TROPHIC ECOLOGY PILOT STUDY IN THE RIVER MURRAY ESTUARY AT PELICAN POINT

Prepared for DEH

Michael C. Geddes and Julie Francis

February 2008

SARDI AQUATIC SCIENCES PUBLICATION NO F2007/001193-1

SARDI RESEARCH REPORT SERIES NO 274

THE UNIVERSITY OF ADELAIDE AUSTRALIA

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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

South Australian Research and Development Institute

SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024
Telephone: 8207 5400
Facsimile: 8207 5406
http://www.sardi.sa.gov.au

This publication may be cited as:

Geddes, M.C. & Francis, J. (2008). Trophic ecology pilot study in the River Murray estuary at Pelican Point. Prepared for DEH. SARDI Aquatic Sciences Publication No. F2007/001193-1; SARDI Research Report Series No. 274.

Printed in Adelaide, February 2008

Author(s): Michael C. Geddes, Julie Francis
Reviewers: Milena Fernandes, Jason Nicol
Approved by: Jason Tanner

Signed:
Date: 26 February 2008
Distribution: DEH, SARDI Aquatic Sciences Library
Circulation: Public Domain

Executive Summary

This is the first study linking prey abundance to trophodynamics in the Coorong. It aimed to sample the invertebrates that occur in the open water, littoral, epibenthic and benthic environments, and to relate these to the diets of four species of fish, (hardyheads, gobies, yellow eye mullet and mulloway). An understanding of the trophodynamics of the system is an important component of appreciating its ecological character.

Sampling was undertaken from 15-17 March 2005 in a one km wide strip across the Coorong just south of Pelican Point. Ten sites were selected in a sampling strategy stratified by depth. Littoral, benthic and plankton samples were taken and data were expressed as density of individuals and as biomass m^{-2}. The guts of twenty individuals of each species of fish were examined for food items and gut contents expressed as number and biomass of food items per fish.

The sediment was generally fine sand and low in organic carbon and total nitrogen, although these increased somewhat at deeper sites. The phytoplankton community was dominated by diatoms. The chlorophyll *a* concentration was 19 µg L^{-1}, which gave an estimated algal biomass of 4,050 mg m^{-3}. Zooplankton numbers and biomass were very low. There was considerable variation between the three littoral samples reflecting differences in the landward and Younghusband Peninsula sides of the lagoon. The benthic samples showed trends of diversity and abundance with depth. In the shallow sites amphipods were the most abundant species followed by the small bivalve *Arthritica* and the polychaete *Capitella.* Other polychaetes were also common. In the mid-depth sites biodiversity was highest with amphipods again numerically dominant but the polychaete *Nephtys* dominant in biomass. At depths below 1.5 m, diversity and abundance dropped off sharply, with only four species and a total of 122 individuals m^{-2} in the deepest site (2.0 m).

Diet analysis of the fish guts showed that the small fish, (hardyheads and gobies) had a largely crustacean diet, dominated by amphipods. Juvenile mullet consumed individuals of the small polychaetes *Capitella* and *Phyllodoce*, while adult mullet had a broad diet of crustaceans, polychaetes, bivalves and plant material. Mulloway was the top predator in the system preying on other fish and crabs.

The food web model was rather simple with phytoplankton, microphytobenthos and filamentous algae the main primary producers, but probably much of the carbon enters the food chain through the detrital pathway. The amphipods and *Capitella* seem to be key species in the transfer to higher trophic levels. Some components of the macroinvertebrate assemblage did not appear to be utilised by the fish species sampled at the time of sampling.

The trophodynamics of the system in 2005 was very different from what it had been in the 1980s. The major difference was the absence of macrophytes, especially *Ruppia megacarpa.* Macrophytes and their epifauna would have provided a direct food source for grazers and scrapers and would have contributed to the detrital pool. In the 1980's the grazers and scrapers included the amphipod *Melita,* the snail *Hydrobia* and the decapod shrimp *Macrobrachium*. All of these species are now in very low abundance in the system.

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1 Introduction

This study begins to develop an understanding of the trophic ecology of the Murray Mouth and Coorong. Quantitative samples from a representative site near Pelican Point (Figure 1) were taken on the 15-17 March 2005 to estimate the composition and biomass of key biological components of the Coorong ecosystem; the phytoplankton, zooplankton, littoral and epibenthic fauna and infauna. In addition a study of the diets of key fish species in the area was undertaken to show what items were being eaten. This allowed the development of a draft trophic model to show the relationships between the zooplankton, epibenthic fauna and infauna, and representatives of the forage fish and commercial fish species. The trophic model shows the major feeding pathways and energy flows in the Coorong ecosystem and identifies key species in feeding pathways to fish.

Figure 1: Satellite map showing the location of Pelican Point relative to the Murray Mouth.

Information is needed on the trophic ecology of the Coorong to allow a better understanding of the ecological character of the Coorong, to inform ecological monitoring and to provide advice for management. Understanding the trophic ecology of the Coorong is one of the key components of the description of the "Ecological Character" of the Coorong developed for the Coorong and Lakes Alexandrina and Albert Ramsar Management plan (Phillips and Muller 2006). Results from this project will act as a pilot for trophodynamic studies in the CSIRO Water for a Healthy Country, CLLAMMecology Research Cluster (Lamontagne et al. 2004). While trophic dynamics will not be explicitly linked to freshwater flows in this one-off sampling, it will be possible to speculate on possible ways in which the system operated in the 1980's during periods of high flow (Geddes and Butler 1984, Geddes 1987).

Most of the ecological studies in the Murray Mouth and Coorong (Geddes and Butler 1984, Geddes 1987, Geddes 2003; Geddes 2005 a, b and c, Geddes and Tanner 2007) have been qualitative or semi-quantitative, and have emphasised the distribution of invertebrates along the salinity gradient in the Coorong. The study by Dittman et al. (2006) undertook quantitative sampling of the infauna using cores taken in shallows along the edge of the Coorong lagoons. The present study takes a quantitative approach to several habitats in the Coorong. Abundance estimates are made for benthic and littoral invertebrates, phytoplankton and zooplankton. These were converted to dry weight biomass by drying and weighing representatives of the major taxa collected.

