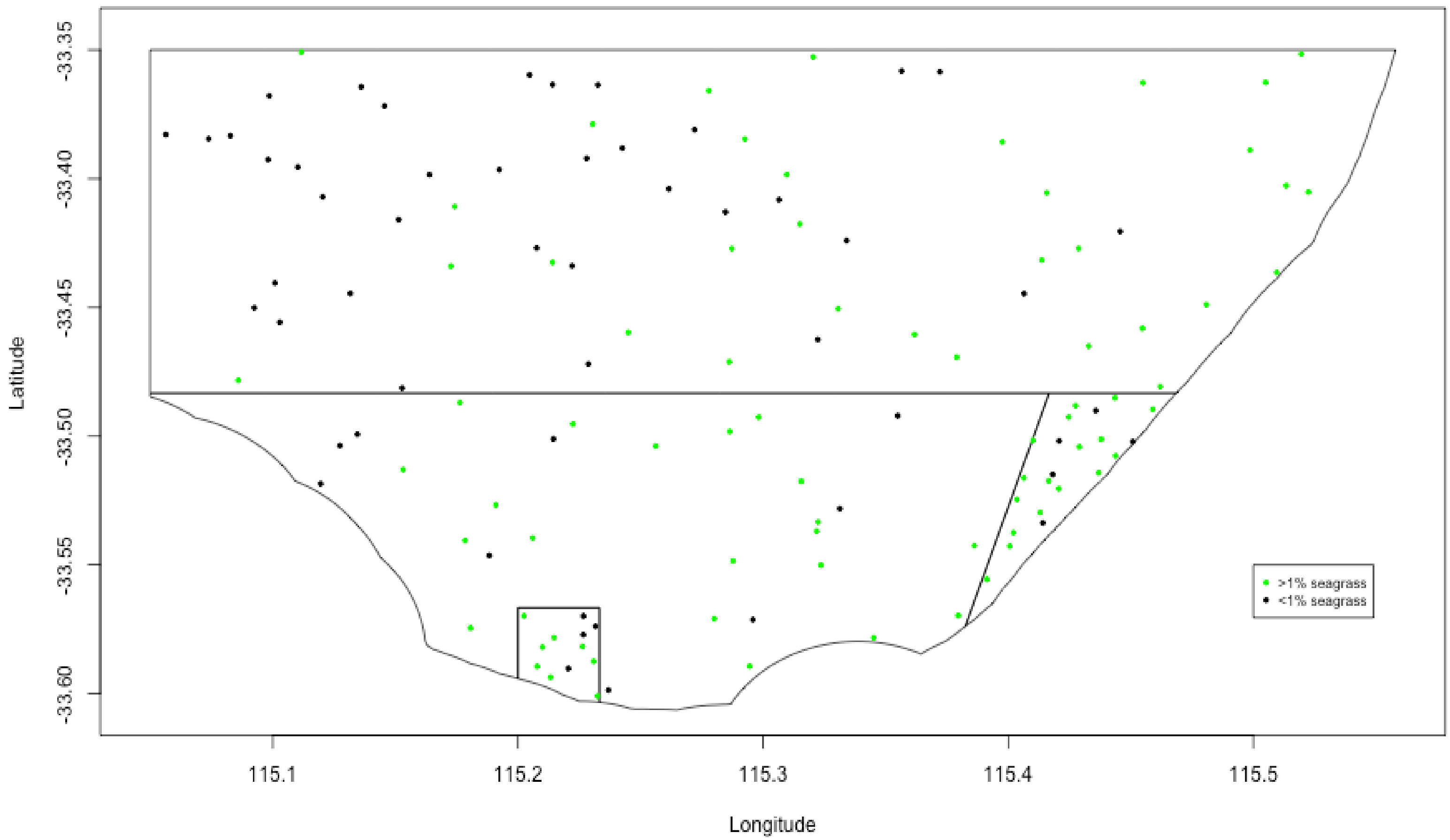

Figure 21 Presence of seagrass at the GRTS sites

Sites were scored according to the percent coverage of invertebrates (None 0%, Trace 0-1%, Sparse 1 - 10%, Low >10 – 25%, Medium >25 – 50%, Dense >50 – 75%, Very dense >75%). Table 4 shows a breakdown of the results by category. Invertebrates were found at 32% of sites outside the Marine National Park Zones and 24% in the Zones (Figure 22).

Percent cover	Outside Marine National Park Zones	In Marine National Park Zones
0 (None)	65 (68%)	26 (76%)
0 -1 (Trace)	16 (17%)	6 (18%)
1-10 (Sparse)	13 (13%)	1 (3%)
11-25 (Low)	1 (1%)	1 (3%)
26-50 (Medium)	1 (1%)	0 (0%)
51-75 (Dense)	0 (0%)	0 (0%)
>75 (Very dense)	0 (0%)	0 (0%)

Table 4 Number of sites falling into each of the Invertebrates percent cover categories. The percentage of sites in and outside of the Marine National Park Zones falling into each category is listed in brackets

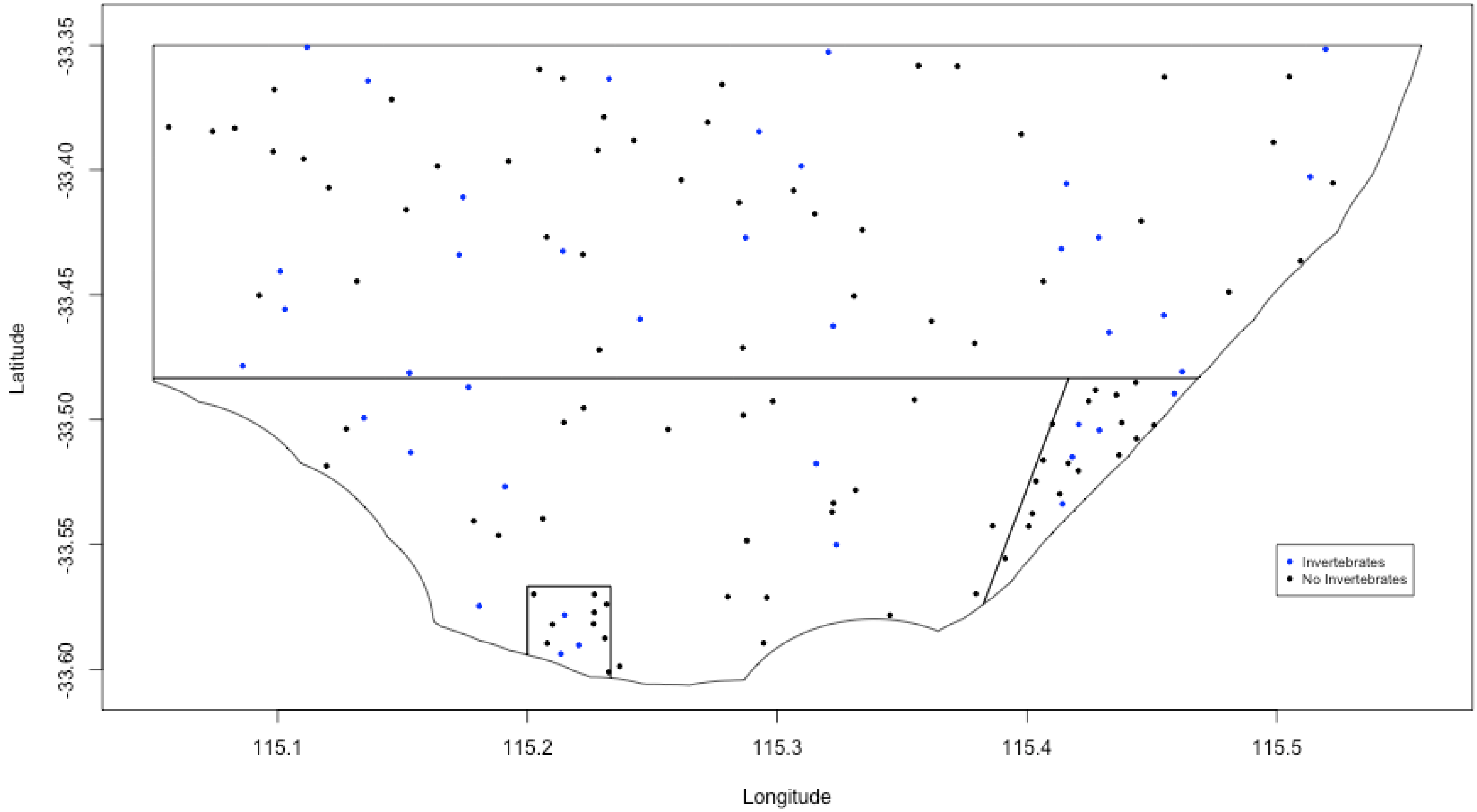

Figure 22 GRTS sites showing presence of invertebrates

Sites were scored according to the percent coverage of algae (None 0%, Trace 0-1%, Sparse 1 - 10%, Low >10 – 25%, Medium >25 – 50%, Dense >50 – 75%, Very dense >75%). Table 5 shows a breakdown of the results by category. Algae were found at 49% of sites outside the Marine National Park Zones and 65% in the Zones (Figure 23).

