Offshore Marine Habitat Mapping and Near-shore Marine Biodiversity within the Coorong Bioregion

A report for the SA Murray-Darling Basin Natural Resource Management Board by the Department for Environment and Heritage, 2006.

Authors:
Jodie Haig (University of Adelaide, Adelaide, SA)
Bayden Russell (University of Adelaide, Adelaide, SA)
Sue Murray-Jones (Coastal Protection Branch, Department for Environment and Heritage, SA)

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Field Research Staff (in alphabetical order):
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Table of Contents

List of Figures

List of Tables

1.0 Executive Summary

The marine waters of the Coorong provide a diversity of habitat types for an abundance of highly endemic fauna and flora, some of which are of conservational significance. The SA Murray-Darling Basin Natural Resource Management Board recognises the environmental value of these Coorong marine areas as a high priority.

The dominant habitat types of the study area (within the offshore regions of the Coorong between Goolwa and "the Granites", a geological feature approximately 45 km north of Cape Jaffa) were largely unknown, as previous ecological studies have been focused within Encounter Bay in the north and Lacepede Bay in the south.

Acoustic mapping, video ground-truthing, SCUBA diving and sediment grabs were used to determine the benthic habitat types of the Coorong offshore marine waters. SCUBA dive transects were conducted on near-shore reefs to provide detailed biological inventories of benthic taxa for a variety of reef habitat environments within Coorong marine waters. Information on existing habitat types, rare, vulnerable and pest species, and general biodiversity in the mid-offshore regions of the Coorong was collected.

No feral or invasive species were observed at any location. In general, reefs appeared to be healthy and in good condition, and supported a high diversity of animal and algal life. A number of rare algal species were found. A surprising finding was the extent of offshore platform reefs in areas marked as sand and shell grit on existing Admiralty charts.

Diversity of fish was generally relatively low, with 18 species recorded, and only between three and six different fish species being observed on each transect; however, rough seas may have affected numbers of fish directly. In addition, poor visibility (in this case associated with the large swells) is well known to affect fish counts. No one species was dominant for the region, and there was much variability between and within sites.

Invertebrates were much more diverse, with a total of 138 invertebrate species recorded. Species assemblages varied both within and between sites. Sites generally either displayed high numbers of crinoids or high numbers of starfish and gastropod

molluscs. Of all the molluscs identified, the grazing gastropod *Turbo undulatus* was the most abundant.

Algae recorded during this study were even more diverse, with 164 species identified. Again, there was considerable variability between sites, with predominantly red foliose algal assemblages occurring on reefs at deep (> 20 m) offshore sites. The shallower high-energy platform reefs of the region were mostly dominated by robust brown branching algae such as *Cystophora* and *Seirococcus*, and the canopy-forming kelp *Ecklonia radiata* with an understorey of red foliose and red encrusting species.

The region directly offshore from the Murray Mouth was characterised by fine sandy sediments. Turbidity was higher adjacent to the Murray Mouth. Salinity, pH, chlorophyll *a*, ammonia and phosphate levels did not appear to display any strong north to south trends; however, different results would be expected during periods of high flow from the Murray River. Total nitrogen declined from south to north along the study area, most likely influenced by nutrient input from the Bonney upwelling to the south.

The data collected provide useful baseline information for future monitoring, and valuable background data on existing major habitats, as well as the algal, fish and invertebrate diversity that is present. The description of available habitat types and existing biota will aid in the future environmental management of this unique stretch of coastline.

2.0 Introduction

Southern Australian waters are home to a diverse range of marine fauna and flora, many of which are not found anywhere else. The southern Australian marine fauna is characterised by low species diversity but has very high species endemicity, with many marine faunal groups displaying over 90% endemicity in southern Australian waters (Wilson and Allen 1987). The marine waters of the Coorong bioregion are no exception. Many of the species that commonly occur within the Coorong marine bioregion are only found along the southern coast of Australia (Edgar 2000).

The Coorong bioregion is made up of a large barrier coast with a series of wetlands, lagoons and lakes on one side of the Younghusband Peninsula and the Southern Ocean on the other. The bioregion comprises 29,830 km^2, 2,048 km^2 of which is within South Australian state waters (Edyvane 1999 and Australian Maritime Boundaries Information System 2001; Figure 1). Currently, approximately 1% of this 2,048 km^2 area is designated as National Parks and Wildlife Reserve (Baker 2000).

The Coorong National Park and lower lakes contain some of Australia's most internationally important and biologically significant wetlands. The area is home to many rare and endangered species, and the inshore and coastal parts have been the focus of many biological and biogeographical studies; the nearshore marine habitats, in contrast, have been little studied.

The ocean side of the Younghusband Peninsula varies from warm in summer to cold temperate in winter, and contains biota typical of such transitional habitats. In areas where data are available, Coorong marine habitats appear to be variable, with complex near-shore reef systems supporting a diversity of habitats and marine organisms. Wave energy is high between the Murray Mouth and the Granites (a geological feature about 45 km north of Cape Jaffa), but lower in the shelter of Cape Jaffa. Any studies that have been carried out in this offshore area have generally been focussed around Victor Harbor to the north and Lacepede Bay to the south of the Coorong bioregion.

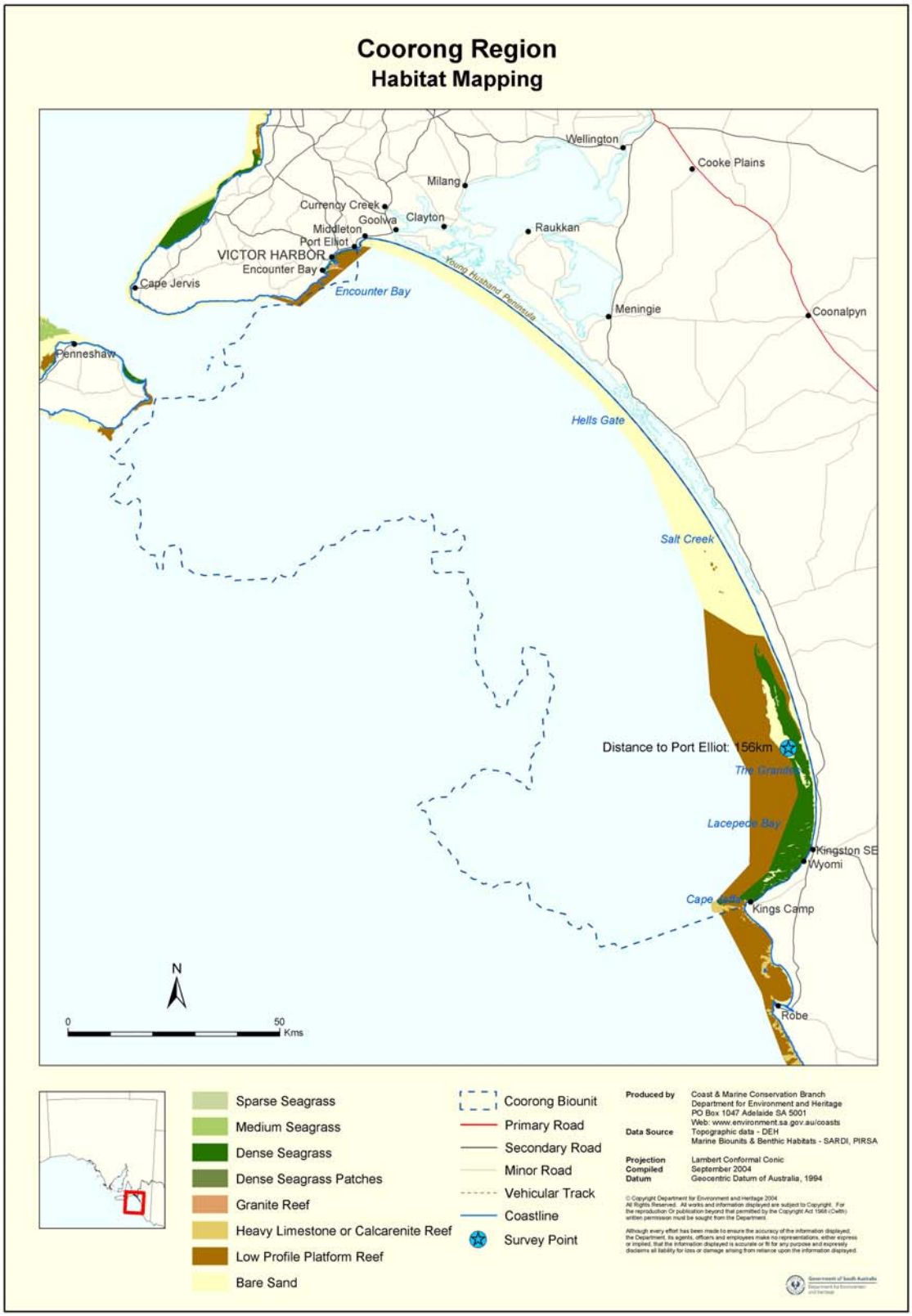


Figure 1. Map showing limits of Coorong Biounit.
Previously known habitat data for the marine waters between of the region also shown.
"Survey Point" represents the geological feature locally known as the Granites (adapted from Edyvane 1999).

Some fine-scale information for the region is available. An extensive technical investigation was carried out between Cape Jaffa and the Granites before establishing aquaculture management zones in Lacepede Bay. This study indicated the presence of extensive seagrass beds inshore, with diverse algal assemblages on reefs further offshore (Sinclair Knight Merz 2001). These habitats extended approximately as far north as the Granites. Apart from this unpublished technical report, fine scale data are not available for the remainder of the offshore waters of the area, between Encounter Bay and the Granites.

Previous investigations at very coarse spatial scales within these marine waters suggested that a series of offshore rocky reefs run parallel to shore on the broad continental shelf (the Lacepede Shelf) between Encounter Bay and Cape Jaffa (Edyvane 1999). The sandy substrates of the central stretches of coast have generally not been colonised by seagrasses due to the high wave energies and active sand movements along this open stretch of coast (Edyvane 1999). Edyvane suggested that much of the high-energy coastline between Encounter Bay and Cape Jaffa would be of low habitat complexity.

The area supports a number of marine species which are of importance to commercial and recreational fisheries (summarized in Edyvane 1999), including Mulloway (*Argyrosomus hololepidotus*), Snapper (*Pagrus auratus*), Snook (*Sphyraena novaehollandiae*), Australian salmon (*Arripis* truttacea), Calamari (*Sepioteuthis australis*) and School shark (*Galeorhinus galeus*). Sandy inshore and reef-related habitats support other commercially fished species such as the Goolwa cockle (*Donax deltoides:* note; predominantly intertidal distribution), Southern rock lobster (*Jasus edwardsii*) and also Green and Black-lipped abalone (*Haliotis laevigata* and *H. rubra*) (Edyvane 1999).

Other species in the area are of conservation significance, including SA's marine icon, the Leafy sea dragon (*Phycodurus eques*); as well as cetacean species, most notably, migrating Southern right (*Eubalaena australis*) and Humpback (*Megaptera novaeangliae*) whales. Despite the abundance of biologically, economically and environmentally significant marine species, no biodiversity surveys have been conducted north of the Granites other than Edyvane's (1999) coarse scale coverage of Encounter Bay. Further, information on the occurrence of species of conservation concern and pest species within the mid-offshore regions of the Coorong is virtually nonexistent.

The Murray Darling Natural Resource Management Board identified the marine waters of the Coorong bioregions as a high priority in their investment strategies[1]. Large knowledge gaps exist within the inshore marine waters of this area, making meaningful decisions about the effective conservation, monitoring and long-term management of offshore water environments difficult. In addition, in order to detect anthropogenic impacts or long-term changes in habitats, baseline data incorporating prior descriptions of existing habitats and the biota that occupy them are essential. Detailed habitat information at ecologically and biologically relevant scales, along with baseline biological surveys are essential for effective monitoring, management and planning.

As there was adequate habitat information for the area south of the Granites, but very little between Port Elliot and the Granites, permission was sought to extend the study area a little beyond the boundaries of the Murray-Darling Basin NRM region. The seaward limit of the study area was selected as up to a depth of 30 m, or out to the State Water limit, whichever occurred first. The landward edge was restricted to the working depth of the vessel being used, and is specified in the methods for each survey technique. The intertidal zone was not included.

All the data available for the study area at the time this project was initiated were compiled into a habitat map (Figure 1).

The aim of this current project was to provide benthic habitat maps of the area and also to provide species lists of the subtidal biota of the Coorong bioregion. To enable comprehensive mapping over broad spatial scales, acoustic technology was used. Complementary to the acoustic mapping, video ground-truthing, SCUBA diving, and benthic grabs within each habitat allowed the topography, benthos and type of sediment to be identified and classified. Water quality data were also collected.

[1] www.dwr.sa.gov.au/nrm/boards/samdb/invest.html, last accessed 14/03/06

3.0 Materials and Methods

A number of different methods were used to survey the benthic habitats of the study area. These included: two methods of acoustic technology, both single frequency and dual frequency sonar; video transects; sample collection via remote anchor grabs; and visual line intercept transects using SCUBA. These are described in detail below.

3.1 Study Sites

Boat transects were conducted from the back of the surf zone at approximately seven metres depth between the Granites and Port Elliot, out to the State Water Limit or the 30 metre depth contour, whichever was encountered first. The southernmost transect was conducted at ~ E139° 38.508', S 36° 16.895' and northernmost transect was conducted at ~ E138° 44.265', S35° 36.400' (Figure 2). The bulk of the survey was carried out from SARDI's Research vessel *Ngerin*, between the 5th and 15th November 2004, although some components were carried out after that date as specified below.

3.2 Sonar Transects

To gain benthic habitat information, acoustic technology was used to collect data including substrate roughness, hardness and texture. Two different mapping methods were used: (A) single beam, dual frequency sonar transects, and (B) dual-beam wide swathe bathymetry transects. Ideally, method B would have been carried out prior to the *Ngerin* trip; however, there are very few swathe bathymetry mappers available, and we were not able to acquire the swathe bathymetry data until January 2005.

For both (A) and (B), transects were conducted perpendicular to the shore beginning outside the surf zone (~7 m depth) and ending at the State Waters boundary or the 30 metre depth contour; this allowed for an average transect length of approximately three nautical miles (5.6 km).

(A) Single beam, dual frequency sonar transects

Available data indicated that habitats to the north of the Murray Mouth were more complex than to the south (Edyvane 1999), most likely due to the high-energy nature of the coast south of the Murray Mouth. Taking into consideration the existing

data and energy nature of the coastline and also the time available to conduct the field study, the survey effort was stratified. Transects were conducted at approximately three nautical miles (5.6 km) apart to the north of the Murray Mouth and five nautical miles (9.3 km) apart to the south of the Murray Mouth. This spatial arrangement allowed for 18 Simrad EQ60 transects (Figure 2).

These 18 transects were carried out from RV *Ngerin* between 5th - 15th of November 2004. Transects were conducted with a Simrad EQ60, single beam, dual frequency sonar system, linked to a Garmin 12 XL Global Positioning System (GPS). Video data, benthic grabs and water quality data were collected at the same time. Analyses were completed using Echoview 3 (Sonardata Pty Ltd). Template and calibration settings are outlined in Table 1 to enable future data comparisons. Hardness and roughness values then underwent a principal components analysis to produce a single index spanning a range of values, which were then grouped, using ESRI ArcMap 8.3, into eight initial classes using Jenks natural breaks method. Sites were determined based on the eight classes (or habitat grouping).

(B) Dual-beam wide swathe bathymetry transects

Seven transects were conducted between 18th - 19th January 2005 with a geo-swathe interferometric wide swathe bathymetry survey system. Seabed texture mapping was based on geo-referenced composite side-scan mosaics and processed using geo-texture seabed classification software. The data collection and analyses were completed in August 2005 by 3D Marine Mapping Pty Ltd.

Table 1. Echoview template and calibration settings used during the "Simrad EQ60" single beam sonar transects.

Template Parameters	Template Values	Calibration Parameters	Calibration Values
Absorption coefficient (dB/m)	0.0523000	Major axis 3dB angle (degrees)	7.20
Sound speed (m/s)	1500	Minor axis 3dB angle (degrees)	7.20
Transmitted power (W)	1000		
Two-way beam angle (dB re 1 Steradian)	-20.50		
Transducer gain (dB)	26.3		
Sa correction (dB)	0		
Transmitted pulse length (ms)	0.256		
Frequency (kHz)	120		

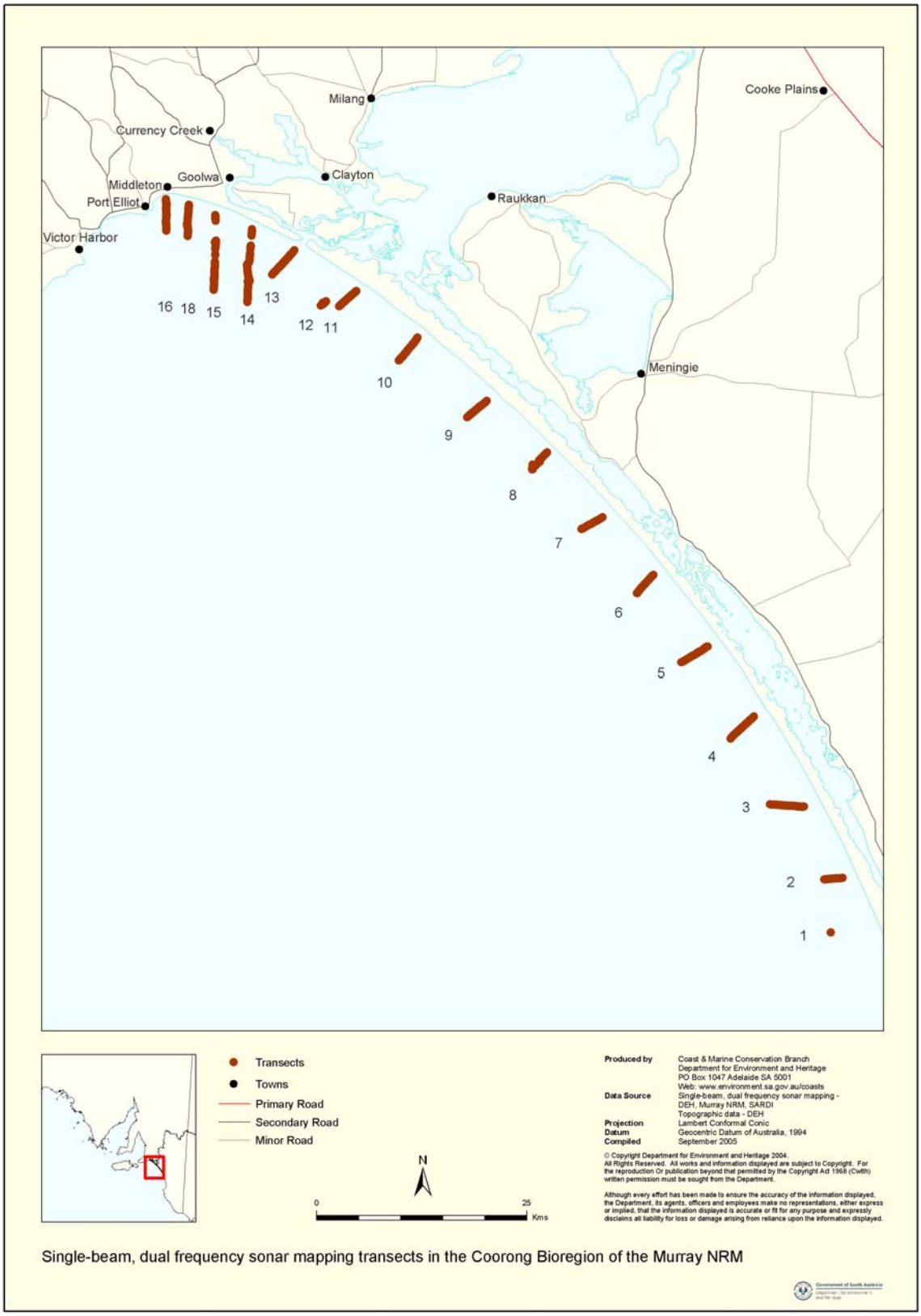


Figure 2. Location of single-beam, dual frequency sonar mapping transects.
Benthic grab samples, water quality data, and video footage of the seafloor were collected at the same time. Data collected from RV *Ngerin*, 5-25 Nov 2004.