Fish diet studies investigated the key food species of four species of fish in the Murray Mouth and northern Coorong near Pelican Point. These diet studies involved gut content analysis to provide identification of food items and estimation of abundance and biomass of food items in each gut. A parallel study by Lamontagne et al. (2007) used stable isotopes to investigate the trophic position of fish collected from the same area.

Information from the quantitative sampling and from the fish diet analysis was used to identify the key food resources for fish. This was then integrated into a model to allow investigation of trophic pathways in the northern part of the Coorong.

The aims of the present study were:

- To undertake a quantitative study of the infauna, littoral and epibenthic fauna, zooplankton and phytoplankton in the North Lagoon of the Coorong at a site near Pelican Point.
- To identify the key ecological components of the Murray Mouth and Coorong ecosystem and describe their feeding ecology.
- To study the feeding ecology of key fish species, including the top predator mulloway, the key fisheries species yellow eye mullet and the forage fish gobies and hardyheads.
- To propose a trophic model for components of the North Lagoon of the Coorong.
- To contribute to an understanding of the ecological character of the Murray Mouth and Coorong.

2 Methods

The study was undertaken from 15-17 March 2005. This followed a 200 day closure of the barrages since 27 August 2004 when there was an outflow of approximately 40GL (Geddes 2005b). Thus, in March 2005 the Murray Mouth was under marine influence and acting as a marine coastal lagoon.

A section of the Coorong approximately 1km wide and stretching across the lagoon was chosen just south of Pelican Point (Figure 2). Ten sites were established from a bathymetric map with four in shallow water less than 40 cm deep, three in depths between 70 and 90 cm and three deeper sites, from 1.6 to 2.1 metres (Table 1 and Figure 2). Sediment samples were collected at all sites, all ten sites were sampled for benthic animals, three sites were sampled for littoral and epibenthic invertebrates, replicate zooplankton samples were taken from site 8 and water samples for phytoplankton and chlorophyll were taken from sites 8 and 10.

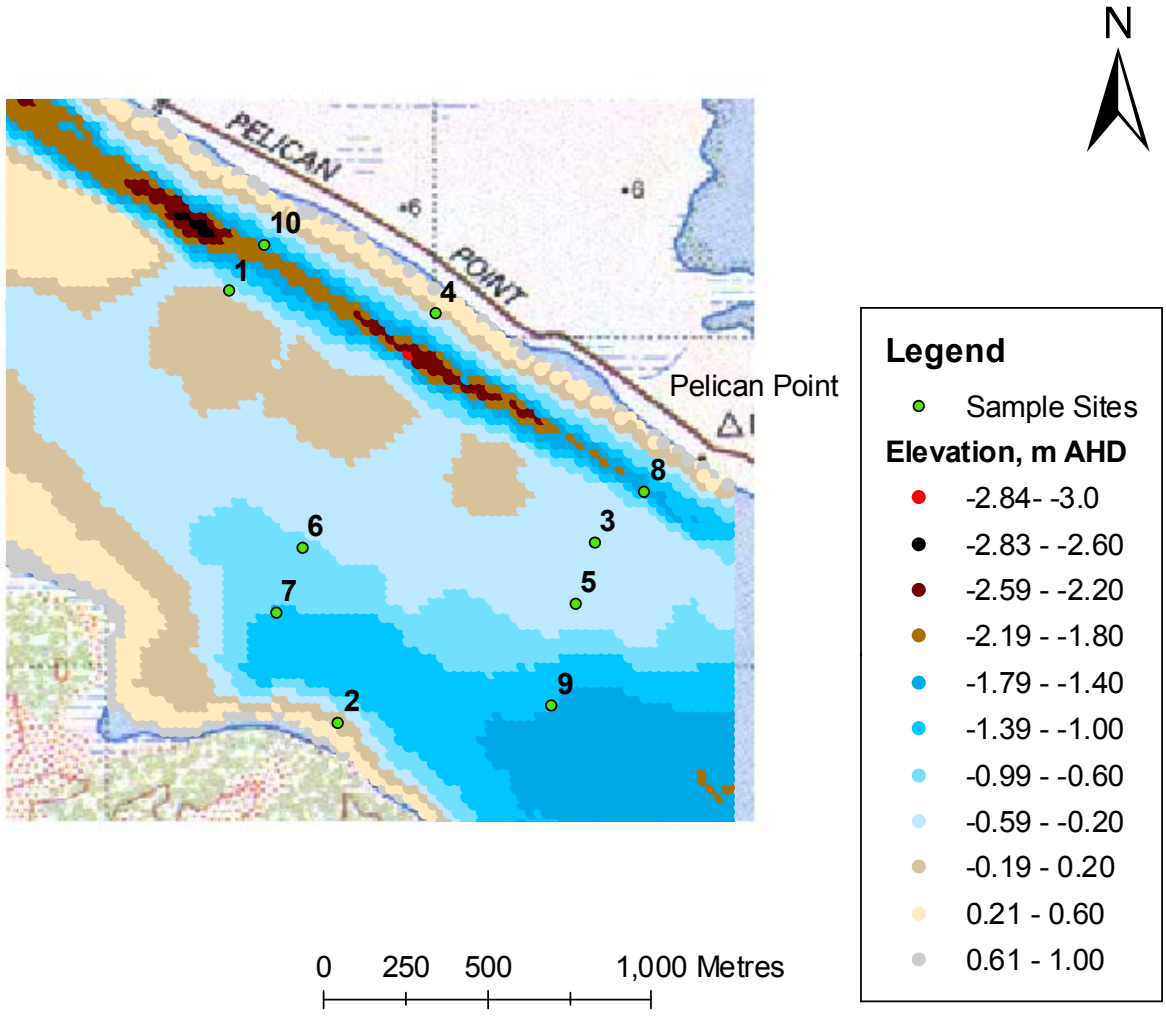

Figure 2: Sampling area near Pelican Point showing bathymetry and the ten sample sites.

Table 1: Sampling sites, their GPS coordinates, depth, sediment type and the samples collected from each site.