Percent cover	Outside Marine National Park Zones	Inside Marine National Park Zones
0 (None)	49(51%)	12 (35%)
0-1 (Trace)	1 (1%)	2 (6%)
1-10 (Sparse)	7 (7%)	4 (12%)
11-25 (Low)	15 (16%)	2 (6%)
26-50 (Medium)	15 (16%)	7 (20%)
51-75 (Dense)	7 (7%)	5 (15%)
>75 (Very dense)	2 (2%)	2 (6%)

Table 5 Number of sites falling into each of the algae percent cover categories. The percentage of sites in and outside of the Marine National Park Zones falling into each category is listed in brackets

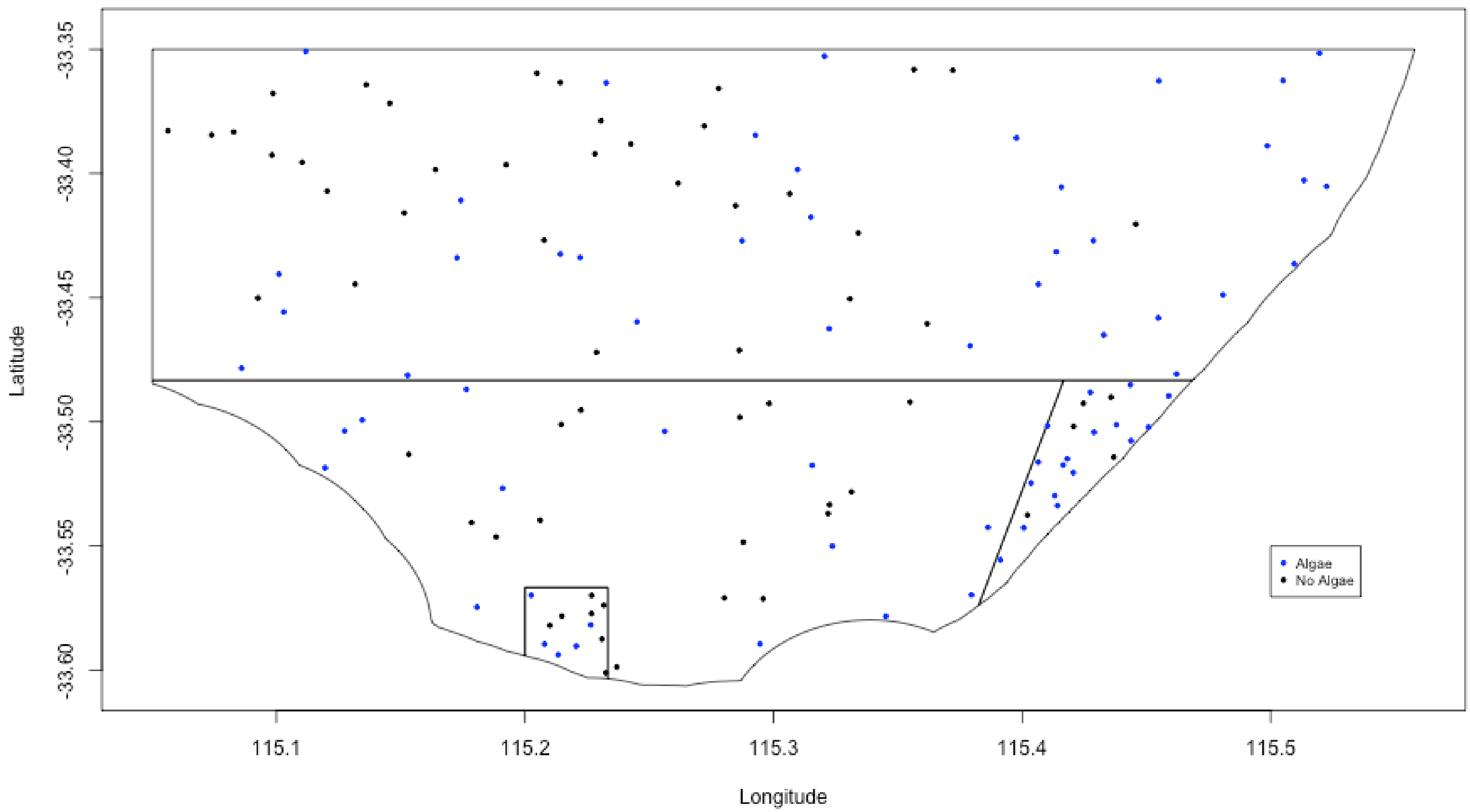

Figure 23 GRTS sites showing the presence of algae

4.1.2 Target sites

There were 38 sites targeted in the field that resulted in scoreable video footage. These sites were selected based on expert opinion (the knowledge of the skipper) in the field as being highly likely to either have a large amount of seagrass or reef present. The presence of seagrass and reef are shown in Figure 24 and Figure 25 respectively. Of particular note is the deep seagrass bed in Figure 24 and the presence of reef in the eastern National Park Zone (Figure 25). Combining these targeted sites with the GRTS sites (Figure 26 and Figure 27 respectively) highlight the large amount of seagrass in the CMR, particularly in the deeper areas, and the density of reef in the eastern Marine National Park Zone.