Using latitude and longitude coordinates which were recorded from the sonar readings, the acoustic data was generated into spatial data as point information using ArcGIS 8.3 software. The spatial data (point data) was then displayed on the associated hardness and roughness readings grouped into respective habitat readings.

Additional video groundtruthing was conducted during November and December 2005 from a chartered vessel. Video groundtruthing data were displayed over both single beam, dual frequency (Appendix 1) and swathe bathymetry (Appendix 2) acoustic data sets using ArcGIS 8.3 software.

3.3 Video Transects

A remotely operated digital video was lowered to the sea floor from RV *Ngerin* to record the existing habitat at the beginning and end of each "Simrad" sonar transect, and at irregular intervals within the transect, in particular when any obvious change of habitat occurred (e.g. from a sand flat to a reef habitat). Video drops varied in time between two and ten minutes depending on the complexity of the habitat being recorded. For example, only short drifts were necessary to classify simple unvegetated sand, while complex limestone reef habitats required longer drifts to enable an accurate habitat classification.

Whilst recording, the boat was allowed to drift in a single direction to ensure each video transect was linear. A basic habitat description was given for each transect and GPS points were recorded at the beginning and end of each video transect. The transect distance was later calculated using each set of GPS data points. Video transect width varied as swell motion altered the vertical position of the camera. This variation, at times, made it difficult to make accurate area calculations. For some sites heavy seas also made assessing and describing habitats difficult.

Analysis of the video footage allowed habitats to be classified hierarchically (see Appendix 3).

3.4 SCUBA Transects

Dive transects were conducted over eight algal dominated reef areas within the Coorong bioregion to provide information from a variety of physically variable reef habitats (Table 2).

Table 2. Location and number of SCUBA dive transects conducted within the study area.

Dive Transect Sites	No of 25 m transects conducted	Depth (m)	Wave Exposure	Approximate GPS Coordinates
West Island (northeast)	3	10	High	S 35° 36.410 E 138° 35.670
Victor Harbor (The Bluff)	4	4-8	Med-High	S 35° 35.307 E 138° 36.325
Knight Beach Point	3	8-10	High	S 35° 32.322 E 138° 41.056
Horseshoe Bay, Port Elliot	4	4-6	Medium	S 35° 32.049 E 138° 41.449
Pullen Island (northwest)	4	4-8	Low-Med	S 35° 32.226 E 138° 41.411
Pullen Island (south)	3	9	High	S 35° 32.351 E 138° 41.442
Frenchman Rock & Basham Beach (Chicken Run)	3	4-5	Med-High	S 35° 31.765 E 138° 41.918
Offshore site 1 (4km from Murray Mouth)*	2	21-22	High	S 35° 47.732 E 139° 12.045

*N.B. bad weather, rough seas and low visibility prevented a representative study of invertebrate and fish species, which might typically inhabit the Offshore site.

Each of the 25 metre long dive transects were conducted by a pair of SCUBA divers. Each pair of divers collected detailed information on faunal and floral assemblages within reef areas. Transects were placed randomly by dropping a weight connected to a buoy from the side of the boat. Depths varied depending on wave energy, topography and site. GPS data were recorded and a 25 m line was reeled out from the weighted start point. The general survey method of Edgar and Barrett (1997) was used, and information on fish, invertebrates, vegetation and feral species collected.

3.4.1 Fish and Invertebrate SCUBA transects

All species of fish within 2.5 m of each side of a 25 m transect line were recorded by one diver, and their abundance estimated, while the other diver searched for introduced marine pests. On a separate pass, one diver recorded all mobile invertebrate species (generally only those > 5 cm in size) within a one metre belt width along and to one side of the transect line; while the second diver performed a line intercept transect (see next section).

All fauna were recorded to species level where possible. Where on-site identification was not possible specimens were taken and preserved in either 70%

ethanol or 3% formaldehyde in seawater (depending on the taxa). Preserved faunal specimens were sent to the South Australian Museum for identification [identifications were carried out by Thierry Laperousaz (invertebrates), Shirley Sorokin (sponges), Greg Rouse (polychaetes) and Karen Gowlett-Holmes (meso-gastropods)].

The complete fauna list was analysed for any protected, rare, commercially significant or pest species. The mean number of individuals within each group was calculated for each of the dive transect study sites.

All invertebrate species were grouped into one of 13 taxonomic groups as follows: ascidians (sea squirts), cnidarians (hydroids, anemones, soft corals) bryozoans (bryozoans, moss animals, lace corals), poriferans (sponges), asteroids (sea stars), crinoids (feather stars), echinoids (sea urchins), holothuroids (sea cucumbers), ophiuroids (brittle stars), gastropods (sea snails), polychaetes (worms), pycnogonids (sea spiders), malacostracans (lobsters, crabs and shrimp).

3.4.2 Algae SCUBA transects

A line intercept transect (LIT) method was used to record lineal cover of algae within a reef habitat. The LIT method, originally described by English *et al*.(1994), has been adapted (Reef Watch 2004b) to better suit macroalgal habitats. A detailed description of the basic LIT method can be found on the Reef Watch website[2]. The method was slightly modified for this study, with a minimum resolution of 5 cm rather than 3 cm. The LIT method was chosen on the basis that it is the least destructive (Turner 1995), and most appropriate method for accurately determining the dominant taxa by both trained and novice divers (Miller *et al.* 1998). The LIT method is simple, yet provides enough detail enough to enable spatial and temporal comparisons.

Algae were placed into morphological categories (Reef Watch 2004a) (see Appendix 4). The lineal measurement for each algal habitat of a single morphological category (>5 cm in length) along the transect tape was recorded on a dive slate, with for each change of habitat being noted. Percent cover of algae was then calculated using the following formula:

Percent cover for algal category A = $\sum L_A$ / TL-$\sum O$ x 100

[2] www.reefwatch.asn.au/; last accessed 14/3/06

where $\sum L_A$ = sum of the total lengths of one algal category

TL = the total length of the transect

$\sum O$ = the sum of lengths of data other than algae (e.g. sand, rock)

Due to the limited taxonomic resolution and under-representation of cryptic, epiphytic and understorey algal species from this method, algal specimens were also collected from transect and grab sites within the Coorong bioregion and preserved in 3% formaldehyde in seawater for later identification. These specimens were identified by Professor Bryan Womersley and staff, of the South Australian Herbarium (collection reference AD-A71764 to AD-A72005). Feral species were recorded at the same time.

3.5 Benthic Sampling

A modified anchor grab with a mesh net was used to collect benthic samples at regular intervals, and wherever a change in habitat was noted. This enabled the confirmation of the type of benthic habitat where the video footage was unclear, as well as allowing collection of specimens. Samples present within the grabs were identified to species level either in the field or were preserved and sent to the South Australian Museum or the South Australian Herbarium for identification.

3.6 Seagrass Collection and Identification

Seagrass specimens were collected during SCUBA transects and sediment grabs and kept for identification. Some additional dives on seagrass were also made to assess condition. Dr Hugh Kirkman identified all seagrass specimens. All seagrass identifications for *Heterozostera* were based on a recent revision of the genus by Kuo (2005).

3.7 Water Quality Data Collection

Water quality in the study area was assessed using two main methods between 5th – 15th November 2004. Physical water parameters were collected in the field using a Hydrolab multi-meter at the inshore (shallow) and offshore (deep) end of every sonar transect, providing water quality data spanning the study area. Water samples were

taken for later nutrient analysis in the laboratory at the inshore end of every second transect.

The Hydrolab multi-meter was used to collect data on chlorophyll *a* concentration, water turbidity, salinity and pH. Readings were taken every metre, from one metre in depth to one metre above the sea floor. Generally, parameters did not differ greatly with depth, so only data from one metre depth are presented in this report.

Water samples were taken from approximately one metre depth using a five-litre container, which could be closed with a remote level. From each five litre sample, two 100 ml sub-samples were taken, one frozen immediately, for total phosphorus, and one filtered (0.45 μm) and then frozen, for inorganic nitrogen and ammonia. Three replicate water samples were taken at each site. It was expected that there would be a south-north gradient in water nutrients because of nutrient input from the Murray River. To detect such a gradient, regressions between latitude and nutrient concentration were used. Nutrient concentration was used as the dependent variable.

For all other physical characteristics of the water (Hydrolab data), single factor analyses of variance (ANOVA) were used; transect was treated as a random factor and ten replicate readings from approximately one metre depth were used. All data analysed were heterogeneous, so ln (X+1) transformation was used to reduce heterogeneity. However, data remained heterogeneous, so significance was judged at the more conservative $\alpha = 0.01$ (Underwood 1997).

4.0 Results

No feral or invasive species were noted at any point.

4.1 Sonar and Mapping Data

The two sonar acoustic data sets (A and B) were combined using a Geographical Information System (GIS) to produce reference maps (Figures 2-4).

The single beam, dual frequency sonar transects spanned approximately 110 km along the coast south of Port Elliot, and provided hardness and roughness data for benthic habitats along the transect lines (Figure 2). The type of sediment directly

under the sonar beam was indicated by hardness data, while the shape of the surface (i.e. sand ripples, rock rubble, seagrass, and algae) was indicated by roughness data. Data were placed into categories, which were consistent with the dual beam swathe bathymetry and video sediment identification. Of the 18 transects, numbers 1, 12 and 17 experienced GPS difficulties and hence data were not able to be conveyed or were only partially conveyed in map form (transect numbers shown in Figure 2).

Groundtruthing was conducted for the single beam, dual frequency sonar transects using video drops and sediment grabs at the same time as transects were conducted (Figure 3). These data were used to identify and classify habitat types.

Complex reef habitat was identified on most of these sonar transects between Port Elliot to 50 km south on transect 8. Much of the 110 km offshore region parallel to the coastline appears to consist of coarse sandy substrates interspersed with algal beds (Figure 3). Seagrass beds were identified from video drops, dive transects and benthic grabs in the near-shore areas of Port Elliot and Victor Harbor.

Dual beam swathe bathymetry was conducted in seven bands to a depth of 30 metres (Figure 4). Swathe maps revealed a series of low platform limestone reefs beginning approximately 4.5 km offshore and extending beyond the study area. Groundtruthing in 2005, and the assimilation of all sonar, video and sediment grab data enabled the interpretation of the many of the habitat types along the swathe bathymetry transects. Data were combined from all mapping techniques to produce two comprehensive habitat maps detailing benthic sediment type and habitat between Victor Harbor and Port Elliot and for a distance of 110 km south parallel to the Coorong coastline (Appendix 1-2). A number of complex reef structures exist close to shore off Port Elliot. Sandy habitats dominate the substrates close to shore and a low platform reef can be seen along the Coorong coast running parallel to shore. Reef is represented in three classifications, vegetated sand in one and other sand types in four (Appendix 1-2).

Groundtruthing showed that four of the swathe texture-mapping substrates to be sand. 3D Marine Mapping was unable to combine all sand types into a single colour, hence all sand types (sand, fine to medium grain size; sand, shell grit present; sand, fine silted; sand, unclassified) are shown on the habitat maps. Some indeterminable substrates were noted in the southern-most reaches of the study area; however, these were unable to be groundtruthed due to budget and weather constraints.

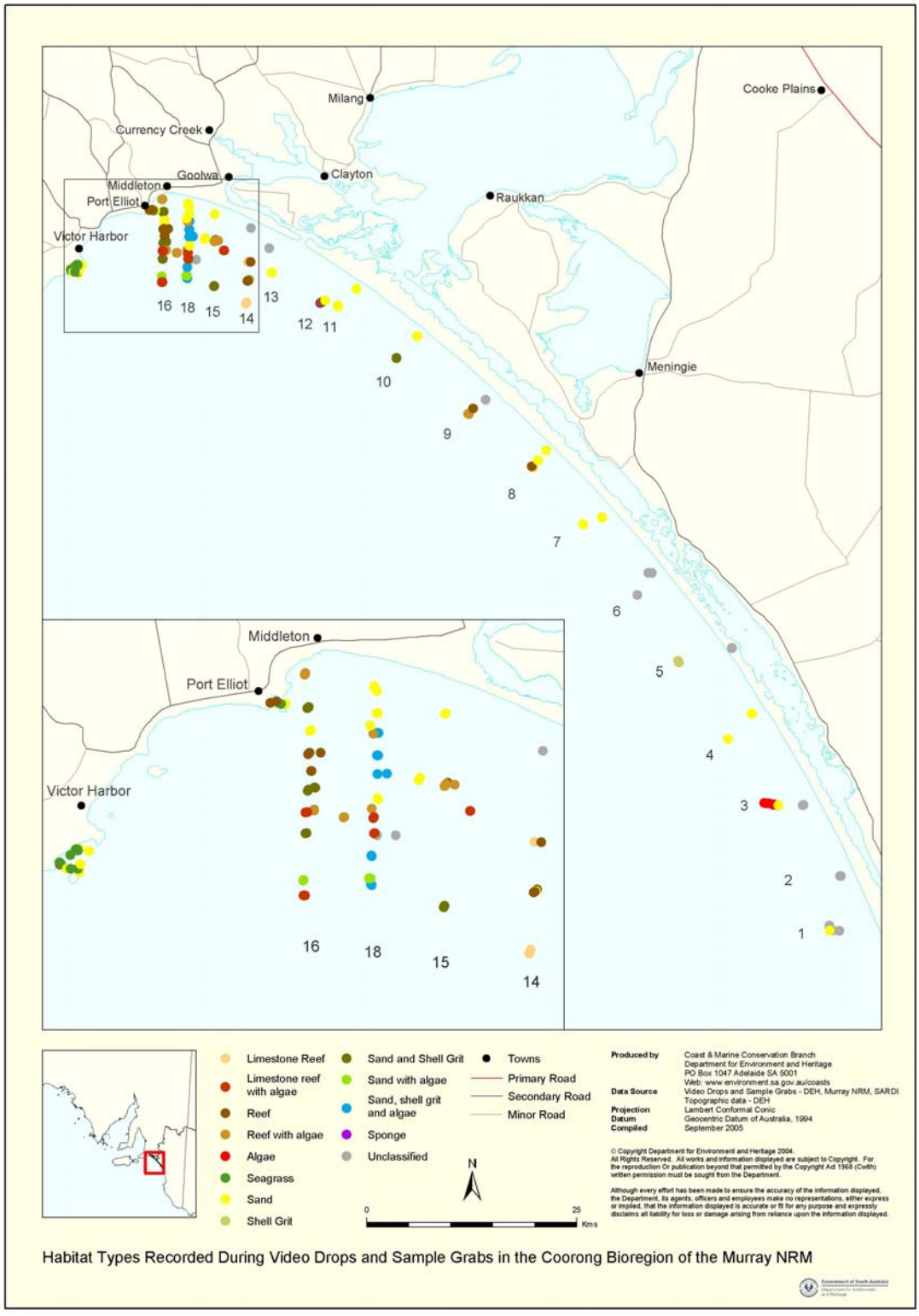


Figure 3. Habitat types recorded during video drops and sample grabs

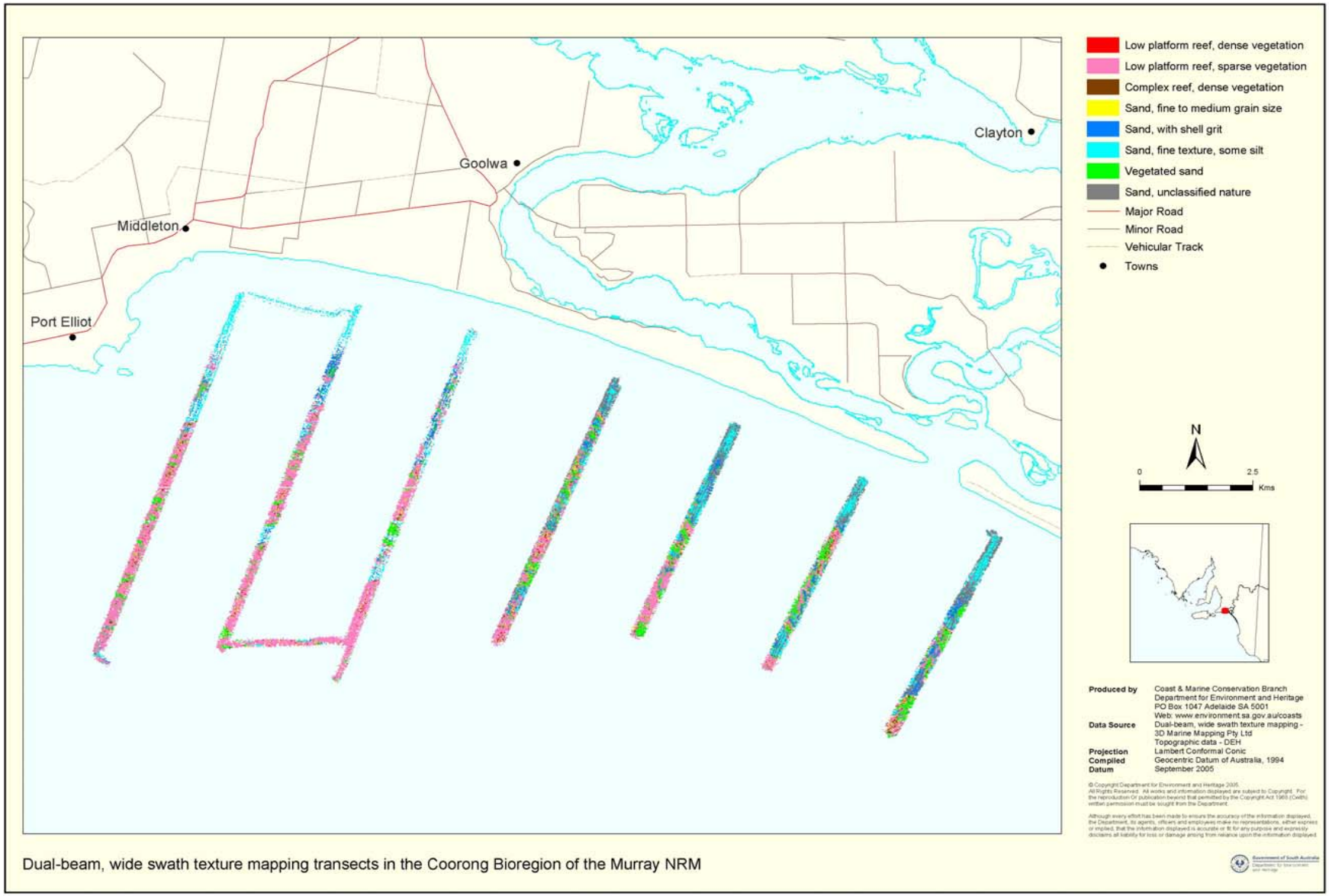


Figure 4. Habitat information from dual-beam, wide swathe bathymetry transects following groundtruthing.