Site	GPS		Description	Depth Stratum	Depth (cm)	Sediment Type	Depth of Oxygenation	Samples Taken	
	Northings	Eastings						Benthic	Littoral
1	321498	6058315	on edge of sand bar	Littoral	30	fine sand	3cm	5 pooled core samples	5 cylinders
2	321833	6056996	off YH Pen. 10m from shore	Littoral	35	fine sand	2cm	5 pooled core samples	5 cylinders
3	322617	6057548	sandbar mid lagoon	Littoral	40	fine sand	2cm	5 pooled core samples	not taken: bad weather
4	322131	6058250	shallow water, 20 m from landward shore	Littoral	40	fine sand	3cm	5 pooled core samples	5 cylinders
5	322556	6057362	sand shoal off Gary's hut	to 1m	70	fine sand	1cm	5 pooled core samples	
6	321723	6057533	sand shoal, mid lagoon	to 1m	65	fine sand	1cm	5 pooled core samples	
7	321644	6057336	edge of channel off YH Peninsula	to 1m	90	fine/v fine sand	2cm	5 benthic grabs	
8	322768	6057703	opp Gary's Hut, landside in channel	>1.5m	160	mud/shellgrit	0.5cm	5 benthic grabs	
9	322485	6057053	in channel off YH Peninsula	>1.5m	170	mud	1cm	5 benthic grabs	
10	321607	6058457	deep water channel	>1.5m	190	mud/shellgrit	0cm	5 benthic grabs	

2.1 Sediment analysis

Sediment samples were taken from the ten sites using a 10 cm diameter corer. In the deeper sites an extension tube was attached to the corer so that bottom cores could be collected. The top 5 cm of the core was carefully extruded from the corer and placed in a labelled plastic bag. The nature of the top layer of the sediment was noted and the depth to which sediment was light coloured and oxygenated was measured (Table 1). Samples were returned to the laboratory and stored frozen until they were analysed.

2.2 Mineral grain size

Samples were thawed, oven-dried overnight at 105 ^{o}C and homogenized. A 50 g sub-sample of each core was muffled for 12 h at 350°C to remove organic matter and allowed to cool. This sample was stirred with a dispersing agent (40 g L^{-1} sodium hexametaphosphate in MilliQ water) for 15 minutes and left to soak overnight. Blank hydrometer (Calton Glass Marketing) readings were noted for the dispersing solution. The sample was stirred for 10 minutes, transferred into a 1 L measuring cylinder and the volume made up to 1 L using MilliQ water. The cylinder was then inverted until the sediment was evenly suspended throughout the water column and placed on a level surface. A hydrometer and temperature reading was taken exactly 2 hours after this placement to determine clay content (<4 µm). The content of the cylinder was then wet sieved through a 63 µm sieve and the retained fraction was dried at

100°C. A stacked series of graded sieves comprising 2000, 1000, 500, 250, 125 and 63 µm mesh size were used to obtain sand fractions. The sample was dry sieved using an automatic sieve shaker (Endecotts EFL2000) set at 5 min. The silt content (4-63 µm) was calculated as the difference between the muffled weight of the sample and the sand and clay fractions.

Mineral grain size distributions were analysed with the software package GRADISTAT (Blott & Pye, 2001). The Folk and Ward graphical method was used to calculate grain size parameters. This method is relatively insensitive to samples with a large particle range in the tails of the distribution and provides a robust tool to compare compositionally variable samples. Parameters used to describe grain size distributions included the mean grain size, the spread of sizes around the mean (sorting), the symmetry or preferential spread of the distribution to one side of the mean (skewness), and the degree of concentration of the grains relative to the average (kurtosis). Although the clay fraction was measured as sediments <4 µm, it was considered to vary in the range 0.25-4 µm for calculation of statistical parameters.

2.3 Sediment chemistry

Samples were freeze-dried, sieved to 500 µm to remove large shell fragments, and homogenized with a mortar and pestle. Carbonate content was determined with a pressure transducer (RS Components, part 348-8065, Iso-Tech voltameter IDM 91) by measuring the increase in pressure generated by the CO_2 released after acidification of aliquots with 5.5N HCl at room temperature. Organic carbon (OC) and total nitrogen (TN) contents were determined with a LECO TruSpec CNS Elemental Analyser and are reported as a fraction of total sediment weight. Pre-treatment of samples for OC analysis included acidification with 1 N HCl to remove carbonates. Weight percentages of OC were corrected for carbonate content.

2.4 Biological samples

Benthic samples were collected with a 5 cm diameter corer when depths were less than 1m and with a 20 cm square benthic grab for deeper sites. Five replicate samples were collected from each site. Where the corer was used, five cores were pooled for each sample. This represented an area of 100 cm^2. Each benthic grab sample represented 400 cm^2. Samples were sieved in the field through a 500 µm mesh, preserved and returned to the laboratory for identification and counting. This method of sampling collected infauna from the top 10 cm and also the epibenthic organisms just above the sediment.

Littoral samples were taken by forcing a 57cm diameter cylinder into the substrate deep enough to seal the sample and then removing the organisms captured in the cylinder with a 500 µm hand net. Hand netting within the water contained in the cylinder continued until no further organisms were being collected. Five replicate littoral samples were taken in this way. Each sample represented an area of 2,550 cm^{-2}. Samples were preserved and returned to the laboratory for identification and counting.

Zooplankton collections were made at site 8 by pulling a 150 µm net of 25 cm diameter obliquely through the water column for 10 m, representing a sample of 1,960 L. Five replicate samples were taken. Zooplankton were identified and counted to taxa and size classes by Dr Russel Shiel (University of Adelaide). Three independent subsamples were taken from each replicate to estimate the abundance of each zooplankter.

Water samples were taken from sites 8 and 10 and sent to the Australian Water Quality Centre, Bolivar, for counting of algal cells and estimation of chlorophyll *a* and *b*.

2.5 Estimating dry weight and biomass

In the laboratory, estimates of the dry weight of organisms from the benthic and littoral samples were made by drying a known number of specimens of a nominated size within each of the taxa at 80^{o}C for 6 hours. This allowed calculation of the dry weight of an average individual in the taxon/size category. The dry weights were of whole animals and so included shell and carapace weight except for the bivalve *Notospisula* where the shell was removed.