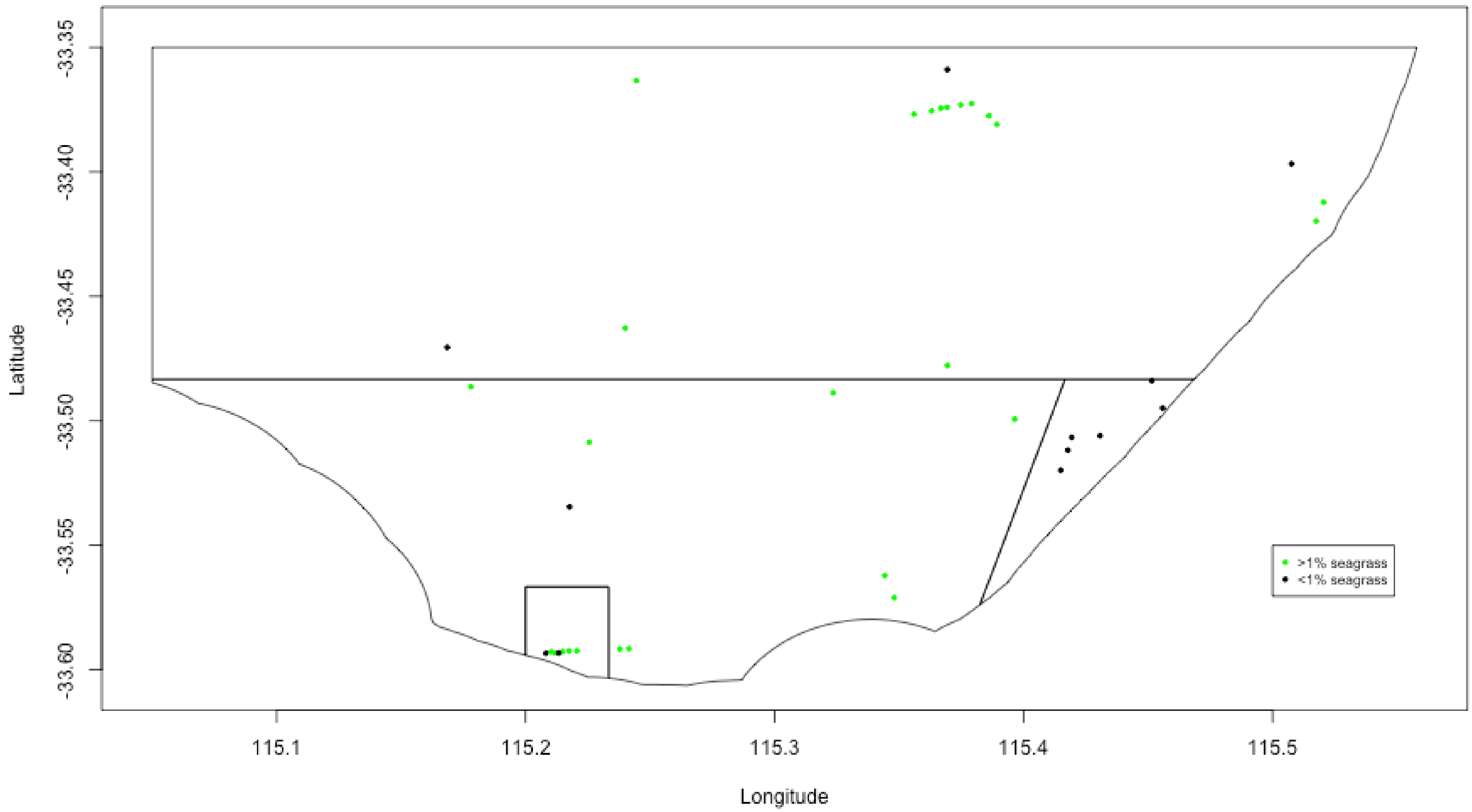

Figure 24 Targeted sites with and without seagrass

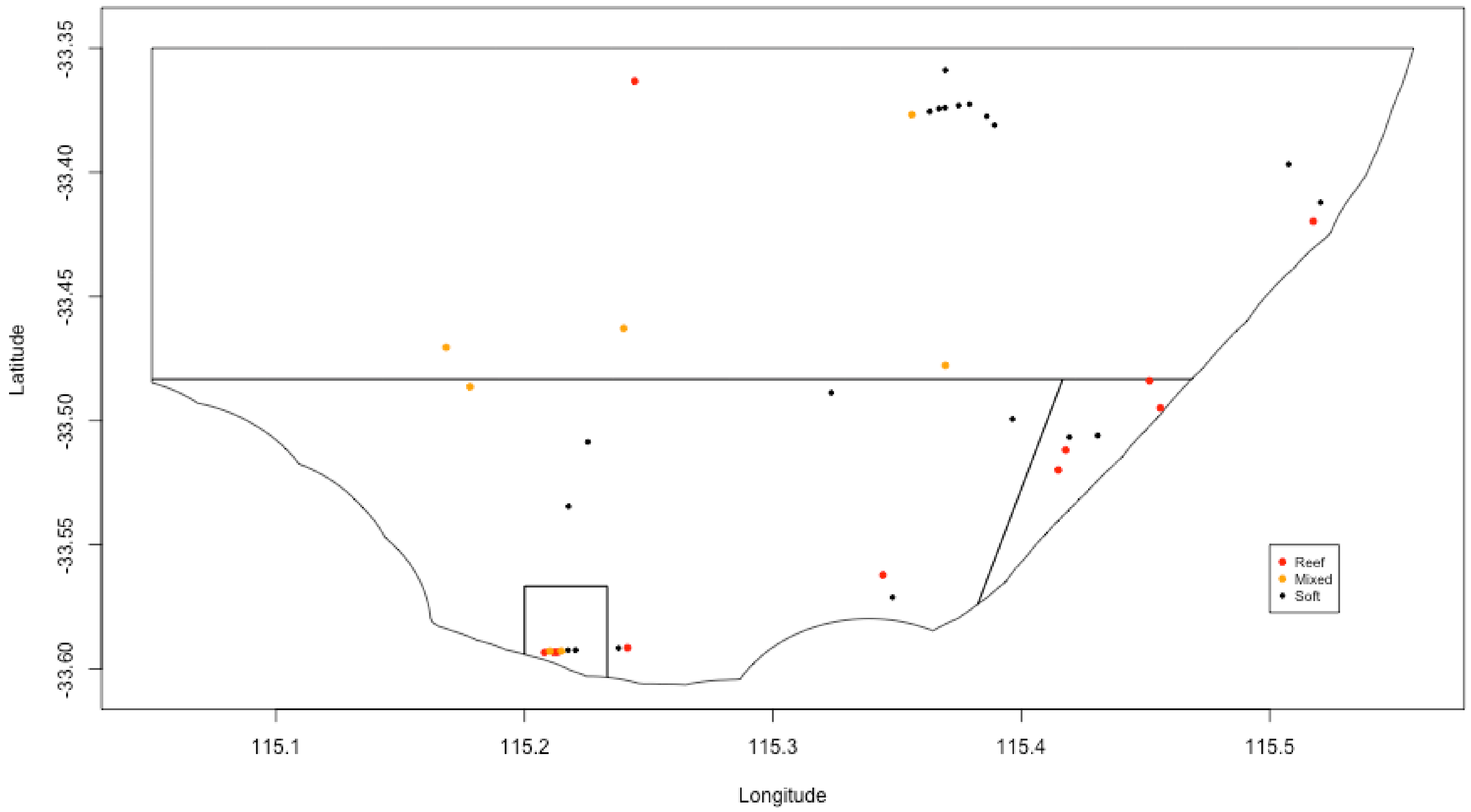

Figure 25 Targeted sites classified as Reef, Mixed or Soft (Sand)