4.2 Fish Transects

Sixteen different fish species were observed from transects within the Coorong bioregion (Table 3). Between three and six different fish species were observed on each transect, except for one of the offshore transects, where only one *Notolabrus fucicola* (Purple wrasse) was seen (Figure 5). Diversity of fish was generally relatively low; however, rough seas may have affected numbers, and poor visibility almost certainly affected counting (both because the fish are less likely to swim in open water, and because they are hard to see). Reef Watch divers generally record higher numbers (even after adjusting for the 50 m transect tape used compared to a 25 m tape used in this study; James Brook, Reef Watch Project Officer, pers. comm.).

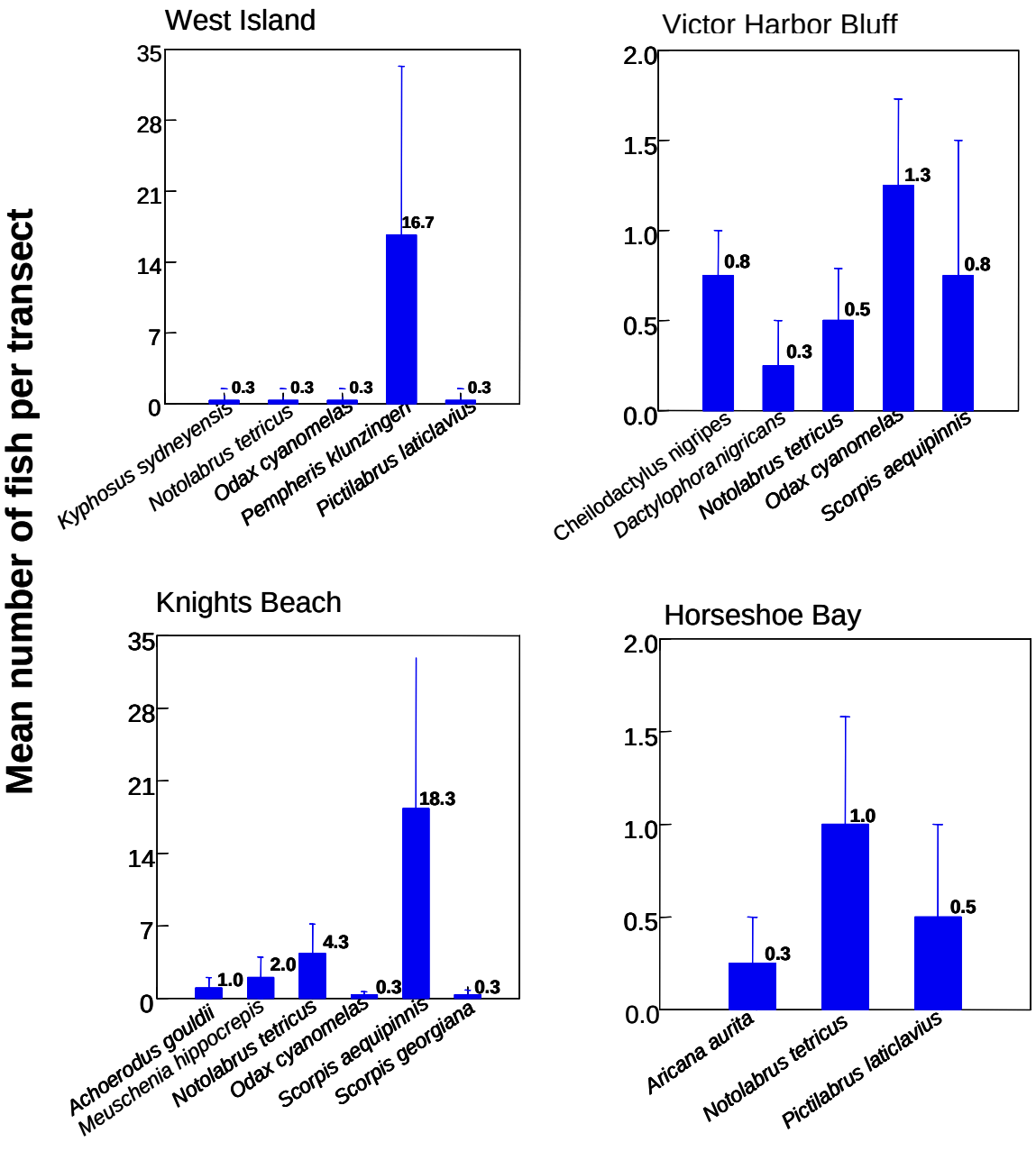
The large and inquisitive reef wrasse, *Achoerodus gouldii*, commonly known as the Western Blue Groper, was seen in three dive transect sites (Figure 5). Another wrasse species, *Notolabrus tetricus* (Blue-throated wrasse), was observed in numbers of between one and eleven across several dive transect sites. Schools of *Scorpis aequipinnis* (Sea sweep) were observed at four sites (Figure 5) and were found in the highest numbers per transect at Pullen Island South (mean = 19, SE ± 3.06) and Knight Beach (mean = 18.3, SE ± 14.52). *S. aequipinnis* were observed to be diver-positive (attracted by diver activity). Anecdotally, divers frequenting South Australian waters have often observed *S. aequipinnis* to aggregate and then follow divers.

Another schooling species, *Pempheris klunzingeri* (Rough bullseye), was observed (n = 50), however this species only occurred on one of the three dive transects conducted on West Island (mean = 16.67, SE ± 16.67; Figure 5). A school of 20 individuals of *P. klunzingeri* were observed at Victor Harbor Bluff (Appendix 5), however, these were not seen on transects conducted for fish counts and hence were not included in the calculations for Figure 5. *P. klunzingeri* were observed to be a diver-negative (repelled by diver activity) schooling reef species.

Table 3. Species and species characteristics observed on SCUBA dive transects within the Coorong bioregion.
(species taken in * recreational or ** commercial fisheries in South Australia). Characteristics taken from Edgar (2000).

Species	Common Name	Characteristics
Achoerodus gouldii	Western blue groper*/**	Inquisitive (diver positive)
Aracana aurita	Shaw's cowfish	A common boxfish in southern Australia
Cheilodactylus nigripes	Magpie perch	Common, feeds on invertebrates in the sediment
Dactylophora nigricans	Dusky morwong	Large, common fish
Kyphosus sydneyanu	Silver drummer	Solitary or schooling reef fish
Meuschenia hippocrepis	Horseshoe leatherjacket	Retreats to caves if threatened (diver negative)
Notolabrus fucicola	Purple wrasse	Gen. abundant in shallow water among kelp[a]
Notolabrus tetricus	Blue-throated wrasse*	Adults: exposed environ. Juv: Inhabit seaweeds
Odax cyanomelas	Herring cale	Feeds on *Ecklonia radiata* & other brown algae
Parascyllium variolatum	Varied cat shark	During day is concealed amongst kelp, nocturnally active
Parma victoriae	Scalyfin	Defends home cave and grazes on front home crop of algae
Pempheris klunzingeri	Rough bullseye	Schools in caves, overhangs. Somewhat diver negative
Pictilabrus laticlavius	Senator wrasse	Lives in algae, sometimes inquisitive. Diver positive or neutral
Scorpis aequipinnis	Sea sweep*	Lives in open, turbulent water. Observed to be diver positive
Scorpis Georgiana	Banded sweep	Remains close to caves and ledges
Tilodon sexfasciatus	Moonlighter	Adults occur in pairs, juveniles are solitary. Diver positive.

[a]Note: found in this study in deep water. Also on edge of range in SA, and not generally observed in shallow water. Characteristics apply to other states.


West Island
35
28
21
14
7
0
0.3
0.3
0.3
16.7
0.3
Kyphosus sydneyensis
Notolabrus tetricus
Odax cyanomelas
Pempheris klunzingeri
Pictilabrus laticlavius
Victor Harbor Bluff
2.0
1.5
1.0
0.5
0.0
0.8
0.3
0.5
1.3
0.8
Cheilodactylus nigripes
Dactylophora nigricans
Notolabrus tetricus
Odax cyanomelas
Scorpis aequipinnis
Knights Beach
35
28
21
14
7
0
1.0
2.0
4.3
0.3
18.3
0.3
Achoerodus gouldii
Meuschenia hippocrepis
Notolabrus tetricus
Odax cyanomelas
Scorpis aequipinnis
Scorpis georgiana
Horseshoe Bay
2.0
1.5
1.0
0.5
0.0
0.3
1.0
0.5
Aricana aurita
Notolabrus tetricus
Pictilabrus laticlavius
Mean number of fish per transect
Fish Species

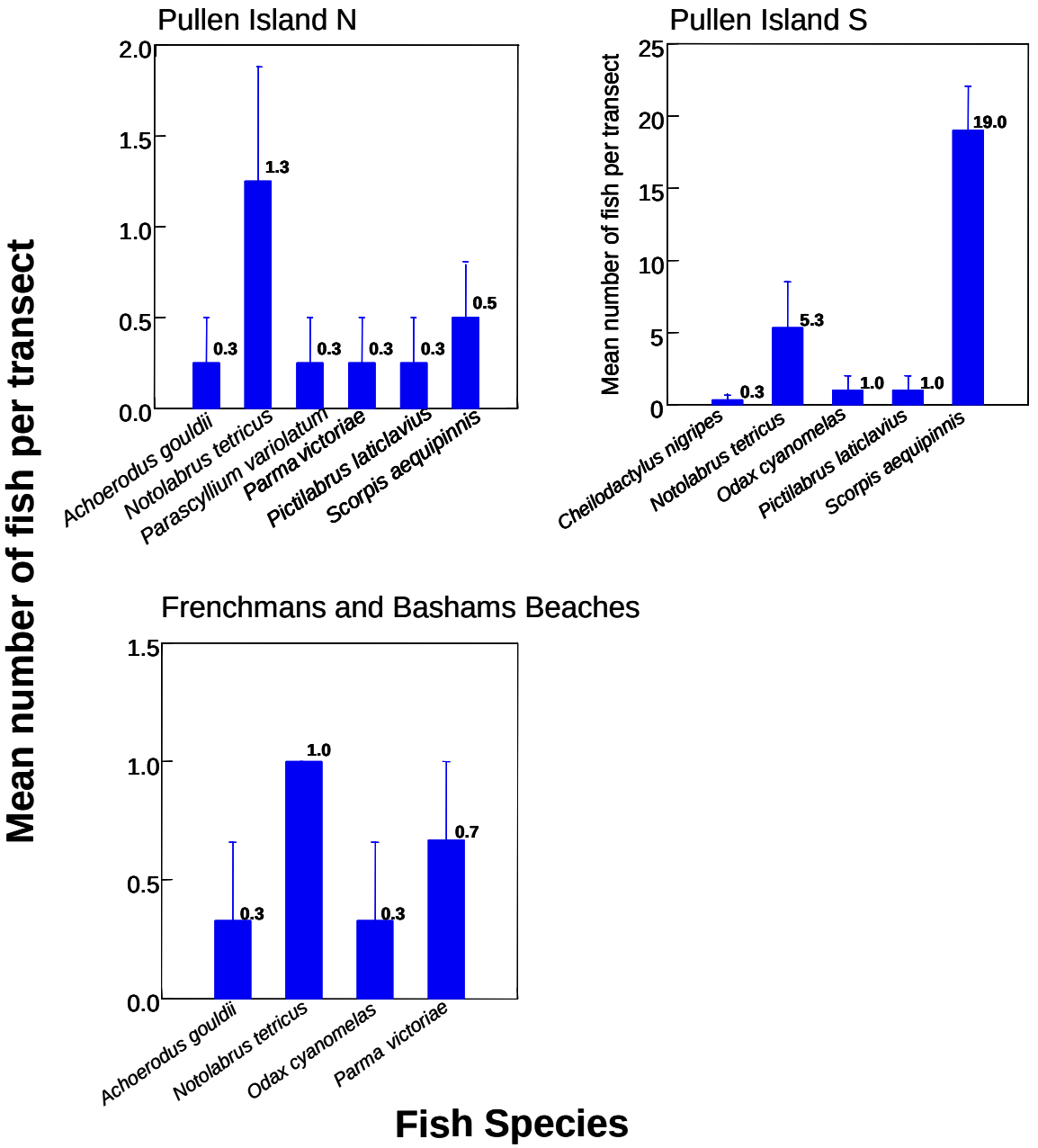


Figure 5. Mean number and standard error of fish species per dive transect at sites within the study area.
Sites are: West Island (n = 3); Victor Harbor Bluff (n = 4); Knight Beach Point (n = 3); Horseshoe Bay (n = 4); Pullen Island North (n = 4); Pullen Island South (n = 3); Frenchman Rock and Basham Beach (n = 3). n = number of transects. Note: Y-axis scale varies between sites.

4.3 Invertebrate Transects

Table 4. Invertebrate species of importance to the recreational and/or commercial fishing industries identified during dive transects.

Invertebrate Fisheries Species	Common Name
Chlamys asperrimus	Doughboy scallop
Haliotis laevigata	Greenlip abalone
Haliotis rubra	Blacklip abalone
Heliocidaris erythrogramma	Sea urchin
Jasus edwardsii	Southern rock lobster
Katelysia scalarina	Mud cockle
Turbo undulatus (Tasmania, NSW)	Periwinkle

A total of approximately 138 invertebrate species were found. It is difficult to be exact, as some species were unable to be precisely identified for various reasons (e.g. immature specimen, inadequate preservation, lack of expertise). Species assemblages varied both within and between sites.

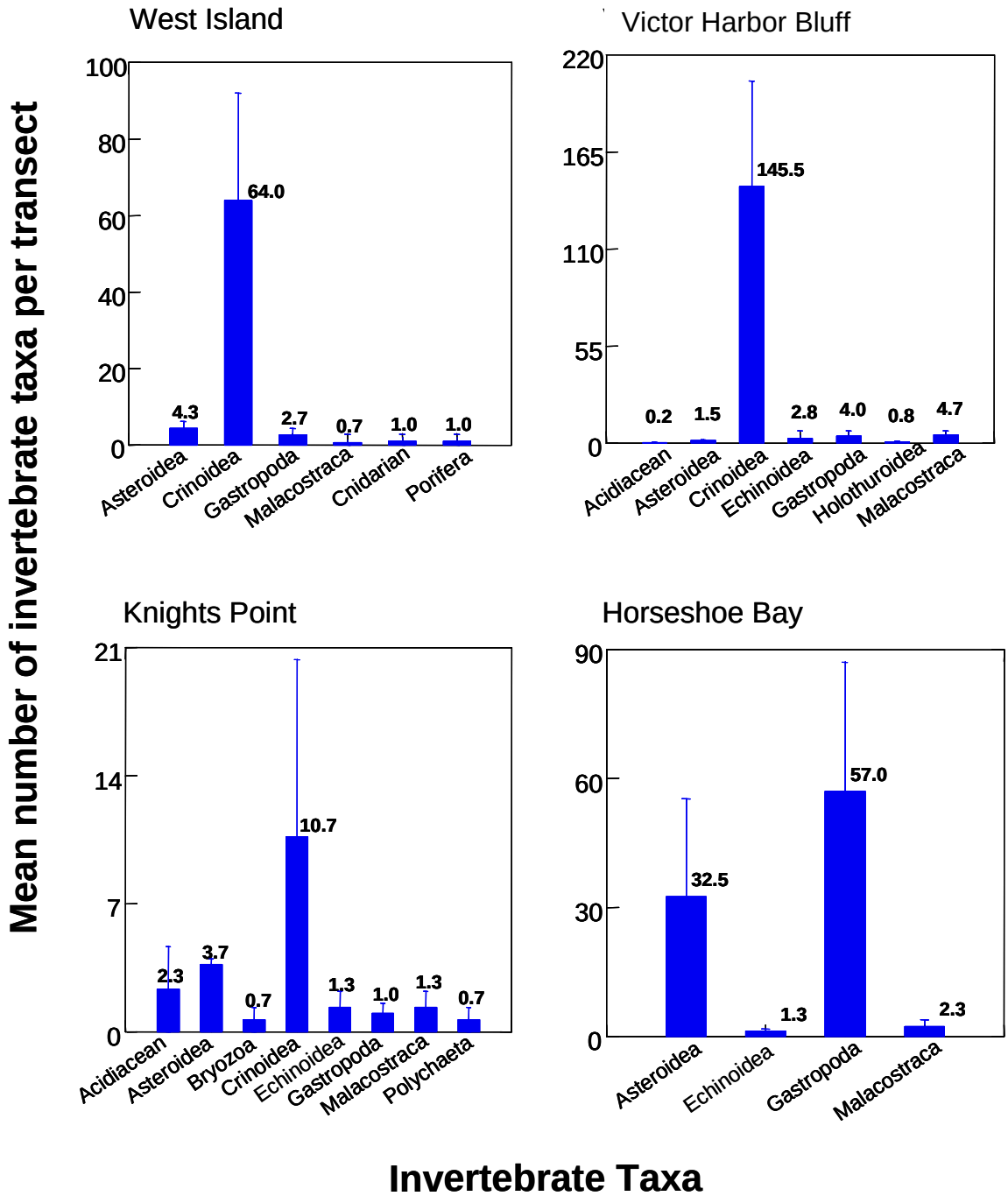
The filter-feeding crinoid species *Cenolia trichoptera* was found to be the most abundant benthic invertebrate along dive transects from West Island, Victor Harbor Bluff, Knight Beach, and Pullen Island South (Figure 6). In all other dive transect sites (Horseshoe Bay, Pullen Island North, and Frenchman Rock and Basham Beach) both asteroids and gastropods were the dominant benthic invertebrates in number, and were found in similar abundances. There were no transects in which Crinoidea, Asteroidea and Gastropoda were all abundant. Sites either displayed high numbers of Crinoidea or high numbers of Asteroidea and Gastropoda.

The dominant asteroid species present at most dive transect sites were the small, omnivorous sea stars *Patiriella calcar* and *P. brevispina* (Figure 6). There was also one group of approximately fifty *Tosia australis* at Horseshoe Bay (Figure 6). One asteroid species (*Nectria ocellata*) was observed on one of the two transects conducted "Offshore" (4 km from the Murray Mouth, Offshore site 1).