The biomass of phytoplankton was estimated from the chlorophyll concentration using the Redfield approximation of 1:200 for the ratio of chlorophyll to dry weight (Reynolds 1984). Zooplankton dry weight was calculated from relationships between length and dry weight developed by Dumont et al. (1975). It should be noted that these methods provide only an approximation of the dry weight of the organisms.

The average dry weight of the various organisms was used to estimate dry weight biomass in the samples. Biomass is presented as mg m^{-2} for the benthic and littoral samples and mg m^{-3} for phytoplankton and zooplankton. The average depth of water in the area sampled was about one metre and so the phytoplankton and zooplankton values approximate biomass m^{-2} and so can be compared with the benthic and littoral biomasses.

2.6 Fish diet

Samples for fish diet were collected by seine net for small mouth hardyheads, tamar gobies and small, <80 mm total length, mullet. Large mullet and mulloway were collected by a commercial fisher, Gary Hera Singh. Twenty guts from each of the fish species were collected and analysed. The stomachs of the fish were preserved in ethanol and returned to the lab for identification and counting of the food items. In most cases food items could be identified to family or genus level. Data from the 20 fish from each taxon were combined to give % occurrence of an item across the 20 fish guts and mean abundance of food items in the gut. Using estimates of the dry weight made above for the major food items found in the guts, the biomass of food items in the guts was determined. The % composition in the diet, by number and by biomass, was then calculated.

3 Results and Discussion

Examination of the top layers of the cores from the ten sites showed that they were oxygenated for only a few centimetres depth (Table 1). For the four littoral sites the depth of the oxygenated layer was up to 3 cm, the mid-depth sites had 1 to 2 cm of sediment oxygenated while the deep sites had only 1 or 0.5 cm oxygenated at sites 8 and 9 and no oxygenated sediment at the deepest site 10.

3.1 Sediment analysis

Mean grain size varied in the range 135 to 329 µm, as fine sands dominated distributions (Table 2). Most samples had a unimodal size-frequency distribution peaking in the fine sand range at 187.5 µm, characteristic of the slightly gravelly sand textural group (Figure 3). This is similar to the sediment analysis of Dittmann et al. (2006) who found the median particle size was fine to medium sands in the 125 to 250 µm size range. At the deepest sites there was a larger proportion of clay (<4 µm) and silt (4-63 µm) showing that finer particles sedimented there.

Table 2: Mineral grain size fractions and distribution parameters for the ten sites.

Sites	1	2	3	4	5	6	7	8	9	10
Grain size fractions (%)										
Clay (<4 µm)	3.52	2.07	3.74	4.16	3.28	4.07	4.80	6.95	6.44	8.35
Silt (4-63 µm)	0.03	0.84	0.0	0.0	0.0	0.0	0.0	0.0	0.38	5.19
Very fine sand (63-125 µm)	7.62	4.03	4.35	2.18	6.68	12.90	13.69	8.07	30.77	5.55
Fine sand (125-250 µm)	83.80	74.19	72.83	89.89	84.15	74.19	74.05	58.51	57.13	23.03
Medium sand (250-500 µm)	4.59	18.17	18.32	3.11	5.34	8.04	6.42	18.67	4.48	16.80
Coarse sand (500-1000 µm)	0.26	0.51	0.68	0.29	0.49	0.71	0.39	6.58	0.64	15.07
Very coarse sand (1-2 µm)	0.09	0.03	0.04	0.16	0.05	0.07	0.22	0.60	0.05	13.04
Gravel (>2000 µm)	0.10	0.17	0.04	0.21	0.01	0.01	0.43	0.62	0.10	12.97
Distribution parameters										
Mean (µm)	172.0	194.0	194.0	175.0	174.0	165.0	162.0	207.0	135.0	329.0
Sorting (s_G) (µm)	1.40	1.50	1.56	1.72	1.40	1.51	1.52	3.17	2.72	8.21
Skewness (Sk_G)	-0.17	0.07	0.01	-0.26	-0.14	-0.17	-0.19	-0.16	-0.47	-0.14
Kurtosis (K_G)	1.28	1.26	1.37	2.65	1.31	1.35	1.37	3.80	2.73	1.12

At sites 1 to 7 sorting values were 1.4 to 1.7, indicating that sediment at these sites was well sorted. Sites 8, 9 and 10 were poorly sorted with sorting values from 2.72 to 8.21. This reflected the higher proportion of clay and silt, and for site 10 the high proportion of coarse particles which consisted of calcareous fragments from worm tubes. Thus site 10 was clearly within a depositional area. An excess of fine particles led to mostly fine skewed distributions (Sk_G -0.3 to -0.1). Kurtosis values (K_G) from 1.12 to 3.80 indicated strongly peaked curves

with better sorting in the central portion than the tails, mostly leptokurtic (1.11-1.50) to very leptokurtic (1.50-3.00).