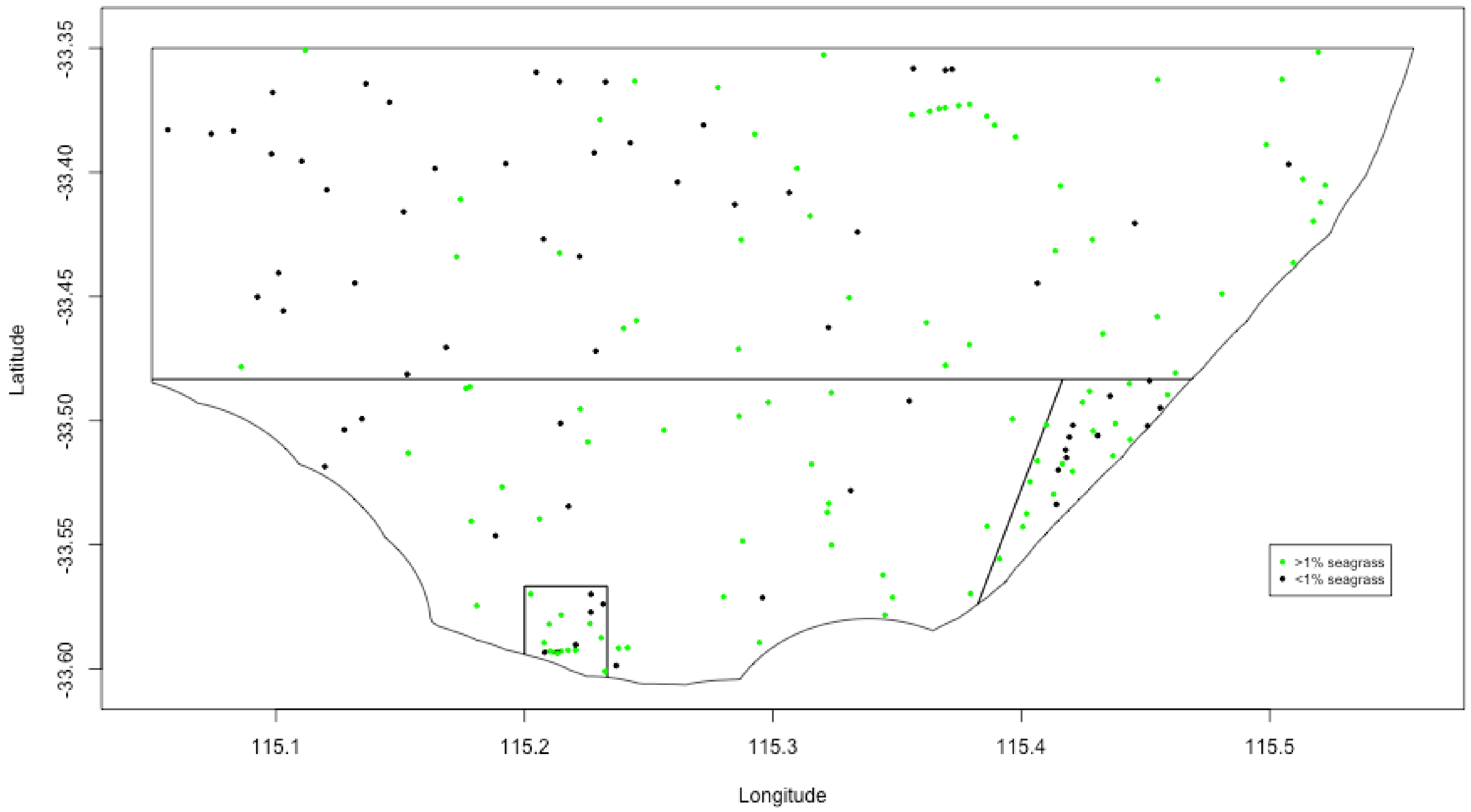

Figure 26 All sites classified as with/without seagrass

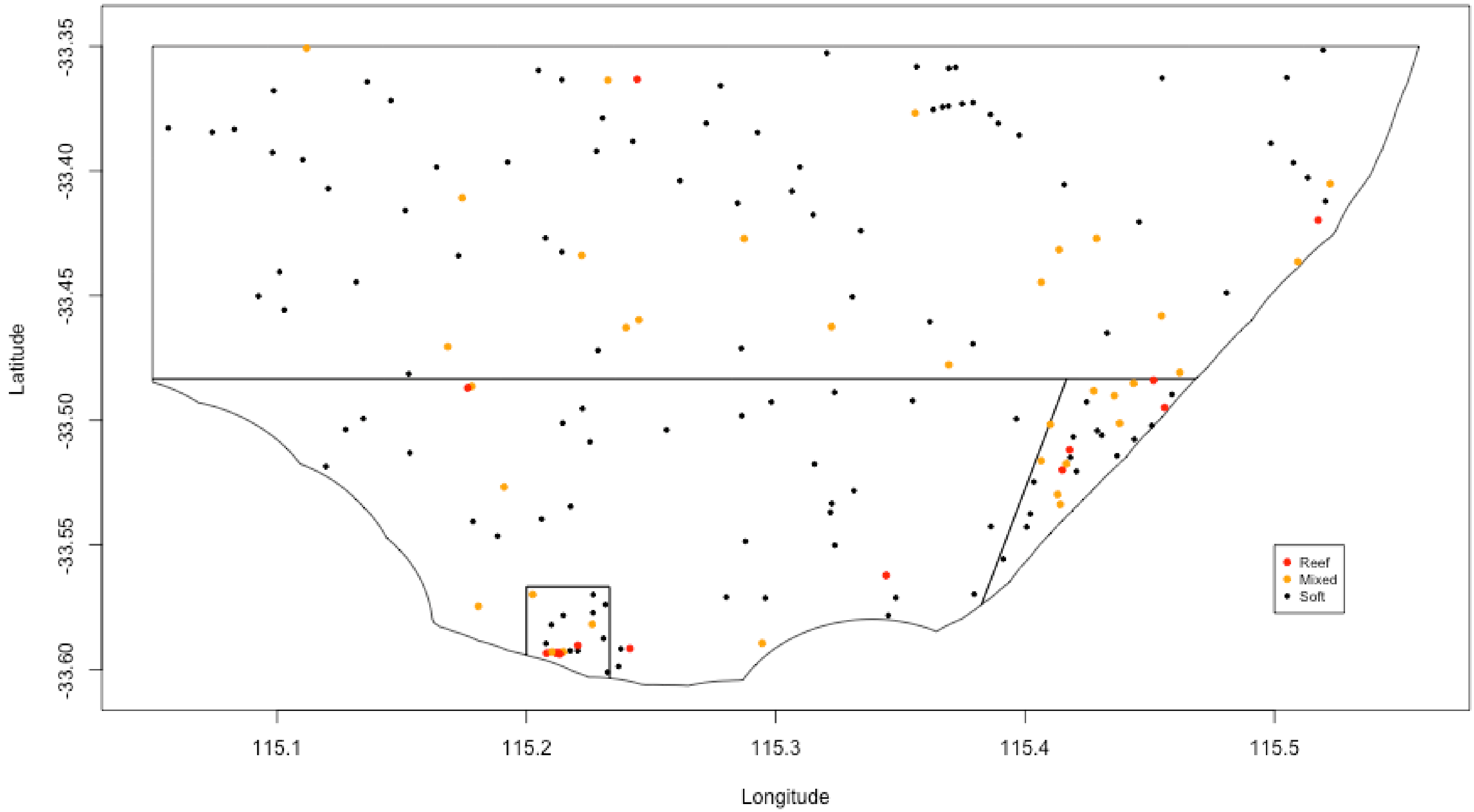

Figure 27 All sites classified as Reef, Mixed or Soft (Sand)

4.1.3 Fish assemblages

We recorded 8086 fish from 148 species. Some species could not be identified to species level (eg *Apogonidae spp, Bothidae spp, Decapterus spp*) due to their size and the resolution of the video and were pooled to family level for the statistical analysis.

The PERMANOVA revealed depth as a significant covariate while both substratum and dominant biota were statistically significant (Table 6).

Source	df	Sums of squares	Mean squares	Pseudo-F	*p* values
Depth (m)	1	41743	41743	20.636	0.0001
Dominant Biota	2	48328	24164	11.788	0.0001
Substratum	2	16605	8302.3	4.05	0.0001
Substratum x Dominant Biota	2	5212.7	2606.3	1.271	0.1695
Res	153	313640	2049.9		
Total	160	425530			

Table 6 Results from a two-factor PERMANOVA for the fish assemblages in Geographe CMR

We ran a Canonical Analysis of Principal Coordinates (CAP) for Substratum (Sand, Reef and Mixed) and Biota combined to visualise whether the same location pattern seen in the PERMANOVA results was apparent (Figure 28). There was separation between samples on sand with no vegetation, samples with Sand and Seagrass and samples with Reef and Algae. A significant trace statistic (P<0.001) supports the PERMANOVA results that the composition of the fish assemblages differs between substratum and biota types. Vectors for fishes with a Pearson Correlation of 0.5 or greater are overlaid on the CAP to demonstrate the benthic habitat/substratum affiliations.

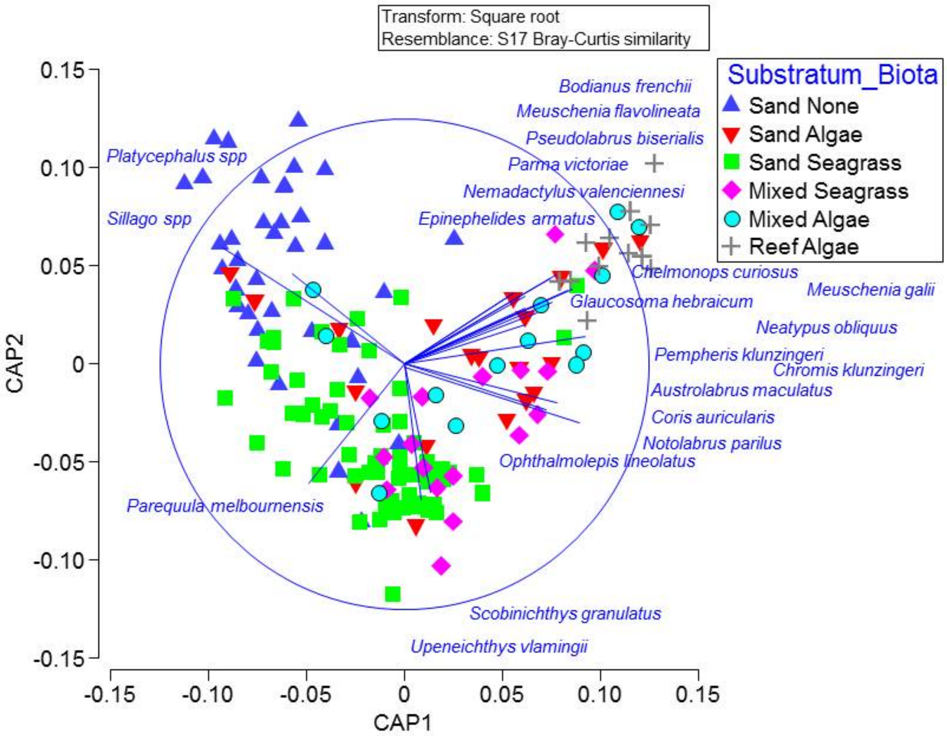

Figure 28 Canoncial Analysis of principle coordinates for the combination of Substratum and dominant Biota.

A DISTLM showed that all the environmental variables measured had a significant influence on the composition of the fish assemblage accounting for 27.83 % of the variation in the fish assemblage. The Marginal tests for the DISTLM (Table 7) showed that algae accounted for the most variation within the assemblage (14.84%) followed by depth (9.8%) and the presence of reef or sediment (9.22 % each).

Variable	**SS(trace)**	**Pseudo-F**	***p***	**Prop.**
Depth	41743	17.294	0.0001	0.098096
Invertebrates	32908	13.327	0.0001	0.077334
Algae	63178	27.723	0.0001	0.14847
Seagrass	32678	13.226	0.0001	0.076794
Sediment	39234	16.149	0.0001	0.092201
Reef	39234	16.149	0.0001	0.092201
Soft	34596	14.071	0.0001	0.081302
Mixed	13121	5.0586	0.0003	0.030834

Table 7 A distance based linear model testing the influence of environmental variables measured

The BEST solution (AIC = 1526 and R^2 = 27.83) chose Depth, Invertebrates, Algae, Seagrass and either Sediment or Reef as the variables most influencing the model.

This is supported visually by a distance-based redundancy analysis which visualises the composition of the fish assemblage and the correlations with the six environmental components chosen.

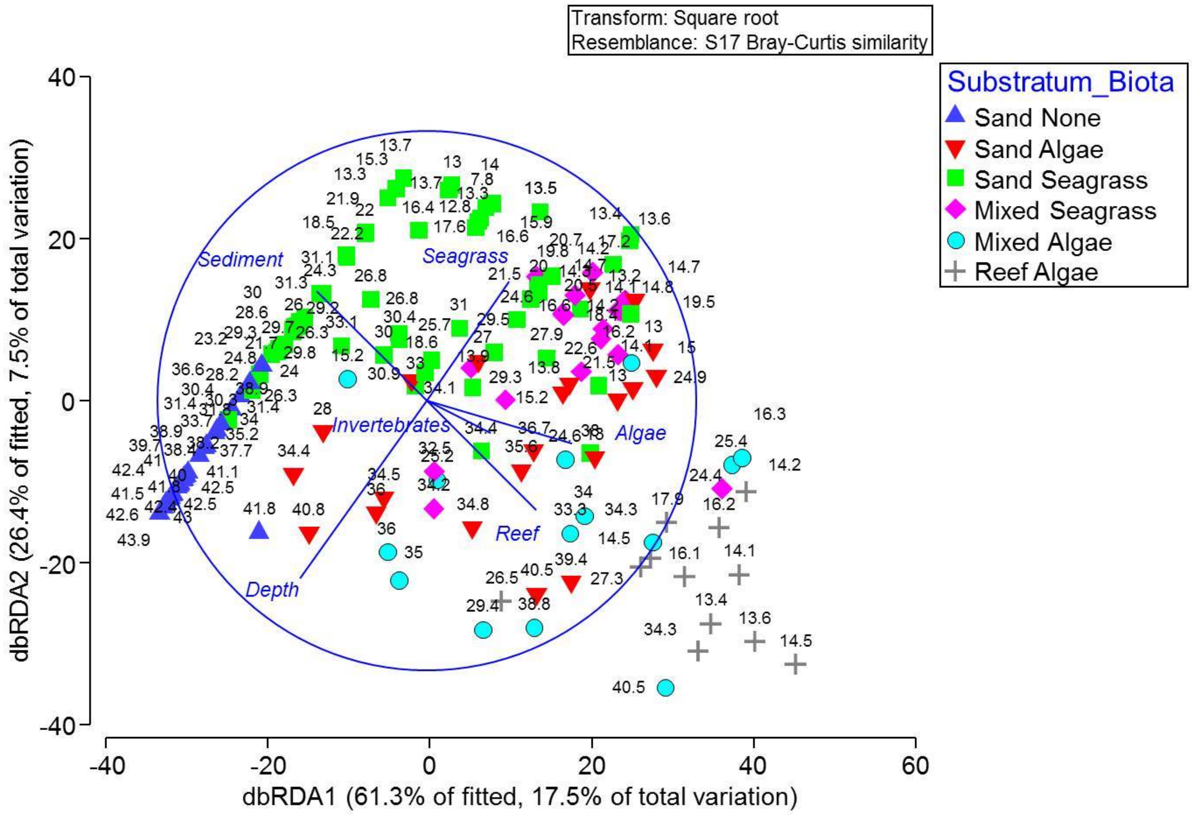

Figure 29 A distance-based redundancy analysis. The point labels represent depth at the site.