Of all the molluscs identified, the gastropod *Turbo undulatus* was the most abundant; occurring in numbers of up to 140 on a single transect (Figure 6). One other gastropod was seen in considerable numbers, the small top shell species, *Austrocochlea odontis*, of which approximately 45 were observed along a single dive

transect at Horseshoe Bay (Figure 6). A full list of invertebrate species found during the study is included in Appendix 5.

An additional dive was conducted at one of the offshore sites (#2). Unfortunately no transects could be conducted due to a 5 m swell running at the time, and data collection was limited to observations. This site formed a pinnacle, the top of which was at approximately 18 m, with ledges dropping off to over 30 m. This site was very different to all others, and was notable for the abundance and diversity of invertebrates, particularly crinoids and ascidians. Some red algae were present, but the site was invertebrate-dominated, rather than algal-dominated.


West Island
Victor Harbor Bluff
Knights Point
Horseshoe Bay
Mean number of invertebrate taxa per transect
Invertebrate Taxa
Asteroidea
Crinoidea
Gastropoda
Malacostraca
Cnidarian
Porifera
Acidiacean
Echinoidea
Holothuroidea
Bryozoa
Polychaeta

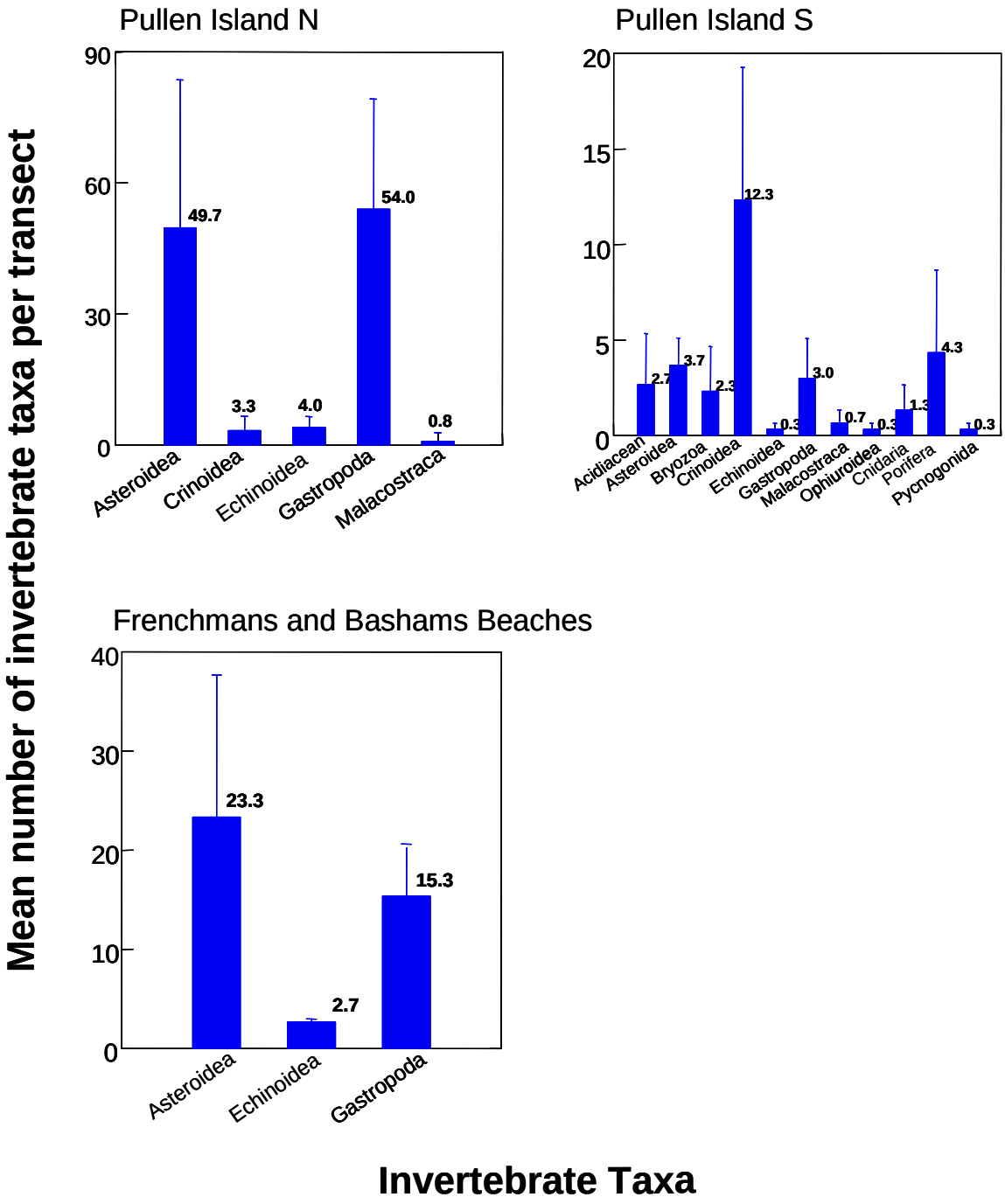


Figure 6. Mean number and standard error of invertebrate taxa per dive transect at sites within the study area.
Sites are: West Island (n = 3); Victor Harbor Bluff (n = 4); Knight Beach Point (n = 3); Horseshoe Bay (n = 4); Pullen Island North (n = 4); Pullen Island South (n = 3); Frenchman Rock and Basham Beach (n = 3). n = number of transects. Note: Y-axis scale varies between sites.

4.4 Algal Transects

Approximately 164 species of algae were identified within the Coorong bioregion. The numbers is not absolute as some species could only be identified to genus (for some species, for example, the absence of reproductive material makes species identification impossible), and these have been counted as the same species unless a description indicated otherwise. A complete list of algal species for each site can be found in Appendix 6. Of the algae collected and identified, three species were found to be of particular interest. These were: *Psilothallia striata,* a rare species with only one other specimen known from southern Australia (from Cape Northumberland); *Pachymenia orbicularis* - this specimen represents the only known male specimen ever found and recorded for this species; and *Nitospinosa tasmanica*, for which a new distribution was recorded (previously only recorded from Victoria and Tasmania).

Horseshoe Bay had the most diverse assemblage of algae, with recorded species falling into 13 categories of algae. Although this site contained a diverse assemblage, it was dominated by brown branching algae (most representative were *Cystophora* and *Sargassum*; Figure 7).

Ecklonia radiata was observed to be the dominant cover (mean cover greater than 55%) at two sites (West Island and Knight Beach; Figure 7). Mixed stands of *Ecklonia radiata* and red foliose algae comprised assemblages at Knight Beach and Pullen Island south (Figure 7). The mixed assemblages at Victor Harbor Bluff, Pullen Island West and Frenchman/Basham Beaches comprised predominantly *Ecklonia radiata* and brown branching algae (predominantly *Cystophora* and *Sargassum*)

The deeper (22 m water depth) offshore sample was dominated by red foliose algae, with non-algal patches contributing over 30% of the overall habitat on transects (Table 5). The other deeper site (18-30 m) for which no LIT was conducted (see description in section 4.3) was notable for its lack of algae. Some red algae were present, but the site was invertebrate-dominated, rather than algal-dominated.

Table 5. Mean percentage cover of benthic habitat transects for Offshore site #1 transects. Site is 4 km from the Murray Mouth; n = 2.

Benthic Habitat	Mean % Cover	Standard Error (±)
Ecklonia radiata	0.2	0.2
Red encrusting algae	4.4	0.44
Red foliose algae	62.7	8.08
Non-algal cover (coarse sand)	32.7	8.71

4.5 Seagrasses

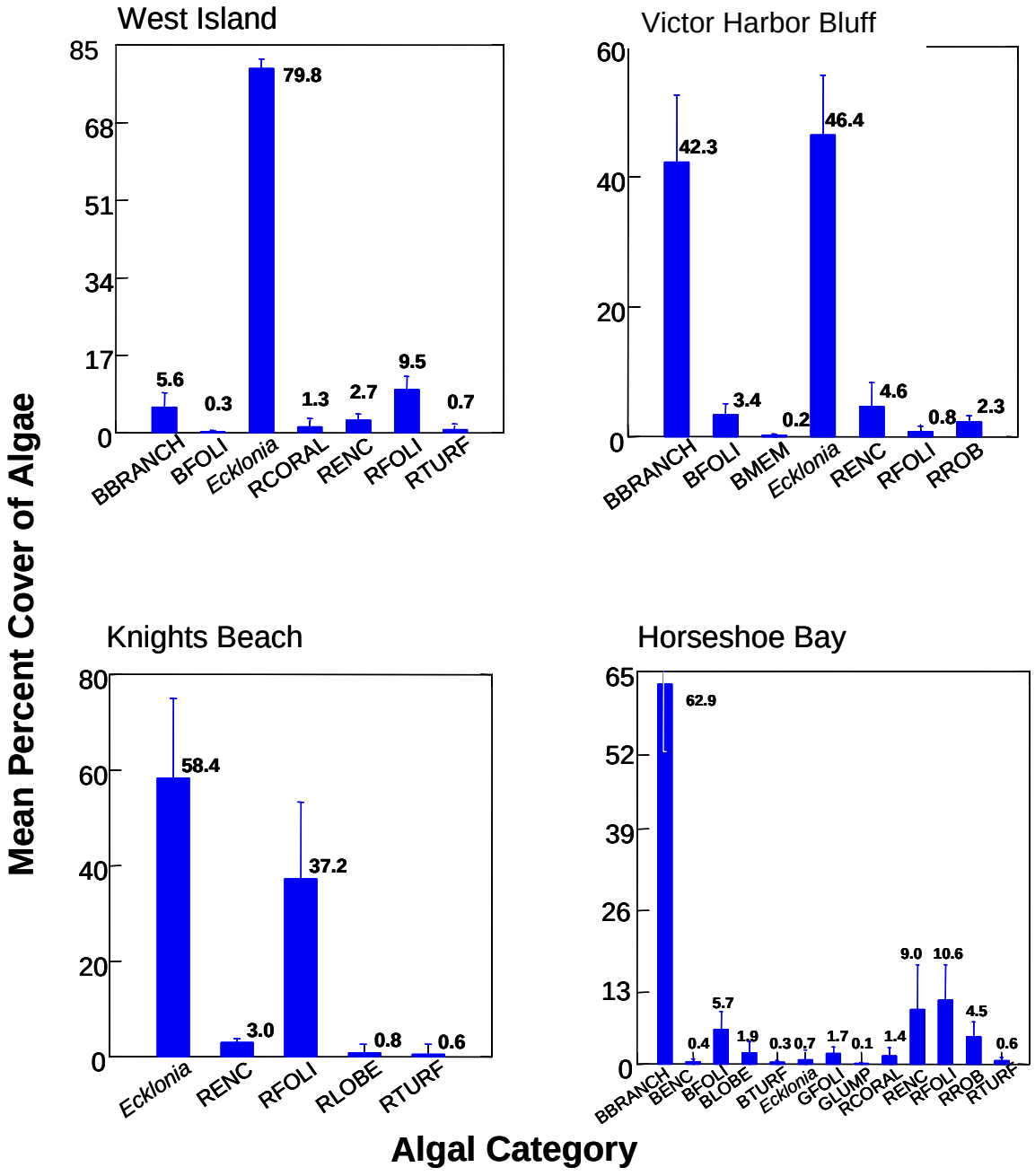
Eight species of seagrass were found within the Coorong bioregion: *Amphibolis antarctica, A. griffithii, Halophila australis, Heterozostera nigricaulis, H. polychlamus, H. polychlamys, Posidonia denhartogii*, and *P. sinuosa* (Table 6). The identifications for *Heterozostera* are based on a recent revision (Kuo 2005). We have included some notes by Dr Hugh Kirkman on reproductive status and substrate, due to current interest in seagrass restoration and the lack of knowledge about flowering and fruiting times. Collections are from SCUBA dives and benthic grabs. All herbarium material was lodged with The University of Western Australia Herbarium.

SEAGRASSES OF ENCOUNTER BAY: Hugh Kirkman, 19 February, 2005

13 November 2004 Near causeway, Granite Island, 7 m. *Halophila australis* Doty and Stone grew with fruits in silty sand over flat limestone reef. The ovaries were obvious on fruiting plants. *Heterozostera nigricaulis* Kuo was also flowering and was dominant amongst *Posidonia sinuosa* Cambridge and Kuo and *Amphibolis antarctica* (Labill.) Sonder ex Aschers. The *P. sinuosa* was flowering but very sparsely. Some *A. antarctica* seedlings were found that may have been 2-3 years old.

14 November, 2004 West Island and King Beach. This bay is densely populated by *Posidonia sinuosa* growing from 7.8 m to 10 m on sand. Only two fruit clusters were found. On the edges of blowouts, *Halophila australis* and *Amphibolis antarctica* grew. Dredging with a custom built hand dredge brought up fruiting *Posidonia denhartogii* Kuo and Cambridge, at 5-8 m. *Heterozostera nigricaulis* was found but it was rare. Towards Newlands Head there was a reef across the bay and *A. antarctica* and *A. griffithii* were dredged from sand inside the reef. Seventeen dredge pulls were made through the bay.

15 November, 2004 Dredging on coarse sand in Horseshoe Bay near Port Elliot brought up some *Heterozostera polychlamys* and *H. nigricaulis* inflorescences, but no roots or rhizomes and vegetative material were found. Later, diving at dredge sites did not reveal any growing plants. On 22 January 2005 Horseshoe Bay was again searched and *H. polychlamys* was found growing in 4.4 m in ripples on coarse sand. Vegetative and reproductive material were collected.


West Island
85
68
51
34
17
0
5.6
0.3
79.8
1.3
2.7
9.5
0.7
BBRANCH
BFOLI
Ecklonia
RCORAL
RENC
RFOLI
RTURF
Victor Harbor Bluff
60
40
20
0
42.3
3.4
0.2
46.4
4.6
0.8
2.3
BBRANCH
BFOLI
BMEM
Ecklonia
RENC
RFOLI
RROB
Knights Beach
80
60
40
20
0
58.4
3.0
37.2
0.8
0.6
Ecklonia
RENC
RFOLI
RLOBE
RTURF
Horseshoe Bay
65
52
39
26
13
0
62.9
0.4
5.7
1.9
0.3
0.7
1.7
0.1
1.4
9.0
10.6
4.5
0.6
BBRANCH
BENC
BFOLI
BLOBE
BTURF
Ecklonia
GFOLI
GLUMP
RCORAL
RENC
RFOLI
RROB
RTURF
Mean Percent Cover of Algae
Algal Category

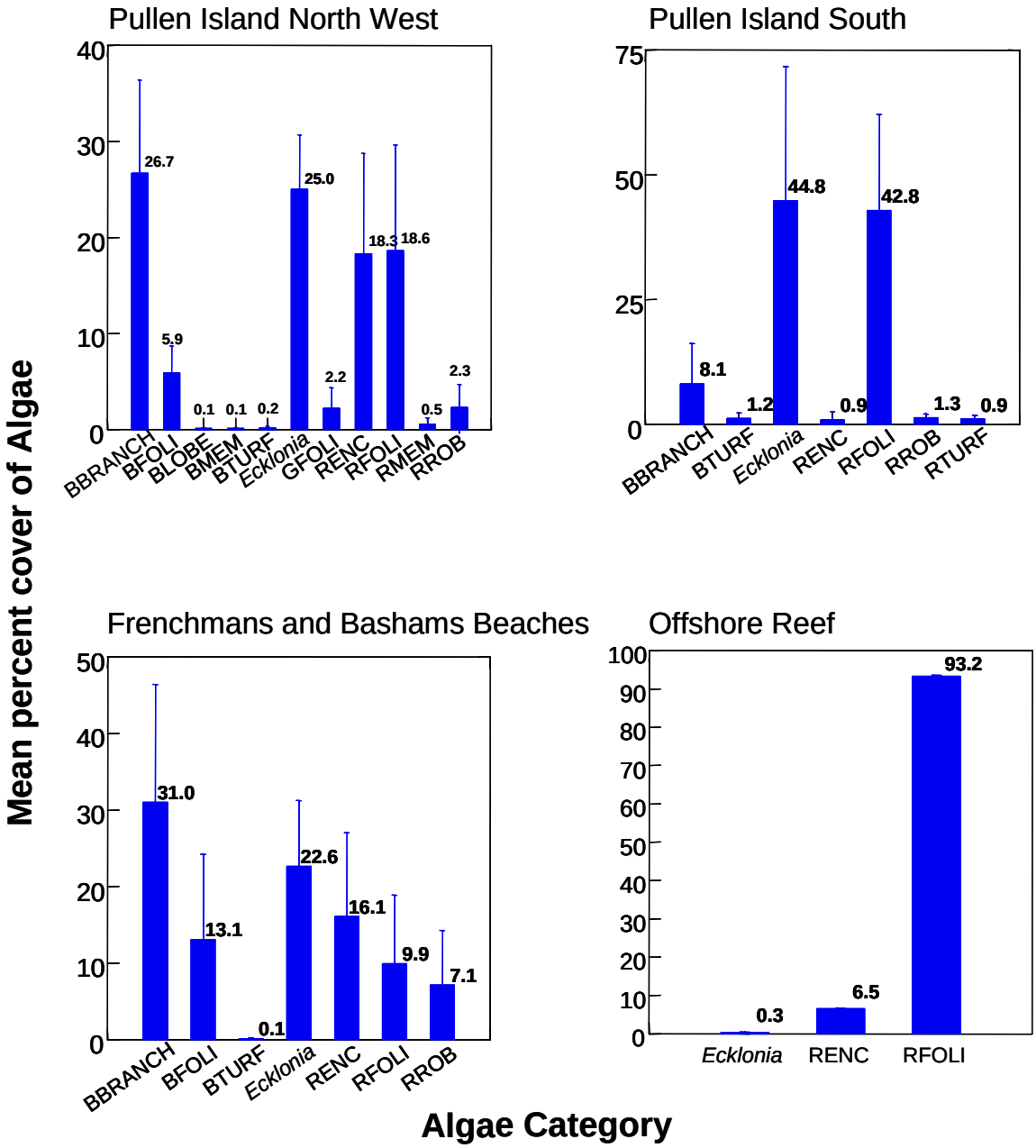


Figure 7. Mean percent cover and standard error for each algal category per dive transect at sites within the study area.
Sites are: West Island (n = 3); Victor Harbor Bluff (n = 4); Knight Beach Point (n = 3); Horseshoe Bay (n = 4); Pullen Island North (n = 4); Pullen Island South (n = 3); Frenchmans Rock and Basham Beach (n = 3); Offshore (Offshore site #1, 4 km offshore from the Murray Mouth, n = 2). n = number of transects. Algal codes are as follows: first letters are B, brown; G, green and R, red; following lettered codes are BRANCH, branching; CORAL, coralline; ENC, encrusting; FOLI, foliose; LOBE, lobe shaped leaf; LUMP, fleshy or ball like; MEM, membranous; ROB, robust branching; and TURF, turfing. Note: Y-axis scale varies between sites.

Table 6. Seagrass species identified by Hugh Kirkman from study sites.