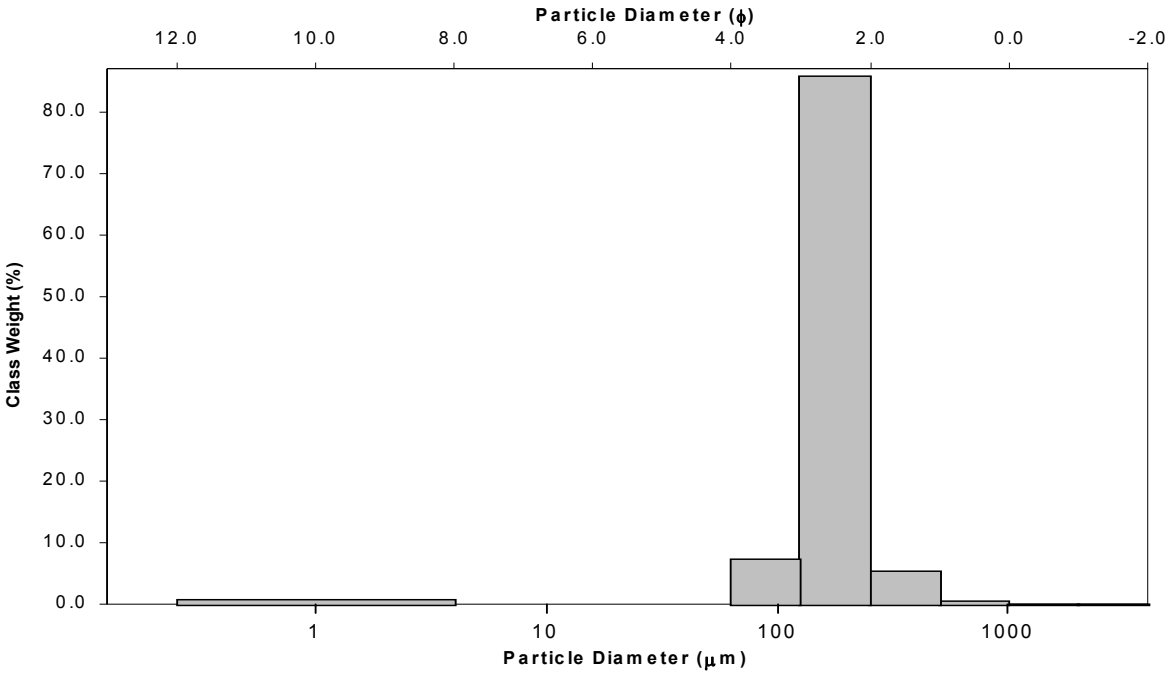

Figure 3: Typical grain size-frequency and distribution of sediments (site 5).

Carbonate contents were low, mostly between 1 and 2% (Table 3). There was a particularly high carbonate value of 7.60% at site 10, reflecting the presence of calcareous tube fragments, and site 2 also had a high value (3.54%) due to bivalve shell fragments. Organic carbon (OC) and total nitrogen (TN) contents were also low, typically below 0.59 and 0.11%, respectively for sites 1 to 9 (Table 3). At site 10 OC was slightly higher reaching 1.46% and TN was 0.19%. This site was therefore characterized by anoxic and nutrient enriched sediment. The molar ratio of OC to TN (C:N) varied between 3 and 9.

Table 3: Carbonate, organic carbon (OC) and total nitrogen (TN) contents of sediments. Also indicated are water column depth and molar ratios of organic carbon:total nitrogen (C:N).

Sites	Depth (cm)	Carbonate (%)	OC (%)	TN (%)	C:N
1	30	1.36	0.21	0.07	3.90
2	35	3.54	0.14	0.05	3.50
3	40	1.28	0.12	0.04	4.20
4	40	2.00	0.31	0.08	5.00
5	70	1.28	0.14	0.04	4.90
6	65	1.28	0.13	0.04	3.90
7	90	1.44	0.44	0.08	6.70
8	160	1.52	0.15	0.05	4.00
9	170	2.08	0.59	0.11	6.50
10	190	7.60	1.46	0.19	9.00

3.2 Phytoplankton and Zooplankton

The phytoplankton community was dominated by diatoms, especially *Asterionella* and *Chaetoceros* (Table 4). There were small numbers of the blue-green alga *Oscillatoria* and Volvocales- *Pyraminonas*. The chlorophyll *a* concentration was 19 µg L^{-1} in both replicates, putting these samples in the moderately eutrophic range. The estimated biomass of phytoplankton material was 4,050 mg m^{-3}. It should be noted that this estimate is based on the general relationship between chlorophyll and dry weight and does not have a high degree of accuracy.

Table 4: Phytoplankton cell counts, chlorophyll concentrations and estimated biomass.

Phytoplankton Counts	Rep 1 cells/mL	Rep 2 cells/mL	Mean cells/mL
Diatoms			
Asterionella	310	70	**190.0**
Chaetoceros	380	265	**322.5**
Gyrosigma	3	3	**3.0**
Nitzschia	12	12	**12.0**
Rhizosolenia	25	35	**30.0**
Navicula	0	2	**1.0**
Cryptomonads	0	5	**2.5**
Dinoflagellates			
Gymnodinium	1	0	**0.5**
Protoperidinium	1	0	**0.5**
Scrippsiella	0	1	**0.5**
Blue-Green Algae			
Oscillatoria	5	0	**2.5**
Eutreptiella	0	0	**0.0**
Volvocales- *Pyraminonas*	0	10	**5.0**
Chlorophyll a (µg/L)	**19**	**19**	**19.0**
Chlorophyll b (µg/L)	**1.6**	**0.9**	**1.3**
Estimated Biomass (mg/m^3)	**4,120**	**3,980**	**4,050**

The diatoms *Chaetoceros* and *Nitschia* were common at Pelican Point in April 2004 (Geddes 2005a) and *Asterionella* and *Chaetoceros* were common in the Murray Mouth and North Lagoon in April 2005, along with *Nitzschia (*Geddes and Tanner 2007*).* In April 2004 the chlorophyll *a* concentration was 3.1 µg L^{-1} at Pelican Point and 10.7 µg L^{-1} 6 km south of Pelican Point. Chlorophyll a concentrations in the Murray Mouth and northern end of the North Lagoon were generally between 3 to 18 µg L^{-1} (Geddes 2005a). Thus the chlorophyll *a* concentration of 19 µg L^{-1} was at the top of the range of values previously reported for the region.

Zooplankton abundances and biomass estimates are given in Table 5. The abundance of zooplankters was low, with the mean value 1,108 plankters per m^{-3} (1.1 L^{-1}). The plankton community included calanoid nauplii and copepodites, cyclopoid and harpacticoid copepodites and adults, and decapod larvae in two size classes. The zooplankters were all small, less than 600 µm, except for the later instar crab larvae. There were no adult calanoid copepods

and few adult cyclopoids. It appears that fish predation had removed the larger members of the zooplankton community. This is consistent with the low number of large plankters collected in the region in April 2004 and April 2005 (Geddes 2005c, Geddes and Tanner 2007). The replicates for counts of the various taxa of copepods and small crab larvae were similar, but the larger crab larvae were very patchy with 11 and 60 m^{-3} in two replicates and none in the other three replicates.

Most of the plankters were small and so had very low dry weights; most less than 1 µg except for the larger crab larvae instars at 10 µg. The total dry weight biomass was estimated at 1,500 µg m^{-3}, and that biomass was dominated by crab larvae in the 360 to 408 µm size range.