4.1.4 Univariate analysis

A significantly greater number of species and individual fish were found on Reef substratum in comparison to Mixed or Sand (Figure 30).

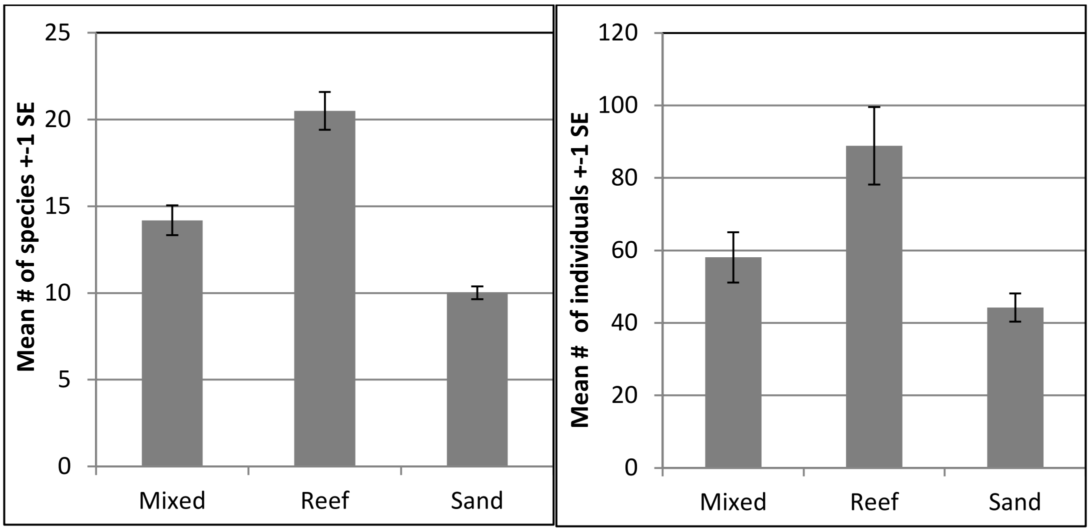

Figure 30 The mean number of species and individual fish on mixed, reef and sand substratum

The species found in the greatest numbers were *Coris auricularis* (mean = 6.9), *Neatypus obliquus* (2.7), *Parequula melbournensis* (5.5), *Pempheris klunzingeri* (3.8), *Pseudocaranx spp* (8.6) and *Trachurus novaezelandiae* (4.9). There were significantly more *Platycephalus* spp in sand habitats where there was no vegetation compared to any other habitat (Figure 31). *Sillago spp* were generally only found in sandy habitat but mostly in particular areas with no vegetation (Figure 32). *Upeneichthys vlamingii* were found in all substratum with a preference for seagrass habitat (Figure 33).