Site	Seagrass Species	Position East	Position South	Depth (m)
Granite Island	*Amphibolis antarctica*	Near causeway		7.0
	Halophila australis	Near causeway		7.0
	Heterozostera nigricaulis	Near causeway		7.0
	Posidonia sinusoa	Near causeway		7.0
West Island	*Amphibolis antarctica*	138° 35 603	35° 35 828	7.7
		138° 35 067	35° 36 126	5.6
		138° 35 110	35° 36 150	6.5
	Amphibolis griffithii	138° 35 603	35° 35 828	7.7
		138° 35 374	35° 35 942	6.6
		138° 35 067	35° 36 126	5.6
	Halophila australis	138° 35 603	35° 35 828	7.7
	Heterozostera nigricaulis	138° 35 527	35° 35 799	5.0
	Posidonia denhartogii	138° 35 543	35° 35 816	8.5
		138° 35 527	35° 35 799	5.0
		138° 35 586	35° 35 794	8.1
		138° 35 603	35° 35 828	7.7
		138° 35 374	35° 35 942	6.6
		138° 35 067	35° 36 126	5.6
	Posidonia sinuosa	138° 35 617	35° 36 261	16.5
		138° 35 406	35° 36 267	9.2
Horseshoe Bay	*Heterozostera nigricaulis*			
	Heterozostera polychlamys			

4.6 Water Quality

Physical water parameters were consistent throughout the study area. Salinity and pH did not differ among transects and no clear south-north pattern was seen, indicating that any outflow of the Murray River did not alter either salinity or pH over larger scales at the time of the study (November 2004). Salinity readings among all sites ranged between 35.4 and 36.0 ‰, while pH readings ranged between 8.0 and 8.2.

Turbidity differed significantly among transects (ANOVA: $F_{9,90} = 17.47$, $p < 0.0001$). Readings from transect 11 were significantly lower than readings from all other transects, while readings from transect 13 were significantly higher than all other transects (Figure 8; plus transect numbers correspond to transects shown on Figure 2). Transect 13 was directly offshore from the Murray Mouth, and it is possible that increased turbidity was due to fresh water outflows, or previous deposition of sediment stirred up by heavy seas during the field trip.

Chlorophyll *a* readings were higher for transects 8-12, with maximum values in transects 9 and 10. There was an abrupt decline between transect 12 and transects 13 and 14 (Figure 9). Transects were significantly different from each other (ANOVA: $F_{9,90} = 175.78$, $p < 0.0001$), which was most evident in the readings from transects 9 (2.42 ± 0.047 mg l^{-1}) and 10 (2.46 ± 0.065 mg l^{-1}), which were up to three times higher than readings for transects 4 and 5 (southern end; 0.98 ± 0.025 mg l^{-1} and 0.65 ± 0.155 mg l^{-1}, respectively) and transects 13 and 14 (northern end; 0.12 ± 0.02 mg l^{-1} and 0.39 ± 0.041 mg l^{-1}, respectively). These data are hard to interpret, as the position of transects 9 and 10 do not correspond to any physical feature (e.g. the mouth of the Murray River) or any pattern in water nutrient concentrations. In general, inshore water, and hence sand, movement is in a northerly direction in Encounter Bay.

Neither the concentration of ammonia nor phosphate differed among sites, nor was a south-north trend present (Figure 10). In contrast, the concentration of total nitrogen generally declined from south to north, and resulted in a significant, though weak, regression ($r^2 = 0.495$, $P = 0.034$). Interestingly, patterns of chlorophyll *a* concentration did not seem to correspond to any pattern in water nutrient concentration.

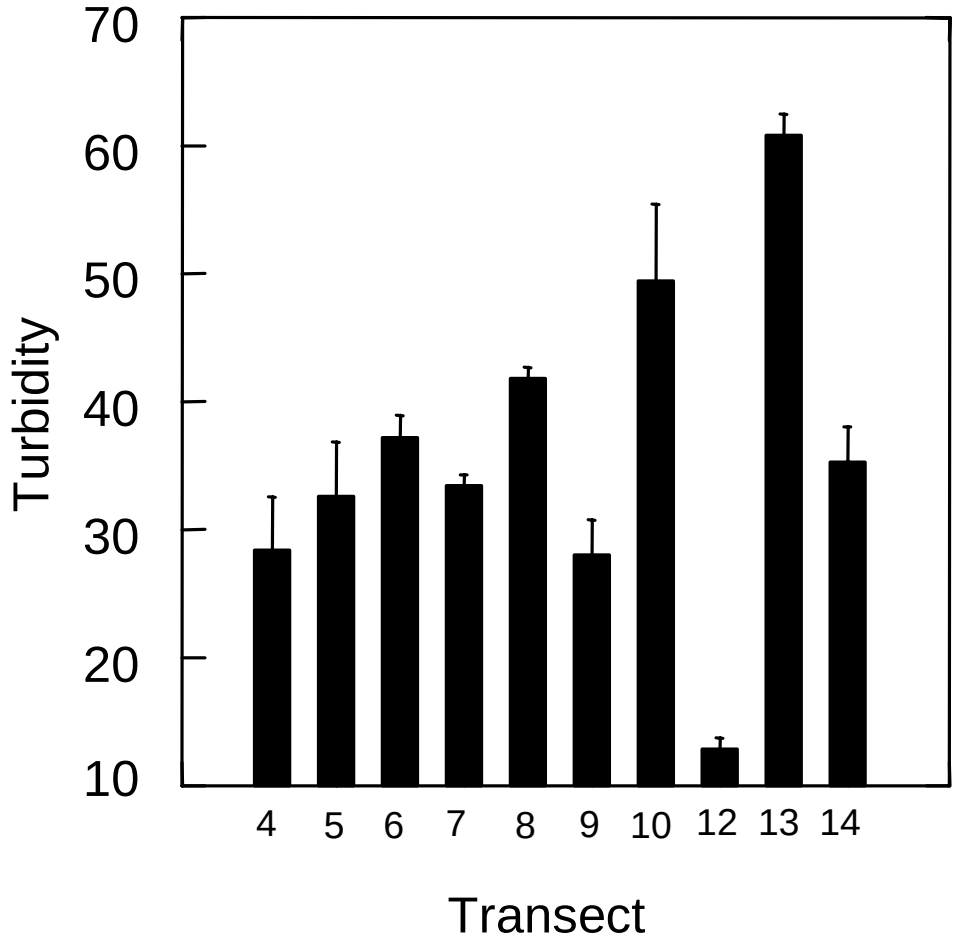


Figure 8. Turbidity readings from the study area.
Transect numbers refer to locations of single-beam, dual frequency sonar mapping transects shown on Fig. 2. Water quality data were not collected from transect 1-4, nor 15-18. Transects are in order of south (transect 4) to north (transect 14).

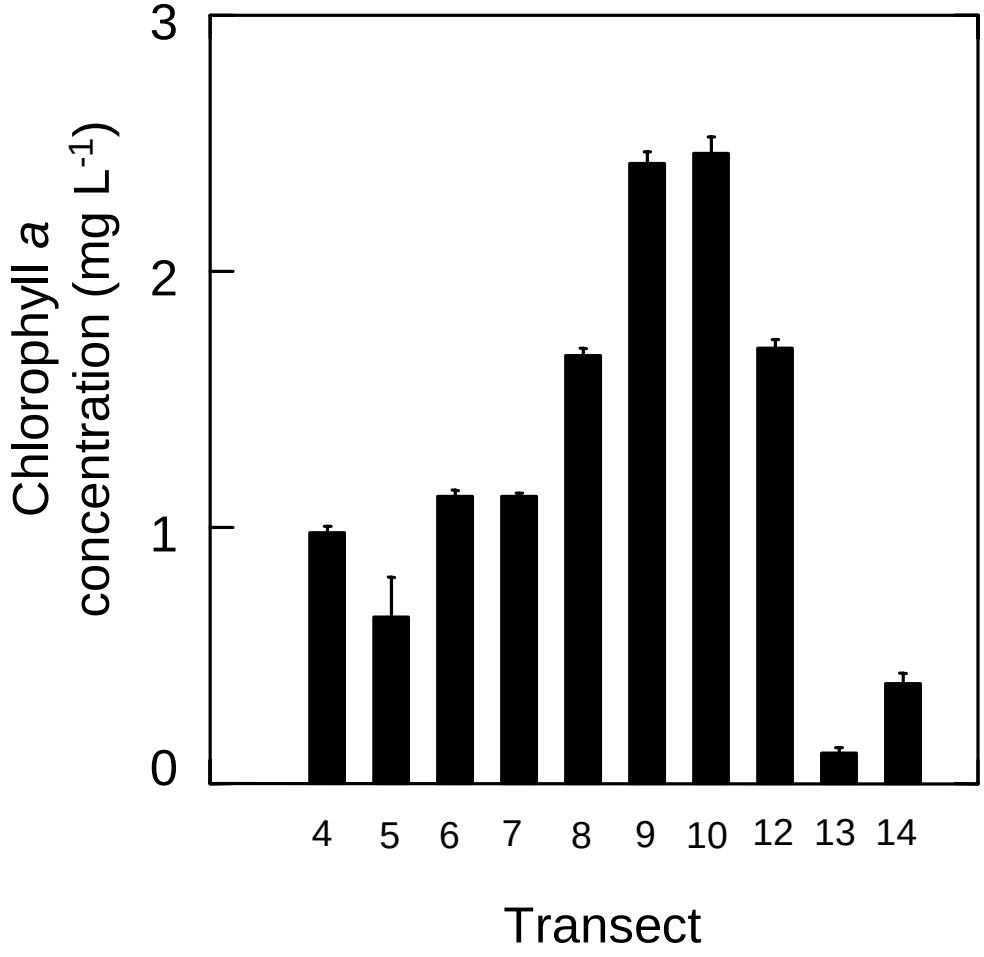


Figure 9. Chlorophyll *a* readings taken from the study area.
Transect numbers refer to locations of single-beam, dual frequency sonar mapping transects shown on Fig. 2. Water quality data were not collected from transect 1-4, nor 15-18. Transects are in order of south (transect 4) to north (transect 14).

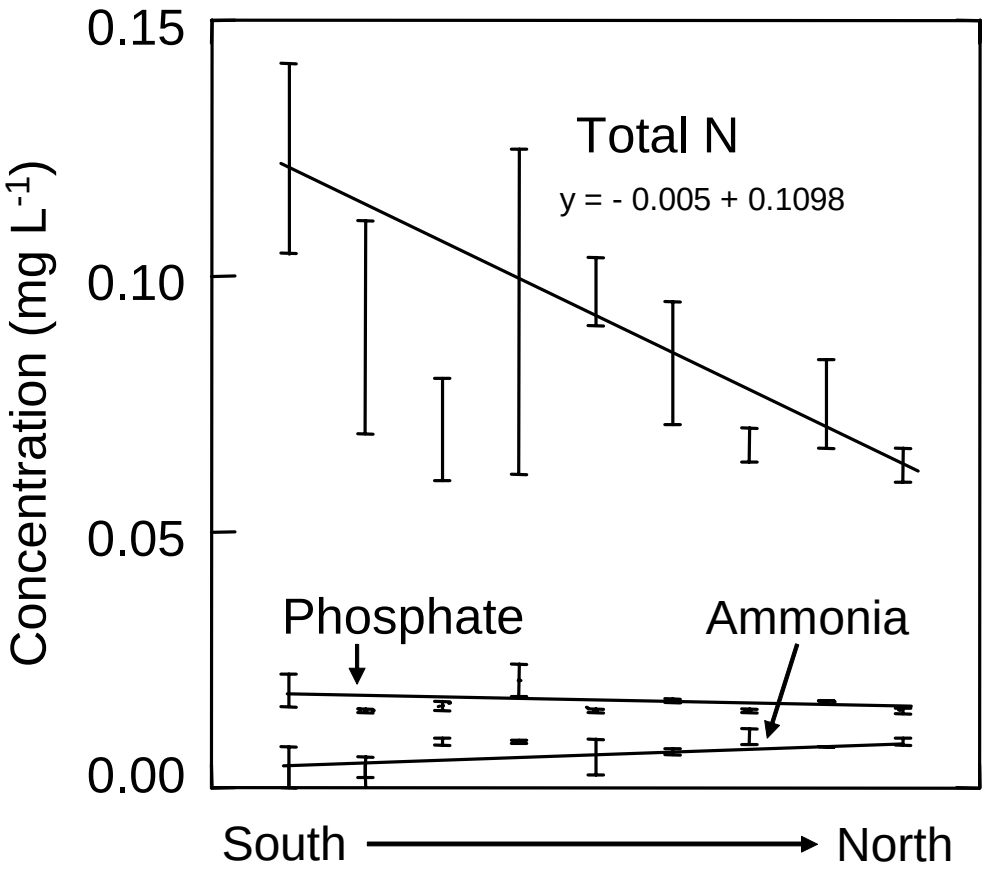


Figure 10. The concentration of ammonia, phosphate and total nitrogen in water samples taken from the study area. Sites are in order of south to north from left to right.

5.0 Discussion

The Coorong Region

The Coorong bioregion is a complex stretch of coastline consisting of a diversity of habitats. A range of exposure types occur between Encounter Bay, Goolwa and the Granites, with the highest wave energies occurring south of the Murray Mouth (Edyvane, 1999). Wave energies and water depths shape the biotic assemblages of this region. Complex algal dominated inshore reef habitats were abundant in the calmer waters of Encounter Bay, with coarse sandy habitats overlying the low platform reefs that run parallel to shore. Previously unmapped in the Coorong bioregion are the complex reef environments that are interspersed between sandy habitats on the offshore limestone platform reef.

General

No feral or invasive species were observed at any location. In general, reefs appeared to be healthy and in good condition, and supported a high diversity of animal and algal life. While at this stage health is a subjective measure, data from this study will be compared to a larger dataset for metropolitan Adelaide and other regions as part of a larger, multi-agency Reef Health project[3].

Habitats

Sand

Coarse sands overlying a low platform limestone reef dominate the Coorong offshore areas. The low platform reefs running parallel to shore are interspersed with more complex reef formations and algal beds. Little fauna was directly observed in these offshore regions; however, poor conditions during sampling may have influenced both the presence of mobile fauna and the ability to see them both on dive transects and during video drops.

[3] FRDC Project #2004/078

Sandy bottoms are known to support both a high diversity and abundance of biota (McLachlan and Erasmus 1983). SCUBA dives were rarely conducted on the exposed, sandy bottom sites, as video drops easily confirmed which type of habitat was present.

Sandy habitats are formed by an accumulation of sediment deposited by waves and long shore currents. The energy of the wave action will dictate the types and size of sediment grains deposited, and the profile of the sandy habitat, which will in turn facilitate the types of organisms capable of inhabiting the zone. For example, a medium wave energy zone typical of southern Australian beaches will consist of fine to medium grain sands, and create a diversity of habitats available to biota (Jones and Short 1995). It is likely that high wave energy and constant sand movements to the south of the Murray Mouth prevent the settlement of many sessile species (Edyvane, 1999); however, these areas are likely to provide habitat for an abundance of infaunal invertebrate biota. Dependent on sediment particle size, invertebrates in and on the sandy habitats of the Coorong are likely to be dominated by worms (nematodes, polychaetes, flatworms and ribbonworms); crustaceans (crabs, amphipods and isopods) and molluscs (Jones and Short 1995). The Goolwa cockle; *Donax deltoides*, is particularly abundant in inshore, mainly intertidal areas, and forms the basis of a large commercial fishery (Murray-Jones and Johnston 2003). There is likely to be a rich interstitial fauna as well (McLachlan and Erasmus 1983); however, interstitial life has been little studied at present.

Seagrass

Seagrass beds are important habitats providing homes for an abundance and diversity of marine wildlife (Keough and Jenkins 1995). Seagrass beds alter physical conditions such as temperature, salinity, turbidity, oxygen concentration and water movement to provide conditions suitable for habitation by periphyton (microscopic organisms), epiphytes, infauna, mobile and sessile epifauna, and also many commercially important juvenile and adult fishes (Keough and Jenkins 1995). Seagrass habitats play an important ecosystem role alongside reef habitats, and protect the coast by buffering wave energy. Many cool temperate marine invertebrates, such as the Southern rock lobster, as well as many fish species are reliant on both seagrass beds and algal-

dominated reef habitats for shelter and feeding grounds during different parts of their lifecycles.

Extensive seagrass beds are present in the nearshore shallow waters between the Granites and Cape Jaffa in the south. The seagrass tails off to the north as exposure increases away from the shelter of Cape Jaffa (Sinclair Knight Merz (2001). Seagrasses are also present around Horseshoe Bay and West Island to the north (Figure 1). The area supports a rich diversity of seagrass, with eight species found in this study. No seagrass patches were observed between the Murray Mouth and the Granites in this study; this is likely to be due to the high wave energies along the central Coorong, which prevent seagrasses from becoming established.

Reef

A series of complex reefs and low platform limestone reefs provide hard substrates suitable for the settlement of sessile biota. Floral and faunal assemblages on these reef surfaces will be shaped predominantly by wave exposure and light availability. Where hard substrates exist in the deeper waters of the Coorong, algal beds are likely to be dominated by depth-tolerant red algae (Edyvane 1999; Raven, Evert et al. 1999). This was observed in this survey, where SCUBA transects, specimen grabs and video transects showed a predominantly red foliose algal assemblage on reefs at deep (> 20 m) offshore sites. Some *Ecklonia* was also seen in abundance at SCUBA dive sites deeper than eight metres (West Island, Knight Beach, Pullen Island South).

Few SCUBA dives were possible on the more exposed sites due to a 5 m swell running at the time of the survey, and only the two offshore sites (mid-transect 18 on Figure 3) were examined in detail by divers. On one site, an LIT was conducted, and this offshore site was observed to be dominated by red foliose algae, with observed fauna limited to a Purple wrasse (*Notolabrus fucicola*), and an asteroid (*Nectria ocellata*). The surge at the other site, even at 25 metres depth, was strong enough to preclude an LIT being carried out, and survey work was limited to observations and sample collection; however, it was noticeable that this reef was completely different from all other reefs examined. It was neither algal-dominated (although there was some *Ecklonia radiata* and red foliose algae), nor scoured clean by shifting sand. This site was the only site observed that was dominated by invertebrates, and was notable for the diversity and density of sessile filter feeders (see species list in Appendix 5, “Offshore #2”).

In contrast to the offshore reefs, the shallower high-energy platform reefs of the region were mostly dominated by robust brown branching algae such as *Cystophora* and *Seirococcus* genera, and also *Ecklonia radiata* with an understorey of red foliose and red encrusting species. This is consistent with Edyvane's (1999) findings. The species assemblages of the near-shore marine habitats between West Island and Goolwa are typical of cool temperate marine environments, with hard substrates, boulders, crevices and ledges suitable for habitation by many of the algae, fish and invertebrate species observed during SCUBA transects.

Mixed stands within these areas are often equally as extensive (spatially) as monospecific stands of *Ecklonia radiata.* This is probably due to local disturbance patterns (Goodsell and Connell In Press). Both *E. radiata,* and brown branching genera such as *Cystophora* and *Sargassum,* are important habitat building species. Kelps such as *E. radiata* greatly alter rates of water flow, sedimentation, shading and scouring. These factors significantly influence the faunal and floral species assemblages under the canopy (Eckman *et al*. 1989; Kennelly 1989; Kennelly 1995).