Table 5: Zooplankton abundance and biomass estimates for five replicate samples (mean of 3 subsamples) and overall means.

Coorong Zooplankton:	**Dry Weight**	**Rep #1**		**Rep #2**		**Rep #3**		**Rep #4**		**Rep #5**		**Overall Mean**	
	Av//ind	**Mean**	**Mean Biomass**	**Mean**	**Mean Biomass**	**Mean**	**Mean Biomass**	**Mean**	**Mean Biomass**	**Mean**	**Mean Biomass**	**Mean**	**Biomass**
Taxon [size]	µg	n m^{-3}	mg m^{-3}	n m^{-3}	mg m^{-3}	n m^{-3}	mg m^{-3}	n m^{-3}	mg m^{-3}	n m^{-3}	mg m^{-3}	n m^{-3}	mg m^{-3}
Copepoda: Calanoida: nauplii [168-280 µm]	0.1	358.2	35.8	71.4	7.1	148.1	14.8	152.4	15.2	78.2	7.8	**161.7**	**16.2**
Copepoda: Calanoida: copepodites [392-488 µm]	0.5	238.8	119.4	309.5	154.8	125.3	62.7	285.7	142.9	156.5	78.2	**223.2**	**111.6**
Copepoda: Cyclopoida: copepodite [408 µm]	0.5	0.0	0.0	0.0	0.0	22.8	11.4	19.0	9.5	39.1	19.6	**16.2**	**8.1**
Copepoda: Cyclopoida: adult [560 µm]	1.2	0.0	0.0	11.9	14.3	11.4	13.7	0.0	0.0	0.0	0.0	**4.7**	**5.6**
Copepoda: Harpacticoida: copepodite [240-304 µm]	0.3	19.9	6.0	47.6	14.3	45.6	13.7	95.2	28.6	39.1	11.7	**49.5**	**14.8**
Copepoda: Harpacticoida: adult [496-576 µm]	1.2	79.6	95.5	71.4	85.7	91.2	109.4	57.1	68.6	117.3	140.8	**83.3**	**100.0**
Ostracoda: cf. *Candonocypris* [785 µm]	5.0	19.9	99.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**4.0**	**19.9**
Ostracoda: juvenile [280-464 µm]	1.0	0.0	0.0	11.9	11.9	11.4	11.4	19.0	19.0	0.0	0.0	**8.5**	**8.5**
Decapoda: larvae [360-408 µm]	2.0	517.3	1034.7	750.0	1500.0	353.2	706.5	704.8	1409.5	391.2	782.3	**543.3**	**1,086.6**
Decapoda: later instar [800-1220 µm]	10.0	0.0	0.0	59.5	595.2	11.4	113.9	0.0	0.0	0.0	0.0	**14.2**	**141.8**
Total plankters		1,234	1,391	1,333	2,383	820	1,057	1,333	1,693	821	1,040	**1,108**	**1,513**

3.3 Littoral Samples

The abundance and biomass of littoral and epibenthic organisms at sites 1, 2 and 4 are shown in Table 6. Each value is the mean of counts from five replicate samples taken with the 57 cm diameter cylinder. This cylinder captured the epibenthic fauna and nektonic forms such as small fish and crabs.

At site 1, a sand shoal mid lagoon, the amphipods *Paracorophium* and *Megamphopus* and the bivalve *Arthritica* were the numerically dominant species and the mean total abundance of invertebrates was 5,900 individuals m^{-2}. At site 2 in shallow water a few metres off the Younghusband Penninsula there was a very high abundance of amphipods and moderate numbers of *Capitella* and *Arthritica,* giving a mean total abundance of 19,100 individuals m^{-2}*.* Site 4 was on the landward side of the lagoon and the habitat consisted of a few centimetres of sediment overlying a rock shelf. The abundance of invertebrates was much lower with 1,300 amphipods m^{-2}, and 28 and 53 *Simplisetia* and *Capitella* m^{-2} giving a mean total abundance of 1,400 individuals m^{-2}. The overall means across the five replicates in three sites showed that amphipods were numerically dominant, 7,400 individuals m^{-2}, followed by *Arthritica* , 1,000 individuals m^{-2}, *Capitella*, 220 individuals m^{-2} and with much smaller numbers of *Simplisetia*, mysids, *Nephtys*, *Prionospio*, *Boccardia* and *Hydrobia*.

At sites 1 and 2 hardyheads were collected in the sampler, although it was not designed to capture highly mobile species like fish. The mean number of hardyheads at site 1 and 2 were 28 and 19 individuals m^{-2}. No fish were captured at site 4, perhaps because different characteristics of the habitat made the cylinder trap less effective. Crabs were collected at sites 2 and 4, but not at site 1. Sites 2 and 4 were along the edges of the lagoon while site 1 was mid-lagoon and crabs may have preferred the edge habitat.

The biomass data reflect the abundance and the dry weight of the taxa. At site 1, *Arthritica* had the greatest biomass followed by the amphipods and the hardyhead fish. The biomass data for *Arthritica* include the weight of the bivalve shell; the tissue weight would be much less. The biomass without fish was 1,804 mg m^{-2}. When fish were added this came to 1,902 mg m^{-2}. At site 2 the very high abundance of amphipods meant that they represented the major part of the biomass when crabs were excluded; 950 mg m^{-2} of the 1,693 mg m^{-2} biomass. The crabs had a very much larger individual dry weight, from 800 to 3,900 mg, and so the modest number of 3.9 m^{-2} represented 12,930 mg m^{-2}. This biomass included carapace weight. At site 4 the amphipods, *Simplisetia (Ceratonereis)* and *Capitella* contributed to the small biomass of 127 mg m^{-2} The 2.4 crabs m^{-2} represented a much greater biomass1,900 mg m^{-2}. The overall means show that *Arthritica* had the highest biomass of the epibenthic species, 760 mg m^{-2}, followed by amphipods, 400 mg m^{-2}, *Capitella*, 29 mg m^{-2}, and *Nephtys*, 18 mg m^{-2}. The crabs, because of their large weight, represented a much greater biomass of 4,940 mg m^{-2} and the fish 50 mg m^{-2}.