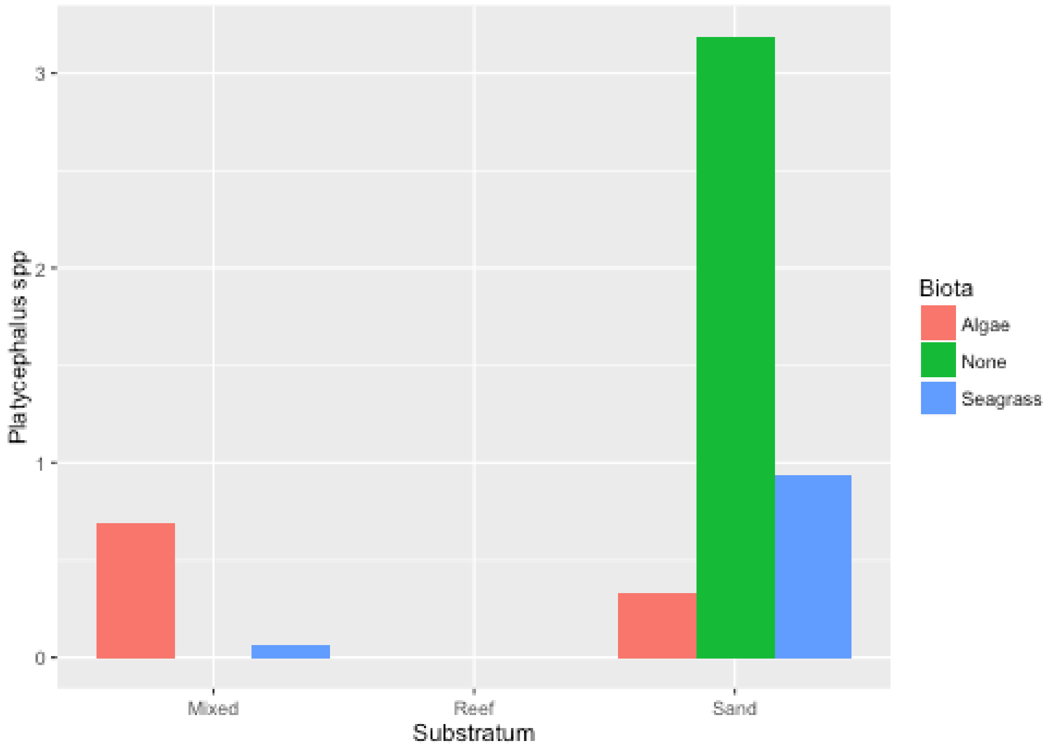

Figure 31 The mean MaxN of *Plactycephalus spp* by Substratum and Biota

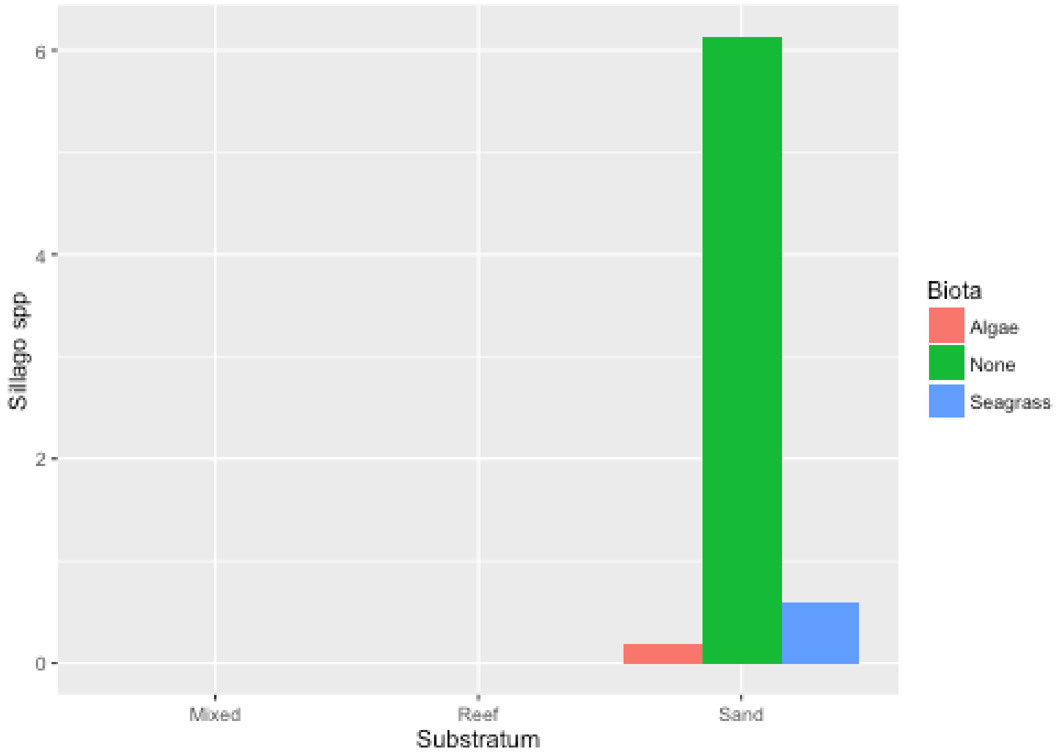

Figure 32 The mean MaxN of *Sillago spp* by Substratum and Biota

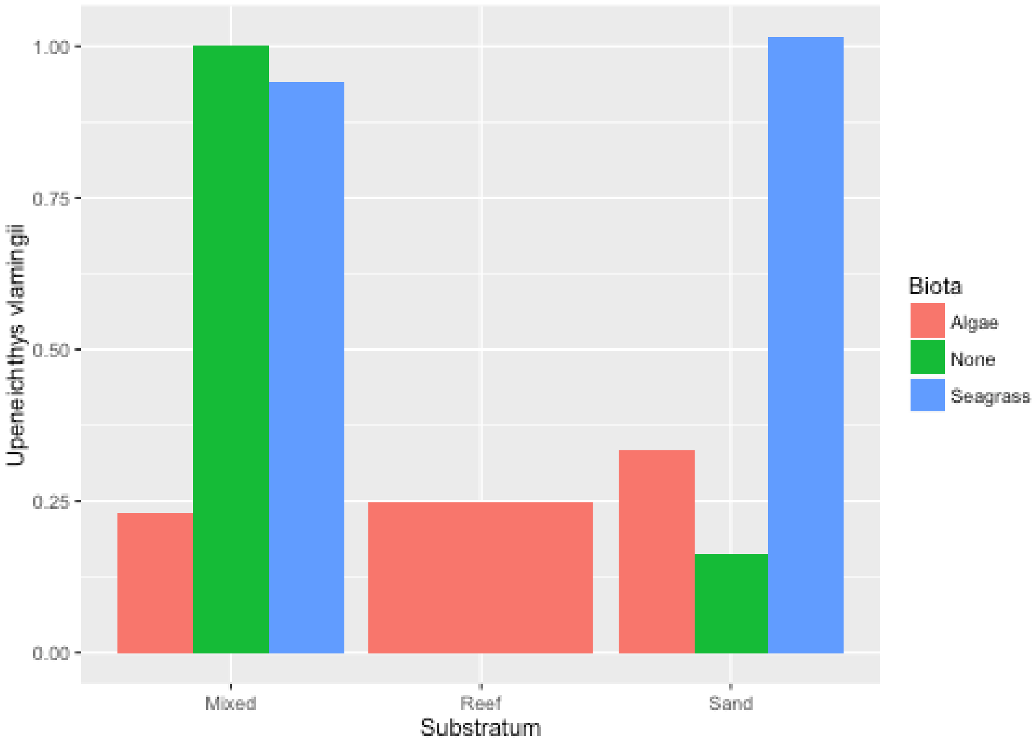

Figure 33 The mean MaxN of *Upeneichthys vlamingii* by Substratum and Biota

Notolabrus parilus and *Coris auricularis* were found across all substratum and biota, with counts highest in reef habitats and a preference for some vegetation over none (Figure 34 and Figure 35 respectively).

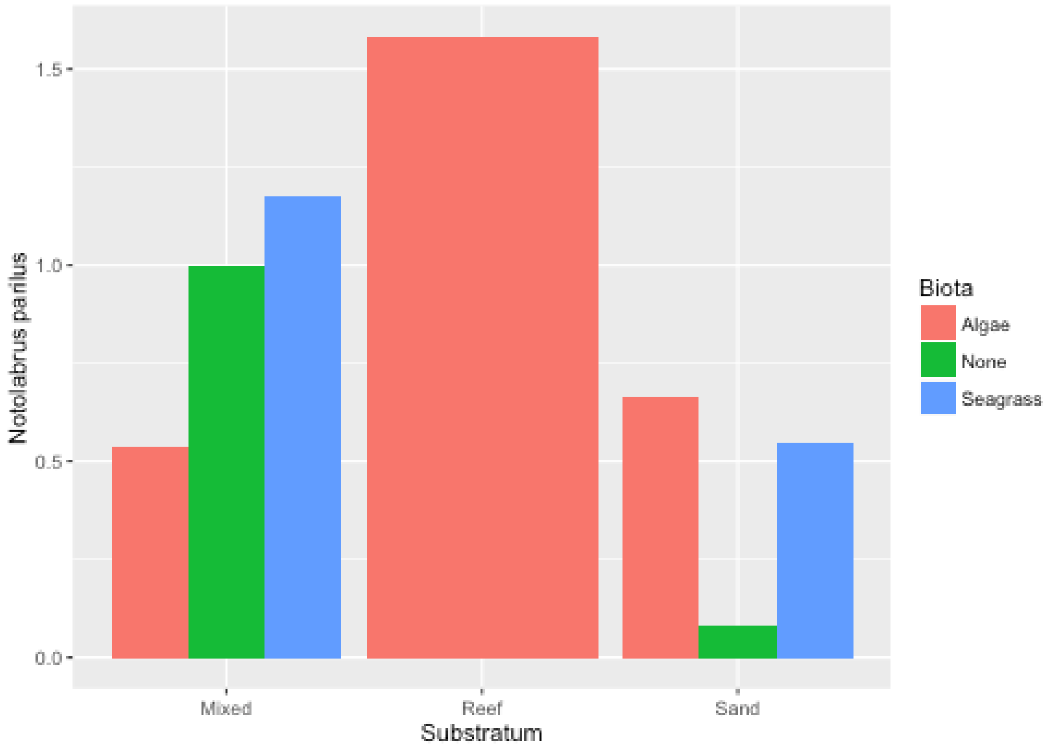

Figure 34 The mean MaxN of *Notolabrus parilus* by Substratum and Biota

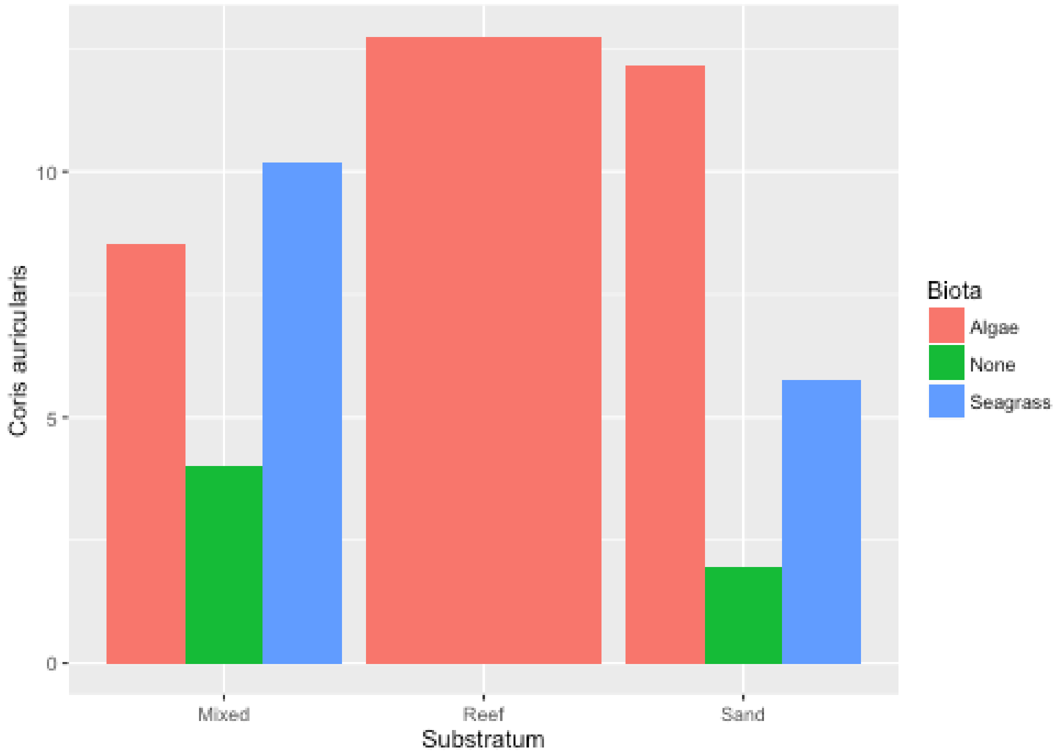

Figure 35 The mean MaxN of *Coris auricularis* by Substratum and Biota

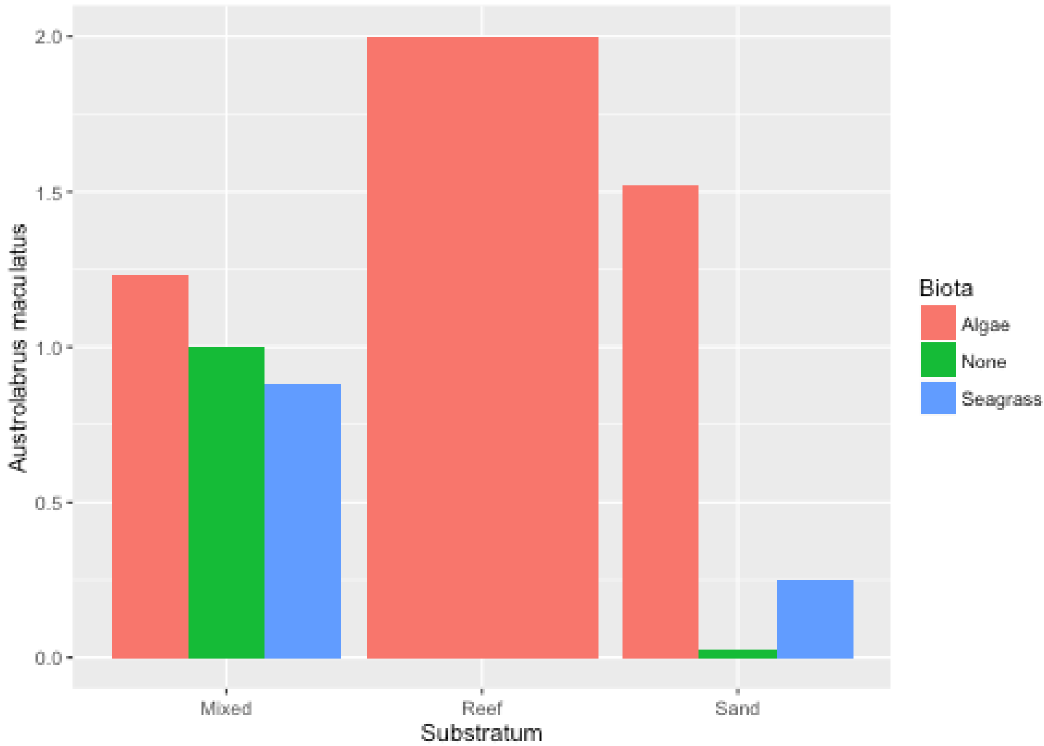

Figure 36 The mean MaxN of *Austrolabrus maculatus* by Substratum and Biota

Austrolabrus maculatus were found across all substratum (Figure 36). In sandy areas there were many more in areas with algae compared to seagrass or no vegetation.