Much of the fauna identified from SCUBA transects are considered reasonably common in southern Australian waters (pers. comm. Thierry Laperousaz, SA Museum). Note that for many marine invertebrates, even common ones, there is little biological, taxonomic or distributional information available. This is particularly true for many South Australian marine invertebrates. Hence even common species may never have been actually recorded from this area previously.

Sampling using SCUBA transects is likely to under- or over-represent some species. For example, species that may be over-represented on dive transects include diver positive fish such as Sea sweep, *Scorpis aequipinnis* and Western blue groper, *Achoerodus gouldii*. Fish closely associated with algae including some wrasse (eg *Notolabrus fucicola,* juvenile *N. tetricus*), and Herring cale (*Odax cyanomelas)* may be missed, while large and conspicuous or easily recognisable species can be over-represented, e.g. the dusky morwong, *Dactylophora nigricans,* or the featherstar *Cenolia trichoptera.* Other under-represented biota include very small and cryptic species (<5 mm), which were not included in transect counts (such as epiphytes, encrusting sponges, ascidians, amphipods, ostracods and small gastropods). Understorey and shade-tolerant encrusting algae such as *Zonaria*, *Lobophora*, *Colpomenia*, *Padina*, *Ulva*, *Corallina* or *Rhodymeni*a are likely to be under-represented, as are cave and crevice dwellers e.g. Scaly fin, *Parma victoriae*;

Bullseye, *Pempheris klunzingeri*; and the urchin *Centrostephanus tenuispinus* are all typically under-represented in diver transects. We did not dive at night, so nocturnally active species of fish are likely to be under-represented e.g. the Varied catfish *Parascyllium variolatum*, and invertebrates such as lobster (*Jasus edwardsii*), brittle stars (*Astroboa ernae*), holothurians (*Stichopus mollis*), and some gastropod species including abalone (*Haliotis* sp*), Clanculus undatus*, *Conus anemone*, and *Scutus antipodes* (Edgar 2000; Kennelly 1995). Biases such as these are inherent in any study of this type. Not all taxa will be samples equally, and some species are more weather- and visibility-dependant than others. However, most of the biases are fairly reproducible, e.g. fish that were over-represented in diver transects because the fish were attracted to divers are likely to always be over-represented. In any case, the methods used are designed to detect changes over time against a baseline, rather than to estimate absolute abundances of organisms.

Disturbance

Biodiversity and species richness are thought to be key factors in effective ecosystem function (Duarte 2000; Edgar *et al.* 2004), which contributes heavily, both directly and indirectly, to human welfare (Costanza *et al.* 1997). Compromising the integrity of inshore rocky algal reefs and seagrass beds decreases ecosystem function, increases biodiversity loss and amplifies existing threats to already vulnerable and endangered species. As well, algae and seagrass beds play an important role in buffering wave energy and preventing coastal erosion, hence any disruption to these habitats can have wide-reaching consequences.

Both natural and anthropogenic sources of disturbance play crucial roles in the dynamics of inshore reefs in the Coorong. Disturbances include algal grazing by fish and invertebrates, storms, fishing, recreational activities (diving, boating), sand scouring, and inputs such as fresh water, sediment and pollutants. While disturbance was not a focus of this study, we discuss below two natural disturbances of relevance to the study region, which both may be exacerbated by anthropogenic influences.

Natural Disturbance: Input from the Murray River

The Murray River is a significant source of fresh water and sediment input to the Coorong coastal area. The flow of the Murray is integral to the ecosystem functioning of the Coorong bioregion as a whole; hence, changes to flow rates of the Murray

River invariably impact on surrounding coastal areas. For example, recruitment of the Goolwa cockle in SA is thought to be strongly linked to phytoplankton blooms, which are in turn triggered by flows from the Murray (Murray-Jones and Johnston 2003).

Results from the single beam, dual frequency sonar transects suggest that there are more fine sandy sediments at the mouth of the Murray than there are elsewhere in the study region, as might be expected. These findings are reflected by water quality data, which showed that turbidity was higher adjacent to the Murray Mouth. Salinity, pH, chlorophyll *a*, ammonia and phosphate levels did not appear to display any strong north to south trends; however, different results would be expected during periods of high flow from the Murray River (at the time of the survey, the Murray Mouth was being dredged in an attempt to open it).

Total nitrogen did decline from south to north along the study area. This may be related to the Bonney upwelling near Robe, which brings nutrient-rich water from below the continental shelf to the surface waters of the southern Coorong. The higher levels of total nitrogen observed in the south of the Coorong did not appear to have affected a change in plankton, as chlorophyll *a* levels remained similar across the entire study area. Murray River-related disturbances to adjacent marine ecosystems could be assessed by their intensity, timing and frequency of disturbance to determine if new management regimes should be implemented (this data is also needed in order to understand the productivity of the area, and for effective fisheries management for species such as the Goolwa cockle (Murray-Jones and Johnston 2003)). Regular monthly sedimentation and water quality assessment over a representative time frame would give a better indication of the impacts the Murray River outputs may have on adjacent marine habitats. In addition, regular disturbances such as flooding predate European settlement, but post-settlement there have been extensive alterations in flows, flooding regimes, nutrient input and sediment loads, all of which will have had, and will continue to have, impacts on the marine environment. Freshwater flows are essential for the health of estuaries and adjacent marine habitats (Scheltinga *et al*. In Press).

Natural Disturbance: Algal grazing

The key controlling factors responsible for the shaping of individual habitats are area specific. Grazing is thought to be a major form of disturbance on temperate, algal-

dominated reef habitats. As canopy-forming algae can positively influence the number of grazers beneath a canopy (Edgar 2004), so too can grazers change algal-dominated habitats. Animals such as gastropods, abalone, lobsters, sea urchins and some fish graze on microscopic algal sporelings and new algal growth, and in this way play a large role in the structuring of the adult algae assemblages (Kennelly 1995). On some temperate Australian reefs, in large aggregations, both the gastropod mollusc *Turbo undulatus* and the sea urchin *Heliocidaris erythrogramma* have been shown to denude large areas of reef of their resident algae (Edgar 2000). *T. undulatus* grazes predominantly on *E. radiata* and *Caulerpa* species (Clarkson and Shepherd 1985). We found this species in large numbers in the study areas of Horseshoe Bay and Pullen Island North West (Figure 6). Resident grazers may be expected to play some role in shaping the species composition on a local scale, and have been recognized as having a major effect on kelp forests world wide (Steneck *et al.* 2002); however, a complex relationship exists between grazers, nutrient levels and canopy forming algae (Russell and Connell 2005). New evidence has shown that urchin grazing is generally weak across southern Australia (Hart and Connell, unpublished data). Grazers are therefore, unlikely to pose any real threat to algal-dominated reef habitat integrity within South Australian marine waters; however, factors such as increased nutrient levels in coastal waters, overfishing of the predators of grazing invertebrates, or an extension of the range of a grazing species may change this. For example, the large purple urchin, *Centrostephanus rodgersii* is the major grazer in most of eastern Australia and is closely associated with urchin barrens (large bare areas). This species has recently become more established in Tasmania, most likely due to a southern extension of the East Australia Current. As a result, urchin barrens are becoming more common in Tasmania (Edgar, pers. comm.). If this species extends its range to SA, it is not known what effect on algal communities it could have.

Future Directions

This study has provided valuable new information detailing the complexity and biodiversity of habitats within the study area. The area contains a very rich and diverse complement flora and fauna. The topography of the area is much more

complex than is indicated by existing charts and maps of the area. For example, existing Admiralty navigational charts show the bottom as “shell grit” over areas that this survey has identified as rocky reef. We will be making the data available to the relevant Department.

This study will assist in informed and focused decision-making for future research, conservation and environmental monitoring efforts. Recreational applications of this study may be to aid divers in planning dives on aesthetic habitats within the Coorong and also to educate and excite the public on how unique and vulnerable our southern marine habitats and resident species are.

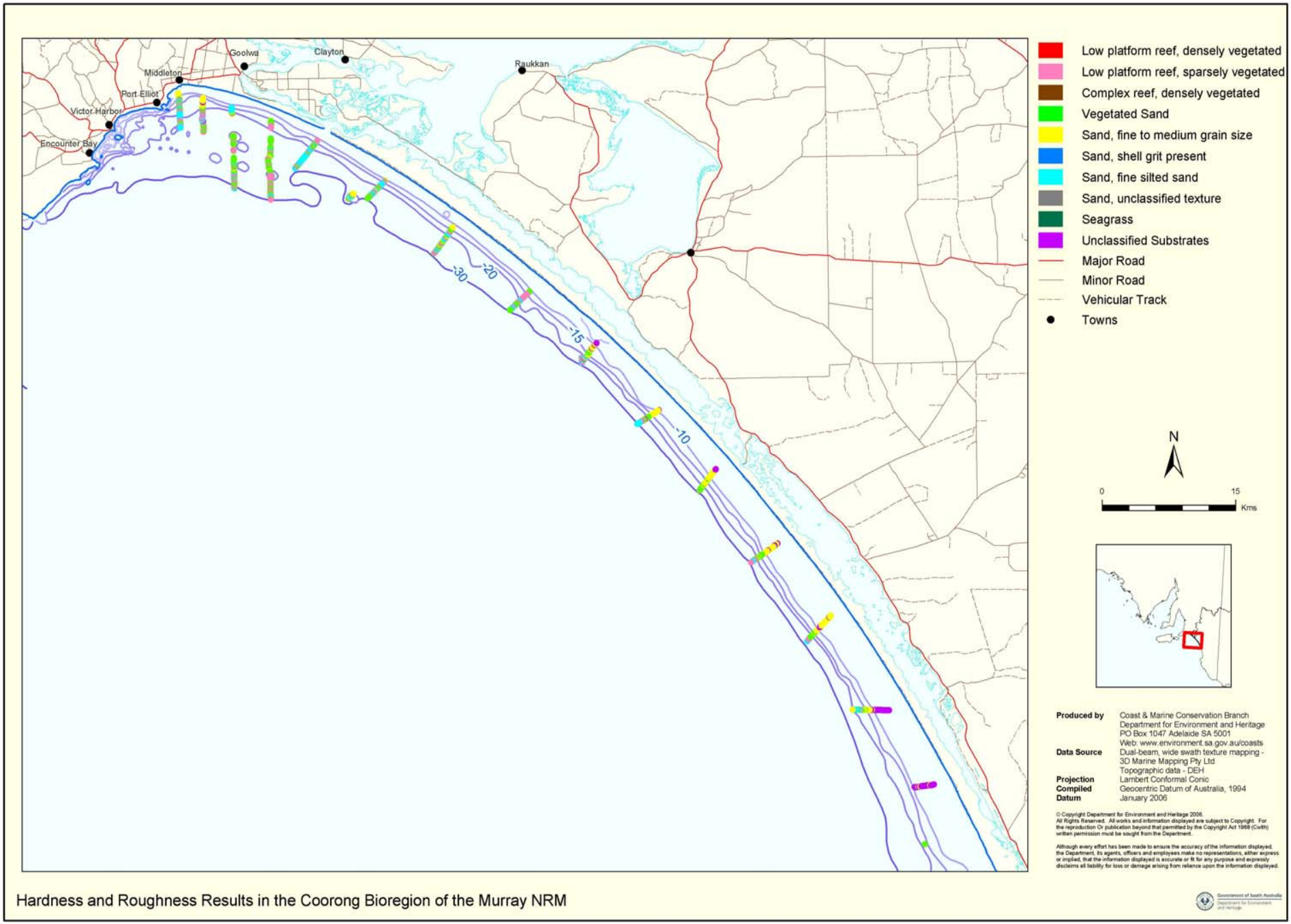
In addition, in order to assess year-to-year variability in algal recruitment and the distribution and abundance of flora and fauna, ongoing monitoring should be carried out on the near-shore, more accessible reefs. The community dive-monitoring organisation, Reef Watch is currently expanding its program to include regional areas. These kinds of monitoring programs assist in information gathering and long-term conservation. Indeed, as part of a community extension project for this current study, working in cooperation with Reef Watch, community divers have already been trained in the LIT and fish and invertebrate count methods, and have begun collecting data in order to give a baseline dataset that includes temporal variability. A series of regional workshops and a brochure are also being planned, along with some algal identification slates for divers.

This study provides an important pool of baseline data providing an understanding of the current status of the benthic habitat of the region, and outlining an overview of the reef organisms typical to the region. Species lists provide important information, and assist in identification and monitoring of rare species or new arrivals to the region. It is important to note that the sampling design used was aimed at providing a broad information base rather than a focused ecological study; however, as previously stated the work also forms an extension to a large Reef Health project being carried out elsewhere in the state and the information from this study will be compared to the larger dataset in order to gain an understanding of the health of the reefs in this area, as well as enabling a comparison of species richness and biodiversity between regions.

Potential future studies within Coorong habitats may include habitat requirement studies on species found in the Coorong, such as the Western blue groper. Considerable ecological research potential exists in Coorong habitats,

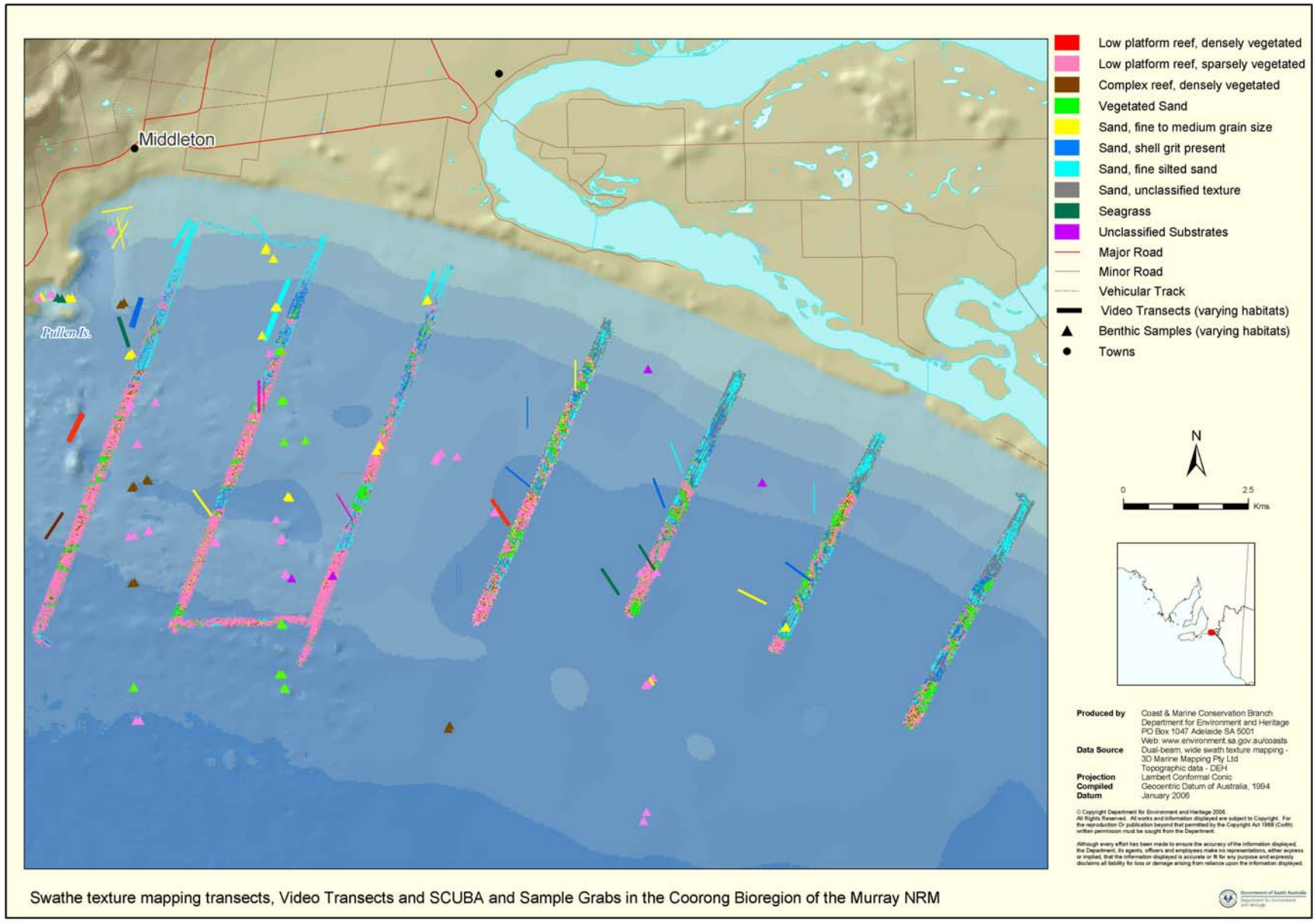
answering questions such as “are there filter feeder and grazer dominated communities?” or “how does wave exposure shape invertebrate or algal communities?” Further, very little plankton research has been conducted in South Australian waters. Zooplankton is an integral part of marine food webs however, virtually no information exists on seasonal distribution and abundance patterns of zooplankton in southern Australia (Aust 1998), and the influence of upwelling from the Murray Canyons has been little studied.

Appendix 1: Sonar Habitat Map of the Coorong



Hardness and Roughness Results in the Coorong Bioregion of the Murray NRM

Appendix 2: Swath-mapping Habitat Map of the Coorong



Appendix 3: Benthic Habitat Classification

The system used for classification of benthic habitats
The habitat classification system is hierarchical, in that it is impossible, for example, to have "un-vegetated sand" with "dense seagrass".

Habitat Group	Dominant Type	Habitat modifier
Unveg Sand	Flat	Small
Unveg Sand/Grit	Ripples	Large
Unveg Grit		
Veg Sand	Algal beds	Patchy
Veg Sand/Grit	Seagrass	Sparse
Veg Grit		Dense
Reef/Sand Patch	Red algae	Patchy
Low Platform	Red/Brown algae	Sparse
Complex Reef	Green algae	Dense
	Other (e.g. encrusting forms only)	

Abbreviation	Definition
UnVeg	Unvegetated substrate
Veg	Vegetated substrate
Sand	Fine sand
Sand/Grit	Mix of fine sand and shell grit
Grit	Shell grit
Small	Ripples < 10 cm high
Large	Ripples > 10 cm high
Reef/Sand	Flat (platform) reef interspersed with sand patches
Low platform	Flat platform reef, topographically simple
Complex reef	Reef with complex topography (e.g. ledges and dropoffs etc.)
Patchy	Patches of seagrass/algae isolated from each other
Sparse	Continuous seagrass/algae but not dense (can see a lot of substrate between plants)
Dense	Can see little substrate between seagrass/algae

Appendix 4: Reef Watch Algal Morphological Classifications

Physical Characteristics			Colour		
Size (cm)	**Shape**	**Texture**	**Red**	**Green**	**Brown**
n/a	Surface crust	Hard	RENC	-	BENC
< 2	Fine, feathery	Soft/slimy	RTURF	GTURF	BTURF
2 – 7	Branched & spiky or fern like	Hard	RCORAL	-	-
2 – 20	Membranous, think sheets	Soft/slimy	RMEM	GMEM	BMEM
2 – 20	Bushy, many branches, can be delicate	Soft	RFOLI	GFOLI	BFOLI
2 – 20	Flattened & rounded or fan shaped lobes	Firm	RLOBE	GLOBE	BLOBE
2 – 20	Fleshy fronds or ball-like	Firm	-	GLUMP	BLUMP
2 – 100+	Robust, branched with robust or leaf-like lobes	Leathery	RROB	-	-
20 – 100+	Robust, branched, often bushy in appearance	Leathery	-	-	BBRANCH
20 – 200+	Robust, flattened blades, strong stalk at base	Leathery	-	-	BLEATH

Appendix 5: Faunal Species List

Species list for all fauna observed within the study area during SCUBA biodiversity surveys (with location, phylum, class, species name, common name, number of individuals observed, water depth observed at and South Australian Museum (SAM) collection identification number provided). *Commercially fished species **Recreationally fished species. Note: where specimens were collected from different depths, numbers have been recorded separately. Hence some species occur several times within a site.