Table 6: Mean littoral abundance and biomass of five replicate samples at three sites. Note the mean values have been calculated without crabs and fish, without crabs and with crabs and fish.

Locality	Dry Weight Av/ind mg	1		2		4		Overall Means	
Littoral Biomass		**Mean** n m^{-2}	**Biomass** mg m^{-2}	**Mean** n m^{-2}	**Biomass** mg m^{-2}	**Mean** n m^{-2}	**Biomass** mg m^{-2}	**Mean** n m^{-2}	**Biomass** mg m^{-2}
CRUSTACEA									
Amphipod *Paracarophium/ Megamphopus*	0.05	3,100	170	17,900	950	1,300	70	**7,400**	**400**
Mysis <6mm	0.1	3.1	0.3	0.0	0.0	0.0	0.0	**1.0**	**0.1**
Mysis >6mm	1.0	2.4	2.4	0.0	0.0	0.0	0.0	**0.8**	**0.8**
Crabs *<20mm*	800	0.0	0.0	0.8	630	2.4	1,900	**1.0**	**840**
Crabs *>20mm*	3,900	0.0	0.0	3.1	12,300	0.0	0.0	**1.0**	**4,100**
POLYCHAETES									
Nepthys australiensis	20.0	0.9	20.0	0.8	16.0	0.0	0.0	**0.6**	**18.0**
Simplisetia aequisetis <10mm	0.1	0.4	0.0	0.0	0.0	13.0	0.7	**4.5**	**0.2**
>10mm	0.7	0.0	0.0	0.0	0.0	15.0	10.0	**5.0**	**3.0**
Capitella capitata cf. <10mm	0.1	26.0	1.6	580.0	47.0	53.0	37.0	**220.0**	**29.0**
Prionospio	0.1	1.6	0.2	0.0	0.0	0.0	0.0	**0.5**	**0.1**
Boccardia	0.1	0.0	0.0	0.0	0.0	2.4	0.3	**0.8**	**0.1**
BIVALVES									
Arthritica <2mm	0.5	2,600	1,300	480	240	2.4	1.2	**1,000**	**510**
>2mm	2.5	130	310	180	440	0.0	0.0	**100**	**250**
Hydrobia	2.5	0.0	0.0	0.0	0.0	3.1	8.0	**1.0**	**3.0**
FISH									
Hardyheads *<18mm*	2.2	20.0	43.0	16.0	36.0	0.0	0.0	**12.0**	**26.0**
22mm	7.0	8.0	55.0	2.4	17.0	0.0	0.0	**3.5**	**24.0**
TOTALS without Fish or Crabs		**5,864**	**1,804**	**19,140**	**1,693**	**1,388**	**127**	**8,734**	**1,214**
TOTALS with fish without Crabs		**5,892**	**1,902**	**19,158**	**1,746**	**1,388**	**127**	**8,750**	**1,264**
TOTALS with Crabs + Fish		**5,892**	**1,902**	**19,162**	**14,676**	**1,391**	**2,027**	**8,752**	**6,204**

3.4 Benthic samples

The benthic abundances and biomass for the ten sites are shown in Table 7. Each value represents the mean of five replicate samples. The sites can be grouped by depth as shallow, sites 1 to 4, mid-depth, sites 5 to 7 and deep, sites 8 to10. At sites 1, 2 and 3 total invertebrate numbers ranged from approximately 17,000 L^{-1} at sites1 and 3 to 73,600 at site 2. The high abundance at site 2 was due to amphipods, *Capitella* and *Arthritica*. Site 2, on the Younghusband Peninsula side of the Coorong, was the only site to have the larger bivalve *Notospisula*. Site 4 had a quite different fauna with lower numbers of amphipods, fewer *Capitella,* no *Arthritica*, and a large number of the polychaete *Nephtys*. This site was situated on the landward side of the Coorong and was over a rock shelf overlaid by a shallow layer of sediment. The overall mean across the five samples from four sites showed that the amphipods, *Arthritica* and *Capitella* were the most abundant taxa with 16,500, 5,750 and 4,760 individuals m^{-2} respectively. These were followed by *Simplisetia*, 141 m^{-2}, *Nephtys*, 90 m^{-2}, *Notospisula*, 45 m^{-2}, *Australonereis*, 18 m^{-2}, and *Phyllodoce*, 30 m^{-2}.

The estimated biomasses at the littoral sites were 4,500 mg m^{-2} at site 3, 5,000 mg m^{-2} at site 4 and 6,800 mg m^{-2} at site 1. The highest biomass was at site 2, 38,900 mg m^{-2}, mostly comprised of the bivalves *Arthritica* and *Notospisula*.

The mid-depth sites, 5, 6 and 7, were dominated by amphipods with particularly high abundance at site 7. The polychaete *Nephtys* was also common at all three sites as were *Capitella* and *Arthritica*. The overall means showed a high predominance of amphipods, 22,100 m^{-2}, followed by *Arthritica*, 600 m^{-2}, *Capitella*, 550 m^{-2}, and lower numbers of *Prionospio*, *Notospisula*, *Phyllodoce*, *Tellina*, *Simplisetia*, *Boccardia* and mysids. It is interesting to note that *Prionospio*, *Boccardia*, *Tellina* and mysids were not collected in the benthic cores in the littoral zone. The biomass at the three sites respectively was 3,630, 6,970 and 6,730 mg m^{-2}, with *Nephtys,* 3,700 mg m^{-2}, amphipods, 1,170 mg m^{-2}, *Phyllodoce*, 230mg m^{-2} and *Arthritica*, 290mg m^{-2}, the major contributors to the biomass.

The abundance and biomass of invertebrates at the deep sites 8, 9 and 10, was lower with amphipods, *Capitella* and *Prionospio* the main components. At the deepest site, site 10, abundance and biomass were extremely low, with only 120 individuals m^{-2} in total and a biomass of only 25 mg m^{-2}.