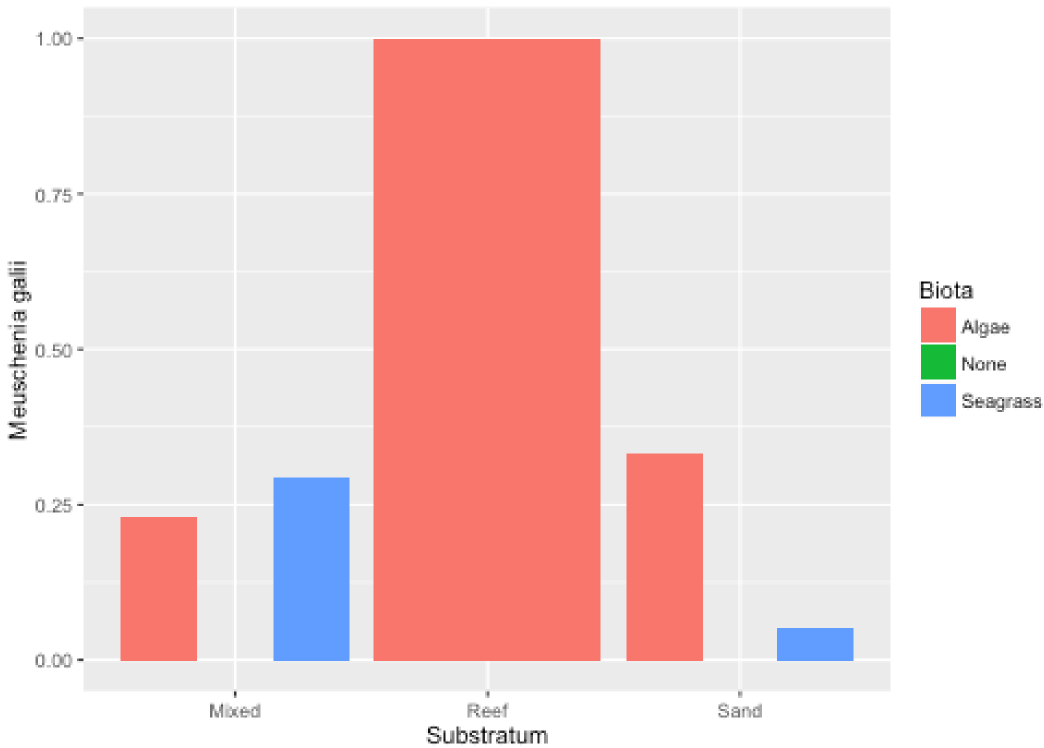

Figure 37 The mean MaxN of *Meuschenia galii* by Substratum and Biota

There were no *Meuschenia galii* or *Glaucosoma hebraicum* in areas with no vegetation (Figure 37 and Figure 38 respectively).

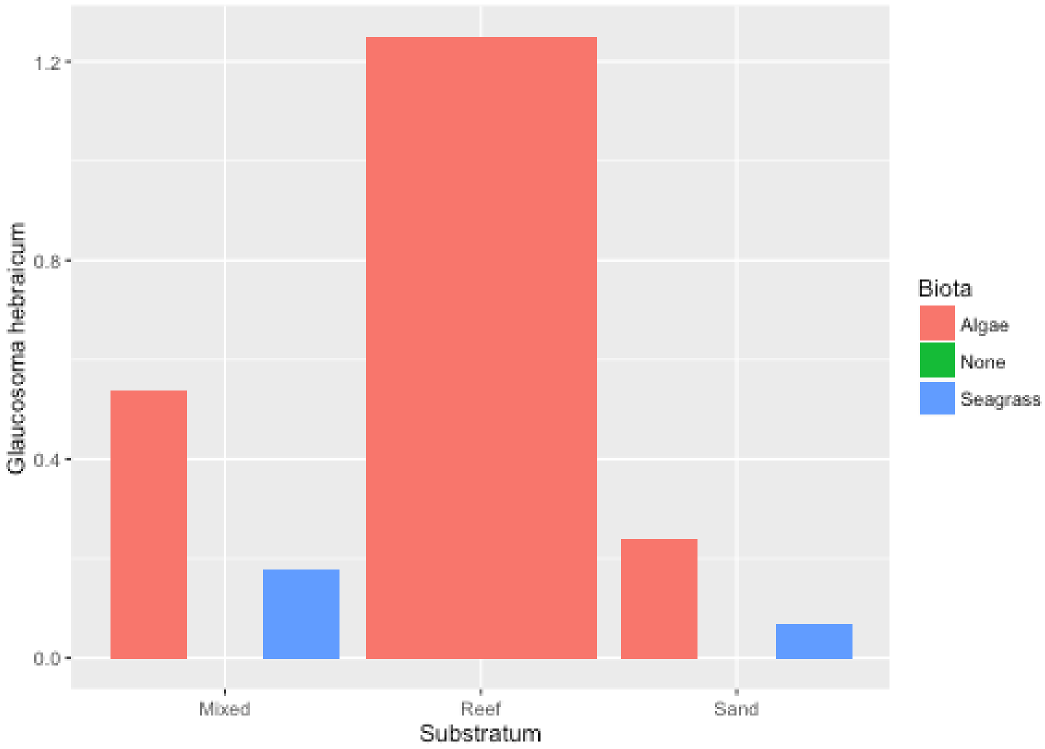

Figure 38 The mean MaxN of *Glaucosoma hebraicum* by Substratum and Biota

4.2 AUV

The proportion of images in each of the substratum categories (number of images in category divided by total number of images) at the AUV sites is summarised in Table 8. The greatest amount of reef was found Outside the Park east (49%) followed by Offshore Mid (12%) and Inside Park east (9%). It should be noted that these sites were selected by hand and therefore are indicative only of these particular sites and not the surrounding areas. Except for the offshores sites, the aggregated biota results (Table 9) indicate at least 50% of sites' habitats comprised some seagrass. Some examples of the AUV footage are given in Figure 39.

	Inside Park east	**Inside Park west**	**Offshore Deep**	**Offshore Mid**	**Outside Park east**	**Outside Park west**
Reef	0.091	0.072	0.019	0.118	0.486	0.012
Mixed	0.091	0.145	0.528	0.217	0.095	0.241
Obscured reef	0.106	0.000	0.000	0.034	0.007	0.012
Sand	0.712	0.783	0.453	0.631	0.412	0.735

Table 8 Proportion of images falling into each of the substratum categories at the AUV sites