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
West Island (West)	Chordata	Chondrichthyes	*Parascyllium variolatum*	Varied catshark	1	10	
		Osteichthyes	*Cheilodactylus nigripes*	Magpie perch	1	8	
			Meuschenia flavolineata	Yellow-striped leatherjacket		8	
			Threpterius maculosus	Silverspot	1	10	
	Echinodermata	Asteroidea	*Nectria macrobrachia*		3	8	
			Nectria ocellata		1	8	
			Nectria ocellata		2	10	
			Nepanthia troughtoni		1	8	
			Pentagonaster duebeni		2	8	
			Petricia vernicina		1	8	
		Crinoidea	*Cenolia trichoptera*		89	8	
			Cenolia trichoptera		95	10	
	Mollusca	Gastropoda	*Dicthais orbita*		3	8	
			Haliotis rubra	Blacklip abalone*/**	2	8	
			Phasianella ventricosa		1	8	
			Phasianella ventricosa		1	10	

Location	Phylum	Class	Species	Common name	Count	Depth	SAM ID
West Island	Bryozoa		*Adeonellopsis foliacea*		-	5	L1183
(North east)	Chordata	Acidiacea	*Clavelina mollucensis*		-	5	
		Chondrichthyes	*Parascyllium variolatum*	Varied catshark	-	5	
		Osteichthyes	*Kyphosus sydneyanus*	Silver drummer	1	10	
			Meuschenia flavolineata	Yellow-striped leatherjacket**	1	5	
			Notolabrus tetricus	Blue-throated wrasse*	1	10	
			Odax cyanomelas	Herring cale	1	10	
			Pempheris klunzingeri	Rough bullseye	50	8	
			Pictilabrus laticlavius	Senator wrasse	1	10	
			Threpterius maculosus	Silverspot	-	5	
	Cnidaria	Anthozoa	*Epizoanthus sabulosus*		-	5	
			Mopsella klunzingeri		-	5	
		Hydrozoa	*Solanderia fusca*		-	5	H1406
	Echinodermata	Asteroidea	*Nectria macrobrachia*		-	5	
			Nepanthia troughtoni		2	10	
			Pentagonaster duebeni		1	10	
			Pentagonaster duebeni		-	5	
		Crinoidea	*Aporometra wilsoni*		-	5	K2246
			Cenolia trichoptera		8	10	
		Ophiuroidea	*Astroboa ernae*		-	5	
	Mollusca	Gastropoda	*Haliotis rubra*	Blacklip abalone*/**	1	10	
			Phasianella ventricosa		-	5	D19362
	Porifera		*Carteriospongia sp.*		-	5	S995
			Echinoclathria sp.		-	5	S997
			Spongid sp.		-	5	S992

Location	Phylum	Class	Species	Common name	Count	Depth	SAM ID
West Island cont…	Porifera		*Clathria (Thalysias) sp.2*		-	5	S993/994
(North East)			*Astrophorid sp.*		-	5	S996
			Raspailia (Raspailia) sp.		-	5	S991
Victor Harbor	Chordata	Acidiacea	*Clavelina cylindrica*		-	8	
(The Bluff)		Osteichthyes	*Cheilodactylus nigripes*	Magpie perch	1	5	
			Cheilodactylus nigripes	Magpie perch	1	8	
			Cheilodactylus nigripes	Magpie perch	1	4.5	
			Cheilodactylus nigripes	Magpie perch	1	5	
			Dactylophora nigricans	Dusky morwong**	1	8	
			Enoplosus armatus	Old wife	1	5	
			Enoplosus armatus	Old wife	-	8	
			Notolabrus tetricus	Blue-throated wrasse*	1	5	
			Notolabrus tetricus	Blue-throated wrasse*	1	8	
			Odax cyanomelas	Herring cale	2	5	
			Odax cyanomelas	Herring cale	1	8	
			Odax cyanomelas	Herring cale	2	5	
			Pempheris klunzingeri	Rough bullseye	20	5	
			Pempheris klunzingeri	Rough bullseye	-	8	
			Scorpis aequipinnis	Sea sweep*/**	3	4.5	
	Crustacea	Malacostraca	*Jasus edwardsii*	Southern rock lobster*/**	5	5	
			Jasus edwardsii	Southern rock lobster*/**	2	5	
			Jasus edwardsii	Southern rock lobster*/**	-	8	
			Plagusia chabrus		1	5	
			Plagusia chabrus		3	4.5	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Victor Harbor cont… (The Bluff)	Echinodermata	Asteroidea	*Nectria ocellata*		1	5	
			Patiriella calcar		1	8	
			Tosia australis		3	4.5	
		Crinoidea	*Cenolia trichoptera*		214	5	
			Cenolia trichoptera		100	4.5	
			Cenolia trichoptera		268	5	
		Echinoidea	*Amblypneustes ovum*		1	5	
			Amblypneustes pachistus		-	8	K2247
			Centrostephanus tenuispinus		2	4.5	
			Centrostephanus tenuispinus		-	8	
			Heliocidaris erythrogramma		7	5	
			Heliocidaris erythrogramma		1	5	
		Holothuroidea	*Stichopus mollis*		1	5	
			Stichopus mollis		-	8	
	Mollusca	Gastropoda	*Dicthais orbita*		1	4.5	
			Pleuroploca australasia		1	5	
			Turbo undulatus		11	4.5	
			Turbo undulatus		3	5	
Granite Island (Harbor)	Echinodermata	Asteroidea	*Coscinasterias muricata*		-	11	
			Uniophora granifera		-	11	
	Mollusca	Bivalvia	*Chlamys asperrimus*	Doughboy scallop*/**	-	11	
		Gastropoda	*Cabestana tabulata*		-	11	D19361
			Cassis fimbriata		-	11	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Knight Beach (The Point)	Annelida	Polychaeta	*Sabellastarte sp.*		-	11	
	Bryozoa		*Steginoporella chartacea*		-	11	L1182
			Bugularia dissimilis		-	11	
	Chordata	Acidiacea	*Eudistoma maculosum*		-	11	E3468
			Hermandia momus		-	11	
			Herdmania fimbriae		-	11	E3469
			Leptoclinides sp.		-	11	E3467
			Polycitor giganteus		-	11	
			Pyura australis		-	11	E3458
			Unknown ascidian		-	11	E3466
		Osteichthyes	*Achoerodus gouldii*	Western blue groper*/**	3	11.6	
			Cheilodactylus nigripes	Magpie perch	-	11	
			Cheilodactylus nigripes	Magpie perch	2	8	
			Meuschenia flavolineata	Yellow-striped leatherjacket **	1	8	
			Notolabrus tetricus	Blue-throated wrasse*	6	11.6	
			Notolabrus tetricus	Blue-throated wasse*	4	11.6	
			Notolabrus tetricus	Blue-throated wrasse*	2	8.5	
			Notolabrus tetricus	Blue-throated wrasse*	1	8	
			Odax cyanomelas	Herring cale	1	11.6	
			Scorpis aequipinnis	Sea sweep*	47	11.6	
			Scorpis aequipinnis	Sea sweep*	8	8	
			Scorpis georgiana	Banded sweep	1	8.5	
	Crustacea	Malacostraca	Paguristes frontalis (juv)		-	11	C6216
	Echinodermata	Asteroidea	*Nepanthia troughtoni*		2	11.6	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Knight Beach cont… (The Point)	Echinodermata	Asteroidea	*Tosia australis*		1	11.6	
			Tosia australis		1	8	
			Tosia australis		3	8.5	
		Crinoidea	*Cenolia trichoptera*		30	11.6	
			Cenolia trichoptera		2	8	
		Echinoidea	*Heliocidaris erythrogramma*		3	11.6	
			Heliocidaris erythrogramma		-	11	
			Holopneustes porosissimus		1	8.5	
	Mollusca	Gastropoda	*Haliotis laevigata*	Greenlip abalone*/**	1	8	
			Haliotis scalaris	Abalone	-	11	
			Thalotia conica		-	11	D19359
			Turbo undulatus		2	8.5	
			Aracana aurita	Shaw's cowfish	1	4.5	
Horseshoe Bay (South east)	Chordata	Osteichthyes	*Notolabrus tetricus*	Blue-throated wrasse*	2	4	
			Notolabrus tetricus	Blue-throated wrasse*	2	4	
			Pictilabrus laticlavius	Senator wrasse	2	4	
	Crustacea	Malacostraca	*Paguristes frontalis*		-	4	C6217
			Paguristes squamosus		-	4	C6218
	Echinodermata	Asteroidea	*Patiriella brevispina*		20	4.5	
			Patiriella brevispina		7	4	
			Patiriella calcar		49	4	
			Patiriella calcar		3	4	
			Tosia australis		51	4	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Horseshoe Bay cont…	Mollusca	Bivalvia	*Katelysia scalarina*	Mud cockle*/**	-	4	
		Gastropoda	*Astralium aureum*		-	4	D19365
			Austrocochlea adelaidae		-	4	D19357
			Austrocochlea odontis		-	4	D19363
			Austrocochlea odontis		-	4	
			Austrocochlea odontis		5	4	
			Austrocochlea odontis		40	4	
			Clanculus undatus		-	4	D19364
			Clanculus undatus		1	4	
			Cominella lineolata		-	4	
			Cominella lineolata		2	4	
			Cominella lineolata		2	4.5	
			Conus anemone		-	4	
			Conus anemone		1	4	
			Dicthais orbita		1	4.5	
			Fusinus australis		1	4	
	Mollusca	Gastropoda	*Haliotis laevigata*	Greenlip abalone*/**	-	4	
			Haliotis laevigata	Greenlip abalone*/**	2	4	
			Haliotis laevigata	Greenlip abalone*/**	3	4.5	
			Haliotis rubra	Blacklip abalone*/**	1	4	
			Haliotis rubra	Blacklip abalone*/**	1	4	
			Haliotis rubra	Blacklip abalone*/**	5	4.5	
			Penion mandarinus		-	4	
			Penion mandarinus		2	4.5	
			Phasianella australis		1	4	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Horseshoe Bay cont…	Mollusca	Gastropoda	*Pleuroploca australasia*		1	4.5	
			Turbo undulatus		51	4	
			Turbo undulatus		100	4	
			Turbo undulatus		2	4	
			Turbo undulatus		1	4.5	
Frenchman Rock	Chordata	Osteichthyes	*Achoerodus gouldii*	Western blue groper*/**	1	4	
			Notolabrus tetricus	Blue-throated wrasse*	1	4	
			Notolabrus tetricus	Blue-throated wrasse*	1	4.5	
			Odax cyanomelas	Herring cale	1	4	
			Parma victoriae	Scalyfin	1	4	
			Parma victoriae	Scalyfin	1	4.5	
	Echinodermata	Asteroidea	*Patiriella calcar*		48	4	
			Patiriella calcar		17	4.5	
			Tosia australis		2	4.5	
			Tosia australis		-	4	K2239
			Tosia australis variety (009)		1	4	
		Echinoidea	*Holopneustes porosissimus*		2	4.5	
			Holopneustes sp.		1	4.5	
			Holopneustes sp. Red		2	4	
	Mollusca	Gastropoda	*Dicthais orbita*		1	4	
			Dicthais orbita		1	4.5	
			Turbo undulatus		11	4.5	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Bashham Beach (Chicken Run)	Chordata	Osteichthyes	*Notolabrus tetricus*	Blue-throated wrasse*	1	4	
	Echinodermata	Asteroidea	*Tosia australis*		1	4	
		Echinoidea	*Holopneustes porosissimus*		1	4	
			Amblypneustes pachistus		-	4	K2236
	Mollusca	Gastropoda	*Phasianella ventricosa*		1	4	D19355
			Pleuroploca australasia		1	4	
			Turbo undulatus		5	4	
Pullen Island (North)	Echinodermata	Asteroidea	*Patiriella calcar*		-	5	
		Echinoidea	*Holopneustes porosissimus*		-	5	K2238
			Holopneustes purpurascens		-	5	K2240
	Mollusca	Gastropoda	*Dicthais orbita*		-	5	
			Haliotis rubra	Blacklip abalone*/**	-	5	D19356
Pullen Island (North west)	Chordata	Chondrichthyes	*Parascyllium variolatum*	Varied catshark	1	4.5	
		Osteichthyes	*Achoerodus gouldii*	Western blue groper*/**	1	4	
			Notolabrus tetricus	Blue-throated wrasse*	1	4.5	
			Notolabrus tetricus	Blue-throated wrasse*	2	4.5	
			Notolabrus tetricus	Blue-throated wrasse*	1	4	
			Notolabrus tetricus	Blue-throated wrasse*	1	2.5	
			Parma victoriae	Scalyfin	1	4	
			Scorpis aequipinnis	Sea sweep*	1	2.5	
			Tilodon sexfasciatus	Moonlighter	-	5	
			Tilodon sexfasciatus	Moonlighter	20	4	
	Crustacea	Malacostraca	*Plagusia chabrus*		-	5	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Pullen Island cont… (North west)	Crustacea	Malacostraca	*Plagusia chabrus*		1	4.5	
			Plagusia chabrus		1	2.5	
	Echinodermata	Asteroidea	*Patiriella brevispina*		1	4	
			Patiriella calcar		145	4.5	
			Patiriella calcar		52	2.5	
		Crinoidea	*Cenolia trichoptera*		13	4	
		Echinoidea	*Holopneustes porosissimus*		2	4.5	
			Holopneustes inflatus		-	5	K2237
			Holopneustes porosissimus		7	2.5	
			Holopneustes sp. Pink (012)		1	2.5	
			Holopneustes sp. Red (007)		2	2.5	
	Mollusca	Gastropoda	*Dicthais orbita*		1	2.5	
			Fusinus australis		-	5	
			Fusinus australis		2	4.5	
			Haliotis rubra	Blacklip abalone*/***	2	2.5	
			Pleuroploca australasia		1	4.5	
			Pleuroploca australasia		-	5	
			Pleuroploca australasia		9	2.5	
			Turbo undulatus		-	5	
			Turbo undulatus		32	4.5	
			Turbo undulatus		120	4	
			Turbo undulatus		48	2.5	

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Pullen Island (North east)	Chordata	Osteichthyes	*Pictilabrus laticlavius*	Senator wrasse	1	8	
			Scorpis aequipinnis	Sea sweep*/**	1	8	
			Tilodon sexfasciatus	Moonlighter	6	8	
	Echinodermata	Asteroidea	*Patiriella brevispina*		1	8	
		Echinoidea	*Holopneustes porosissimus*		3	8	
Pullen Island (South)	Arthropoda	Pycnogonida	*Pseudopallene ambigua*		-	10	E3474
	Bryozoa		*Canda arachnoides*		-	10	L1177
			Cellaporaria sp.		-	10	L1178
			Celleporaria sp.		-	10	L1181
			Orthoscuticella ventricosa		-	10	
			Amathia wilsoni		-	10	L1180
			Reteporella fissa		-	10	L1175
			Triphyllozoon sp. 3		-	10	L1176
	Chordata	Acidiacea	*Botrylloides perspicuus*		-	10	E3461/64
			Clavelina cylindrica		-	10	E3460
			Didemnum sp.		-	10	E3465
			Oculinaria australis		-	10	E3462
			Polycitor sp.		-	10	E3463
			Pyura gibbosa		-	10	
			Sycozoa cerebriformis		-	10	
			Unknown ascidian		-	10	E3459
		Osteichthyes	*Odax cyanomelas*	Herring cale	3	9	
			Scorpis aequipinnis	Sea sweep*/**	15	9	
	Cnidaria	Anthozoa	*Capnella sp.*		-	10	H1402

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Pullen Island cont… (South)	Cnidaria	Anthozoa	*Coscinaroaea mcneilli*		-	10	H1404
		Hydrozoa	*Amphisbeta maplestonei*		-	10	H1403
			Unknown hydroid		-	10	H1405
	Crustacea	Malacostraca	*Jasus edwardsii*	Southern rock lobster*/**	1	9	
			Jasus edwardsii	Southern rock lobster*/**	-	10	
	Echinodermata	Asteroidea	*Nectria ocellata*		-	10	K2241
			Nepathia troughtoni		-	10	
			Patiriella brevispina		-	10	
			Petricia vernicina		1	9	
			Petricia vernicina		-	10	
			Petricia vernicina		-	10	
		Crinoidea	*Antedon incommoda*		-	10	K2242
			Cenolia trichoptera		20	9	
			Cenolia trichoptera		-	10	
			Ptilometra macronema		-	10	K2244
		Ophiuroidea	*Ophiothrix spongicola*		-	10	K2245
	Mollusca	Gastropoda	*Calliostoma armillata*		-	10	D19358
			Turbo undulatus		1	9	
	Porifera		*Ancorinid sp.*		-	9	S975
			Aplysinopsis?		-	9	S976
			Chondropsis sp.		-	9	S972/987
			Clathria (Wilsonella) sp.		-	9	S988
			Clathrina sp.		-	9	S985/965
			Clathroid calcarea sp.		-	9	S961
			Cymbastela sp.		-	9	S981

Location	Phylum	Class	Species	Common name	Count	Depth (m)	SAM ID
Pullen Island cont… (South)	Porifera		*Dactylia sp. 1*		-	9	S978/9
			Halichondria sp.		-	9	S977
			Haliclona (Haliclona) sp.		-	9	S990
			Holopsamma laminaefavosa		-	9	S959
			Jaspis sp.		-	9	S974
			Leiosella sp.		-	9	S989
			Microcionid sp.		-	9	S964/983
			Raspailia (Raspailia) sp.		-	9	S982
			Teichonopsis cf labyrinthica		-	9	S999
			Tethya sp.		-	9	S973/986
			Thorecta sp.		-	9	S984
			Trachycladus sp.		-	9	S980
Pullen Island (South west)	Chordata	Osteichthyes	*Cheilodactylus nigripes*	Magpie perch	1	11.9	
			Notolabrus tetricus	Blue-throated wrasse*	11	8.5	
			Notolabrus tetricus	Blue-throated wrasse*	4	11.9	
			Notolabrus tetricus	Blue-throated wrasse*	1	11.9	
			Pictilabrus laticlavius	Senator wrasse	3	11.9	
			Scorpis aequipinnis	Sea sweep*/**	25	11.9	
			Scorpis georgiana	Banded sweep	17	8.5	
			Tilodon sexfasciatus	Moonlighter	3	8.5	
	Echinodermata	Asteroidea	*Nectria ocellata (?)*		2	8.5	
			Nectria ocellata (?)		1	11.9	
			Nepanthia troughtoni		1	8.5	