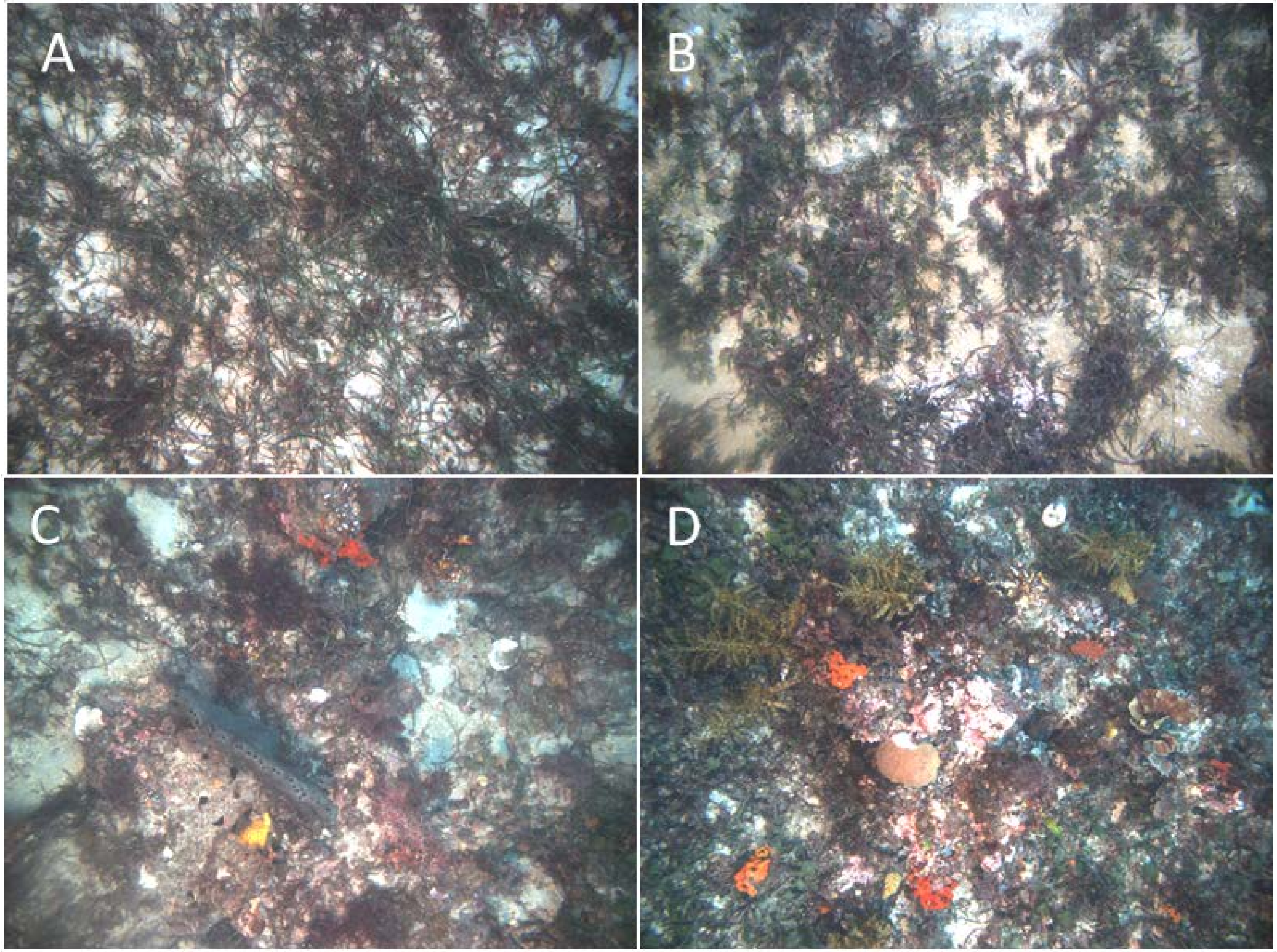

Figure 39 Images from the AUV showing key habitats inside the Geographe Bay National Parks. A) Sand habitat with *Posidonia* meadow, B) Sand habitat with *Amphibolis* meadow, C) Mixed sand and reef habitat with sponges and corals, D) Reef habitat with algae, sponges and corals.

	Inside Park east	Inside Park west	Offshore Deep	Offshore Mid	Outside Park east	Outside Park west
Algae	0.030	0.000	0.024	0.105	0.013	0.000
Algae and coral	0.000	0.000	0.000	0.003	0.000	0.000
Algae and sponges	0.106	0.013	0.506	0.276	0.026	0.012
Algae, sponges and coral	0.015	0.000	0.108	0.053	0.000	0.000
No biota	0.015	0.154	0.325	0.385	0.091	0.000
Seagrass	0.152	0.410	0.000	0.125	0.156	0.023
Seagrass and algae	0.409	0.308	0.012	0.023	0.571	0.640
Seagrass, algae and sponges	0.212	0.051	0.012	0.013	0.143	0.267
Seagrass, algae and coral	0.000	0.000	0.000	0.003	0.000	0.000
Seagrass, algae, sponges and coral	0.015	0.026	0.000	0.000	0.000	0.058
Seagrass and sponges	0.030	0.013	0.000	0.007	0.000	0.000
Sponges	0.015	0.013	0.012	0.007	0.000	0.000
Sponges and coral	0.000	0.013	0.000	0.000	0.000	0.000

Table 9 Proportion of images falling into each of the biota categories at each of the AUV sites

5. DISCUSSION

5.1 Key findings and new knowledge

The majority of Geographe CMR seafloor is covered by unconsolidated sediments, deposited over older clay layers and limestone formations. These limestone formations tend to be long and narrow, creating bands of hard substrate surrounded by unconsolidated sediments. Inside the Marine National Park Zones approximately 40% of the area is reef or mixed reef and sand, while in the combined Multiple Use and Special Use Zones approximately 20% of the sites fall into these categories. These estimates are much higher than were expected based on past knowledge of these areas. The spatial extent of reef was greater than expected, consisting of more than thin, linear ridges as previous surveys have shown and is instead spread through the entire CMR with a concentration of sites in and around the eastern National Park Zone. Linear reef features appear to prevail nearshore in the western National Park Zone, potentially reflecting ancient coastlines.

It was known that nearshore sandy substrate had extensive seagrass beds and thought that they patchily extended into deeper waters, but we now know that there are some areas of extensive seagrass in the deeper waters of the CMR. We estimate 54% of the CMR outside the Marine National Park Zones contain seagrass and 73% in the Zones. In particular, almost half of the sites in the Marine National Park Zones had dense (>50%) seagrass coverage.

Amphibolis and *Posidonia* are the dominant seagrass genera in temperate Australia and were found throughout Geographe CMR. They were particularly dominant between 3 m and 15 m water depth, appearing to form a continuous seagrass landscape (meadows) with patches of reef and bare sand extending throughout the nearshore area. The overall extent of this seagrass landscape is comparative to continuous *Amphibolis* and *Posidonia* meadows found in Shark Bay, which has some of the largest seagrass meadows in the world (Walker et al. 1988). Unlike Shark Bay, however, both these genera are still prevalent in Geographe Bay to approximately 35 m water depth. Seagrass distribution in deeper water is in more patchy configurations, with bare sand dominating the landscape.

A total of 148 species was recorded using BRUVs. The species found in the greatest numbers were *Coris auricularis*, *Neatypus obliquus, Parequula melbournensis*, *Pempheris klunzingeri*, *Pseudocaranx spp* and *Trachurus novaezelandiae*. The fish assemblage patterns were shown to vary significantly by substratum and biota.

5.2 Survey design

The objectives of the baseline survey were three-fold, namely to estimate the proportion of major habitat types, document the fish assemblages and the macrofaunal assemblages (particularly in areas dominated by seagrass) within the CMR. Each of these objectives were largely achieved, although the AUV data requires further refinement and analysis to allow a more detailed study of the macrofaunal assemblages.

The survey approach proved an effective way to provide a CMR baseline and a consistent monitoring approach that will support future comparisons between CMRs and regions. However there were some issues with following the GRTS design that occurred in the field and resulted in a smaller than anticipated sample size. While the GRTS approach provides an excellent means of obtaining spatially-balanced samples that result in unbiased estimates and associated variance measures, difficulties in applying the approach can occur in the field. The nature of GRTS means that large distances separate samples adjacent in the master list so reordering needs to occur before teams head into the field. This reordering means that once a sample size is decided on it is very difficult and not cost-effective to add or remove samples once the sampling has started. In particular it is critical that field teams visit all GRTS sites once a sample size is decided on. In our case the reordering of sites led to some confusion in the field meaning that some sites were missed.

We supplemented the GRTS design with some targeted samples as the field team were concerned that we would not get adequate representation of reef and seagrass using solely a GRTS approach. In reality, the reef and seagrass areas were far more extensive than originally anticipated and the broad, spatially-balanced GRTS approach was able to identify the extent of these features. This highlights the need to ‘discover’ new areas using approaches such as (but not limited to) GRTS rather than returning to areas of known depth and breadth of biodiversity.

The combined random and targeted approach that we used for the BRUVs design allowed us to cover off on multiple objectives. However, this approach has led to a more complex dataset where only a subset of sites can be used for calculating unbiased estimates for benthic habitat so interpreting analyses based on the entire dataset should be undertaken with caution. The target sites should be considered representative of only themselves and not the CMR as a whole (although we would expect similarities between these sites and some others in the CMR).

The addition of a 3rd camera which pointed backwards was useful to better discriminate and document the benthic habitats in the stereo-BRUVs imagery. At times the fish that were being seen on the recordings were obviously associated with a reef habitat. The backward pointing camera allowed us to detect the dominant habitats that were often not recorded by the forward pointing cameras due to the random chance of the orientation of the system when it came to rest on the seafloor.

The AUV survey design was chosen to give a more detailed view of the macrofaunal assemblages across various sites within the CMR. We used the standard approach of broad grids given the tight time frames surrounding the work. However, more thought should be given to AUV designs in the future as we simply chose this approach as the field team were familiar with it (so we expected fewer problems) and it has been utilised in other nearby areas in the past.

5.3 Recommendations for future work

The Geographe CMR project has resulted in a successful baseline for monitoring for this CMR. Some additional work that would improve the understanding of the CMR and surrounds and utility of future monitoring include:

- *Analysing the existing BRUV data in conjunction with supplementary data*. Following the completion of the BRUVs field work undertaken for this project, Curtin University visited an additional 150 sites concentrated in the shallow areas towards the east of the CMR and the inshore areas outside of the CMR. Analysis of this data in conjunction with the existing dataset would allow comparisons between in and outside of the CMR. Curtin University also collected footage from extended stereo-video tows travelling from the coastline out to the CMR (approximately 23 m depth). This footage would provide a better understanding of the changes in the fish and macroalgal assemblages with distance from the shoreline.

- *Considering long-term monitoring*. This project has provided a baseline for monitoring, but we have not yet considered how to build on this baseline to create a long-term monitoring program eg. a rotating panel design? The GRTS master sample provides a foundation for incorporating information collected in future surveys in a statistically valid and efficient way.

- *Collecting multibeam*. There is some existing lidar data in the eastern inshore area overlapping the CMR. However, it would be beneficial to collect multibeam in some areas to start building a map of the CMR, with particular focus on offshore areas which are not covered by the existing lidar dataset. This will enable greater understanding of the function and significance of deepwater habitats.

- *Fine scale analysis of AUV imagery*. The AUV fieldwork and data analysis were completed under very tight time frames due to equipment failure and the limited time the AUV was available. For this reason the full geo-referenced imagery was not available at the time of project completion. Once this becomes available it would be beneficial to undertake final scale analysis of the AUV imagery using methods employed for other CMRs. This will give an assemblage level benchmark of key habitats inside and outside of Marine National Park Zones.

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