Location	Phylum	Class	Species	Common name	Count	Depth	SAM ID
Pullen Island cont… (South west)	Echinodermata	Asteroidea	*Tosia australis variety (009)*		1	8.5	
		Crinoidea	*Cenolia trichoptera*		13	8.5	
		Echinoidea	*Heliocidaris erythrogramma*		-	10	
			Heliocidaris erythrogramma		1	8.5	
	Mollusca	Gastropoda	*Ceratosoma brevicaudetum*		-	10	
			Dicthais orbita		1	8.5	
			Haliotis laevigata	Greenlip abalone*/**	1	8.5	
			Haliotis rubra	Blacklip abalone*/**	1	8.5	
			Pleuroploca australasia		1	8.5	
			Scutus antipodes		-	10	
			Scutus antipodes		1	8.5	
Offshore #1 (T20/T21)	Chordata	Osteichthyes	*Notolabrus fucicola*	Saddled wrasse	1	20	
	Echinodermata	Asteroidea	*Nectria ocellata*		1	20	
Offshore reef #2 Grab (T23/T24) & SCUBA collection	Echinodermata	Crinoidea	*Cenolia trichoptera*		-	24	K2233
			Comatulella brachiolata		-	18	K2235
			Ptilometra macromena		-	18	K2234
	Annelida	Polychaeta	*Filograna implexa*		-	18	
	Bryozoa		*Orthoscuticella ventricosa*		-	18	
			Steginoporella chartacea		-	18	
	Chordata	Acidiacea	*Polycitor giganteus*		-	18	
			Mogula sabulosa		-	18	E3472
			Sycozoa cerebriformis		-	18	
			Pyura australis		-	18	E3473

Location	Phylum	Class	Species	Common name	Count	Depth	SAM ID
Offshore reef # 2 cont…	Cnidaria	Anthozoa	*Capnella gaboensis*		-	18	
			Acabaria sp.		-	18	H1408
			Culicia hoffmeisteri		-	18	
			Mopsella klunzingeri		-	18	
			Zignisis repens		-	18	H1407
	Crustacea	Malacostraca	*Jasus edwardsii*	Southern rock lobster*/**	-	18	
	Echinodermata	Asteroidea	*Echinaster arcystatus*		-	18	
		Crinoidea	*Cenolia tasmaniae*		-	18	K2249
			Cenolia tasmaniae		-	18	K2249
			Cenolia trichoptera		-	18	
			Cenolia trichoptera		-	18	
			Ptilometra macronema		-	18	
		Echinoidea	*Amblypneustes ovum*		-	18	
		Ophiuroidea	*Ophiarachnella ramsayi*		-	18	K2248
			Ophiothrix spongicola		-	18	K2250
	Mollusca	Meso-gastropod	*Mystichonca (syn.= Marseniopsis) wilsoni*		-	18	D19366
	Porifera		*Amphitethya sp.*		-	18	S967
			Axinella sp.		-	18	S966
			Halichondrid sp.		-	18	S969
			Holopsamma laminaefavosa		-	18	S963

Appendix 6: Algal Species List

Algal species list of all specimens identified within the study area. Site, water depth, habitat description and South Australian Herbarium collection reference numbers are given.

Pullen Island NW	**Depth**	**Habitat**
	5.2m	Leeward side of Island
Collection Ref.	**Phylum**	**Species**
AD-A71934	Chlorophyta	*Caulerpa scalpelliformis*
Identified in the field	Phaeophyta	*Acrocarpia paniculata*
Identified in the field		*Carpoglossum confluens*
Identified in the field		*Cystophora moniliformis*
Identified in the field		*Cystophora subfarcinata*
AD-A71937		*Dictyota alternifida*
AD-A71936		*Dictyota diemensis*
Identified in the field		*Dilophus marginatus*
Identified in the field		*Ecklonia radiata*
AD-A71939		*Sargassum fallax*
Identified in the field		*Sargassum vestitum*
Identified in the field		*Scytothalia dorycarpa.*
AD-A71935	Rhodophyta	*Asparagopsis armata*
AD-A71933		*Lithothamnieae*
AD-A71938		*Phacelocarpus apodus*

Pullen Island S	**Depth**	**Habitat**
	7-8m	Reef
Collection Ref.	**Phylum**	**Species**
Identified in the field	Chlorophyta	*Caulerpa longifolia*
Identified in the field		*Codium pomoides*
Identified in the field	Phaeophyta	*Ecklonia radiata*
Identified in the field		*Zonaria sp.*
AD-A71925	Rhodophyta	*?Rhodymenia*
AD-A71921/1932		*Anotrichium sp.*
Identified in the field		*Aparaogopsis armata*
AD-A71930		*Dasyclonium incisum*
AD-A71922		Halymenia plana
AD-A71926		*Haraldiophyllum erosum*
AD-A71920		*Laurencia clavata*
AD-A71923/1924		*Lithothamnieae*
Identified in the field		*Melanthalia obtusata*
AD-A71929		*Ochmapexus minimus*
Identified in the field		*Osmundaria prolifera*
Identified in the field		*Phacelocarpus peperocarpus*
AD-A71931		*Plocamium cartilagineum*
Identified in the field		*Pterocladia capillacea*
AD-A71928		*Shepleya australis*

Frenchmans Rock	**Depth**	**Habitat**
	3-5m	Leeward side, Exposed
Collection Ref.	**Phylum**	**Species**
AD-A71866	Chlorophyta	*Apjohnia laetevirens*

Identified in the field		*Caulerpa longifolia*
Identified in the field		*Caulerpa obscura*
Identified in the field		*Codium pomoides*
Identified in the field	Phaeophyta	*Acrocarpia sp.*
AD-A71873		*Acrocarpia paniculata*
Identified in the field		*Carpoglossum confluens*
Identified in the field		*Cystophora subfarcinata*
AD-A71879		*Dictyota diemensis*
AD-A71880		*Ecklonia radiata*
AD-A71882		*Elachista orbicularis*
AD-A71858		*Halopteris paniculata*
Identified in the field		*Perithalia caudata*
AD-A71857		*Sargassum fallax*
Identified in the field		*Scytothalia dorycarpa*
Identified in the field		*Seirococcus axillaris*
Identified in the field		*Zonaria sp.*
AD-A71870	Rhodophyta	*Acrosorium ciliolatum*
AD-A71865		*Amansia pinnatifida*
AD-A71863		*Anotrichium crinitum*
AD-A71871		*Antithamnion hanovioides*
AD-A71867		*Asparagopsis armata*
AD-A71854		*Callophycus laxus*
AD-A71853		*Callophyllis rangiferina*
AD-A71877		*Curdiea obesa*
AD-A71874		*Dasyclonium incisum*
AD-A71856		*Delisea pulchra*
AD-A71855		*Dictyomenia harveyana*
AD-A71875		*Erythroclonium sonderi*
AD-A71878		*Euptilota articulata*
AD-A71868		*Haraldiophyllum erosum*
AD-A71869		*Hypnea ramentacea*
AD-A71862		*Lenormandia latifolia*
AD-A71864		*Melanthalia abscissa/obtusata*
Identified in the field		*Melanthalia obtusata*
Identified in the field		*Osmundaria prolifera*
Identified in the field		*Phacelocarpus peperocarpus*
AD-A71860		*Plocamium cartilagineum*
Identified in the field		*Plocamium dilatatum*
AD-A71861		*Plocamium preissianum*
AD-A71872		*Polysiphonia decipiens*
Identified in the field		*Pterocladia capillacea*
AD-A71859		*Pterocladia lucida*
AD-A71876		*Rhabdonia coccinea*
Identified in the field		*Rhodoglossum gigartinoides*

Knight Point	**Depth**	**Habitat**
	10-12m	Reef
Collection Ref.	**Phylum**	**Species**
AD-A71824	Chlorophyta	*Caulerpa longifolia*
Identified in the field	Phaeophyta	*Ecklonia radiata*
Identified in the field		*Zonaria sp.*
AD-A71816	Rhodophyta	*?Rhodymenia*
AD-A71830		*?Sarcodia*
AD-A71835		*Acrosorium ciliolatum*
AD-A71846		*Acrothamnion preissii*

Identified in the field		*Amphiroa anceps*
AD-A71837		*Anotrichium crinitum*
AD-A71834		*Antithamnion hanovioides*
AD-A71818		*Callophycus laxus*
AD-A71840/2003		*Dasyclonium incisum*
AD-A71819		*Epiglossum smithiae*
AD-A71851		*Euptilota articulata*
AD-A71839		*Griffithsia ?elegans*
AD-A71838		*Haraldiophyllum ?erosum*
AD-A71831		*Laurencia filiformis*
AD-A71850		*Lenormandia marginata*
AD-A71827		*Lithothamnieae*
Identified in the field		*Melanthalia obtusata*
AD-A71849		*Metamastophora flabellata*
AD-A71821		*Nizymenia australis*
AD-A71823		*Ochmapexus minimus*
Identified in the field		*Osmundaria prolifera*
AD-A71833		*Peyssonnelia capensis*
AD-A71852		*Phacelocarpus apodus*
Identified in the field		*Phacelocarpus peperocarpus*
AD-A71822		*Plocamium ?angustum*
AD-A71817		*Plocamium cartilagineum*
AD-A71848		*Plocamium cartilagineum*
AD-A71820		*Plocamium preissianum*
Identified in the field		*Pterocladia capillacea*
AD-A71844		*Pterocladia lucida*
AD-A71815		*Ptilonia australasica*
AD-A71841		*Shepleya australis*
AD-A71836		*Shepleya wattsii*
AD-A71832		*Sonderopelta coriacea*
AD-A71847		*Spyridia dasyoides*

West Island NE	**Depth**	**Habitat**
	9m	Reef
Collection Ref.	**Phylum**	**Species**
Identified in the field	Phaeophyta	*Ecklonia radiata*
Identified in the field		*Cystophora moniliformis*
Identified in the field		*Sargassum sp.*
Identified in the field		*Seirococcus axillaris*
AD-A71912	Rhodophyta	*Dasyclonium incisum*
AD-A71915	Rhodophyta	*Euptilota articulata*
AD-A71927		*Heterosiphonia microcladioides*
AD-A71918		*Martensia australis*
Identified in the field		*Melanthalia obtusata*
AD-A71914		*Peyssonnelia capensis*
AD-A71916		*Plocamium cartilagineum*
AD-A71917		*Plocamium preissianum*
AD-A71919		*Shepleya australis*
AD-A71913		*Sonderopelta coriacea*

Newland Head	**Depth**	**Habitat**
Kings Beach	6-8m	Reef
AD number	**Phylum**	**Species**
AD-A71943	Phaeophyta	*Cladosiphon filum*
AD-A71957	Rhodophyta	*Asparagopsis armata*

AD-A71944		*Ceramium ?pusillum*
AD-A71946		*Ceramium puberulum*
AD-A71940		*Haliptilon roseum*
AD-A71945		*Jania minuta*
AD-A71947		*Lejolisia aegagropila*
AD-A71941		*Metagoniolithon stelliferum*
AD-A71942		*Pollexfenia pedicellata*

Offshore #1	**Depth**	**Habitat**
`4km offshore from Murray Mouth	20m	Limestone reef
Collection Ref.	**Phylum**	**Species**
	Phaeophyta	*Ecklonia radiata*
AD-A71996	Rhodophyta	*Amansia serrata*
AD-A71977		*Areschougia congesta*
AD-A71973		*c.f.Rhabdonia coccinea*
AD-A71980		*Callophycus laxus*
AD-A71976		*Cladurus elatus*
AD-A71995		*Curdiea angustata*
AD-A71983		*Erythroclonium muelleri*
AD-A71971		*Haraldiophyllum erosum*
AD-A71974		*Hemineura frondosa*
AD-A71985		*Heterocladia umbellifera*
AD-A71972		*Hymenena curdieana*
AD-A71987		*Laurencia ?filiformis*
AD-A71968		*Metamastophora flabellata*
AD-A71999		*Muellerena wattsii*
AD-A71975		*Nizymenia ?australis*
AD-A71981		*Nizymenia conferta*
AD-A71994		*Pachymenia orbicularis*
AD-A72000		*Phacelocarpus ?apodus*
AD-A72005		*Phacelocarpus ?peperocarpos*
AD-A71982		*Plocamium angustum*
AD-A71979		*Plocamium cartilagineum*
AD-A71984	Rhodophyta	*Plocamium leptophyllum*
AD-A71978		*Psilothallia striata**
AD-A71998		*Ptilonia australasica*
AD-A71986		*Rhodophyllis multipartita*
AD-A71969		*Shepleya wattsii*
AD-A71997		*Spyridia dasyoides*

Offshore #2 Grab	**Depth**	**Habitat**
`4km offshore from Murray Mouth	20m	Limestone reef
Collection Ref.	**Phylum**	**Species**
AD-A71962	Rhodophyta	*?Callithamnion*
AD-A71963		*?Nitophyllum ?crispum*
AD-A71990		*?Rhabdonia*
AD-A71952/1966		*Anotrichium ?elongatum*
AD-A71950		*Audouinella ?pacifica*
AD-A71964		*Crassilingua marginifera*
AD-A71958		*Curdiea angustata*
AD-A71960		*Delisea pulchra*
AD-A72004		*Euptilota articulata*
AD-A71967		*Griffithsia gunniana*

AD-A71988		*Halymenia plana*
AD-A71989		*Laurencia ?filiformis f.dendritica*
AD-A71948		*Lenormandia marginata*
AD-A71955		*Myriogramme gunniana*
AD-A71949/1951		*Nitospinosa tasmanica**
AD-A71993		*Pachymenia orbicularis**
AD-A71965		*Peyssonnelia ?dubyi*
AD-A71961		*Plocamium ?costatum*
AD-A71992		*Rhodophyllis ?multipartita*
AD-A71959		*Spyridia dasyoides*
AD-A71991		*Thamnoclonium dichotomum*

Horseshoe Bay	**Depth**	**Habitat**
East	5m	Limestone reef
Collection Ref.	**Phylum**	**Species**
Identified in the field	Chlorophyta	*Caulerpa sp.*
Identified in the field	Phaeophyta	*Carpoglossum confluens*
AD-A71887		*Cystophora ?subfarcinata*
Identified in the field		*Dictyota sp.*
AD-A71902		*Dilophus fastigiatus*
AD-A71898		*Sargassum ?vestitum*
AD-A71881/71895	Rhodophyta	*Amansia pinnatifida*
AD-A71910		*Areschougia congesta*
AD-A71890		*Asparagopsis armata*
AD-A71888		*Ceramium pusillum*
AD-A71907		*Craspedocarpus ramentaceus*
AD-A71903		*Curdiea angustata*
AD-A71883/71884		*Delisea hypneoides*
AD-A71894	Rhodophyta	*Dictyomenia tridens*
AD-A71886		*Echinothamnion hookeri*
AD-A71901		*Gelidium australe*
AD-A71904		*Halymenia muelleri*
AD-A71909		*Involucrana crassa*
AD-A71900		*Lophothalia verticillata*
AD-A71905		*Ochmapexus minimus*
Identified in the field		*Osmundaria prolifora*
AD-A71885		*Platysiphonia victoriae*
AD-A71906		*Plocamium angustum*
AD-A71896		*Plocamium cartilagineum*
AD-A71893/71893		*Plocamium leptophyllum*
AD-A71899		*Pollexfenia pedicellata*
AD-A71892		*Polysiphonia crassiuscula*
AD-A71911		*Ptilocladia vestita*
AD-A71889		*Rhabdonia verticillata*
AD-A71891		*Sargassum linearifolium*
AD-A71908		*Spyridia ?squalida*

Victor Harbor	**Depth**	**Habitat**
Granite Island	6m	
Collection Ref.	**Phylum**	**Species**
AD-A71828	Phaeophyta	*Sporochnus ?radiciformis*
AD-A71810	Rhodophyta	*?Callocolax*
AD-A71807		*?Trailliellopsis*
AD-A71813		*Austrophyllis ?alcicornis*
AD-A71812		*Champia zostericola*

AD-A71826		*Crouania ?shepleyana*
AD-A71811		*Gloiosaccion brownii*
AD-A71814		*Halymenia muelleri*
AD-A71809		*Hypnea ?charoides*
AD-A71829		*Metagoniolithon stelliferum*
AD-A71808		*Ptilocladia ?pulchra*
AD-A71825		*Trithamnion ?gracilissimum*

Coorong	**Depth**	**Habitat**
Offshore Grabs	18-25m	Reef - Rocky Reef
Collection Ref.	**Phylum**	**Species**
AD-A71799	Chlorophyta	*Caulerpa ?flexilis*
Identified in the field	Phaeophyta	*Ecklonia radiata*
AD-A71805	Rhodophyta	*?Dasythamniella*
AD-A71778		*?Lithophylloideae*
AD-A71796		*?Rhodymenia*
AD-A71806		*Acrothamnion preissii*
AD-A71803		*Anotrichium elongatum*
AD-A71804		*Anotrichium elongatum*
AD-A71770		*Anotrichium elongatum*
AD-A71775		*Austrophyllis harveyana*
AD-A71801		*Austrophyllis harveyana*
AD-A71783	Rhodophyta	*Callophycus laxus*
AD-A71764		*Callophyllis lambertii*
AD-A71784		*Callophyllis lambertii*
AD-A71797		*Callophyllis lambertii*
AD-A71772		*Ceramium pusillum*
AD-A71773		*Crassilingua marginifera*
AD-A71786		*Delisea pulchra*
AD-A71802		*Griffithsia gunniana*
AD-A71782		*Hemineura frondosa*
AD-A71765		*Heterodoxia denticulata*
AD-A71769		*Hymenena curdieana*
AD-A71777		*Hymenena curdieana*
AD-A71789		*Hymenena curdieana*
AD-A71795		*Hymenena curdieana*
AD-A71791		*Lithothamnieae*
AD-A71785		*Nitophyllum ?crispum*
AD-A71766		*Nitophyllum crispum*
AD-A71781		*Nitophyllum crispum*
AD-A71780		*Nitospinosa pristoidea*
AD-A71779		*Nitospinosa tasmanica*
AD-A71787		*Nizymenia australis*
AD-A71798		*Peyssonnelia foliosa*
AD-A71774		*Phacelocarpus peperocarpos*
AD-A71794		*Plocamium ?costatum*
AD-A71788		*Plocamium preissianum*
AD-A71790		*Rhodophyllis multipartita*
AD-A71792		*Rhodophyllis multipartita*
AD-A71800		*Rhodophyllis multipartita*
AD-A71793		*Shepleya wattsii*

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