Dittmann et al. (2006) found mean abundances of infauna in the littoral zone in the area near Pelican Point to be the highest of the 21 sites sampled in the Murray Mouth and Coorong. The mean abundance of invertebrates was 37,000 individuals m^{-2}. This compares with the overall mean for the three shallow sites in this study of 27,300 individuals m^{-2}. Amphipods, polychaetes, especially *Capitella*, *Simplisetia* and *Australonereis*, and *Arthritica* were the most abundant species. The mean biomass in the area of the Murray Mouth, expressed as ash free dry weight, was 2.58 g m^{-2}. This compares with the overall mean biomass in the three shallow sites in the present study of 27.3 g dry weight, the higher value reflecting the different biomass units used. Dittmann et al. (2006) suggested that mean abundances of macrobenthos in the Murray Mouth and Coorong generally fall within the densities recorded for other estuarine mudflats in temperate and sub-tropical latitudes, although biomass values are lower than most reported in the literature.

Table 7: Mean abundance and biomass of five replicate benthic samples at ten sites. The sites have been grouped into littoral (<0.5 metre), mid-depth (0.5 to 1 metre) and deep (>1.5 metre) sites

Littoral (<0.5 m)												
Locality		**Dry Weights Av/ind mg**	**1**		**2**		**3**		**4**		**Overall Mean**	
			Mean n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}
CRUSTACEA												
Amphipod – *Paracorophium/Megamphopus*		0.05	14,000	740	36,600	1,900	14,000	750	1,590	80	**16,500**	**870**
POLYCHAETES												
Nepthys australiensis		20.5	190	3,900	0	0	40	840	130	2,700	**90**	**1,860**
Phyllodoce novohollandiae	*<20mm*	0.75	20	15	0	0	20	15	4	3	**20**	**50**
	>20mm	8.55	0	0	20	170	0	0	0	0	**10**	**40**
Simplisetia aequisetis	*<10mm*	0.07	0	0	470	24	0	0	20	14	**120**	**10**
	>15mm	8.0	0	0	65	44	0	0	20	160	**21**	**50**
Australonereis ehrlesi		20.5	20	420	50	1,300	0	0	0	0	**18**	**430**
Capitella capitata cf.	*<10mm*	0.05	80	4	15,700	1,600	20	3	60	8	**4,000**	**400**
	>10mm	0.14	40	56	3,000	410	0	0	0	0	**760**	**120**
Bivalves												
Arthritica	*<2mm*	0.5	2,200	1,100	14,200	7,000	2,200	1,100	0	0	**4,650**	**2,300**
	>2mm	2.5	200	510	3,400	8,500	730	1,800	0	0	**1,100**	**2,700**
Notospisula	*<20mm*	100	20	50	60	5,900	0	0	20	2,000	**25**	**2,000**
	>20mm	150	0	0	80	12,100	0	0	0	0	**20**	**3,000**
Overall Mean NUMBERS & BIOMASS (mg/m^2)			**16,800**	**6,800**	**73,600**	**38,900**	**17,000**	**4,500**	**1,800**	**5,000**	**27,300**	**13,800**

Table 7 continued.

Shallow (0.5-1 m)									
Locality		**5**		**6**		**7**		**Overall Mean**	
	Dry Weights Av/ind mg	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}
CRUSTACEA									
Amphipod - *Paracorophium/Megamphopus*	0.05	2,080	110	7,300	390	56,900	3,000	**22,100**	**1,170**
Mysid *<6mm*	0.1	20	2	0	0	0	0	**7**	**1**
>6mm	1.0	20	20	0	0	0	0	**7**	**7**
POLYCHAETES									
Nepthys australiensis	20.5	140	2,900	270	5,400	140	2,900	**180**	**3,700**
Phyllodoce novohollandiae 20-50mm	8.55	0	0	80	700	0	0	**30**	**230**
50+ mm	16.6	0	0	0	0	20	360	**10**	**0**
Simplisetia aequisetis <10mm	0.7	0	0	0	0	20	14	**7**	**5**
Capitella capitata cf. <10mm	0.05	0	0	0	0	750	40	**410**	**30**
>10mm	0.14	80	10	390	50	410	60	**140**	**20**
Prionospio	0.125	0	0	0	0	290	50	**100**	**17**
Boccardia	0.1	0	0	20	3	0	0	**7**	**1**
Bivalves									
Arthritica <2mm	0.5	690	340	670	330	430	210	**600**	**290**
>2mm	2.5								
Notospisula <20mm	100	80	200	40	100	0	0	**40**	**100**
>20mm	150								
Tellina (small)	2.5	20	50	0	0	40	100	**20**	**50**
Overall Mean NUMBERS & BIOMASS (mg/m^2)		**3,130**	**3,630**	**8,770**	**6,970**	**59,000**	**6,730**	**23,630**	**5,780**

Table 7 continued.

Deep (>1.5 m)									
Locality	**Dry Weights Av/ind mg**	**8**		**9**		**10**		**Overall Mean**	
		Mean n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}	**Mean** n m^{-2}	**Mean biomass** mg m^{-2}
CRUSTACEA									
Amphipod - *Paracorophium/Megamphopus*	0.05	1,400	70	13,400	710	40	2	**4,900**	**260**
POLYCHAETES									
Nepthys australiensis	20.0	90	1,900	20	420	0	0	**40**	**770**
Phyllodoce novohollandiae <*10mm*	0.75	0	0	0	0	20	15	**7**	**5**
Capitella capitata cf. <*10mm*	0.14	0	0	180	30	20	3	**67**	**11**
Prionospio	0.123	220	42	590	60	40	5	**280**	**36**
Bivalves									
Arthritica <*2mm*	0.5	270	130	0	0	0	0	**90**	**43**
>*2mm*	2.5	40	100	0	0	0	0	**13**	**33**
Tellina (small)	2.5	20	50	0	0	0	0	**7**	**17**
Overall Mean NUMBERS & BIOMASS (mg/m^2)		**2,040**	**2,290**	**14,190**	**510**	**120**	**25**	**5,450**	**940**

3.5 Fish diets

The diets of four fish species, with mullet separated into small and large size classes, are shown in Table 8 and presented graphically in Figure 4. Data are given as % occurrence (the % of fish guts that contained a particular item) and as the composition of food items in the gut. The composition is presented as mean number of each food item per fish, and mean biomass of each item per fish.

For the 20 hardyheads, 65% of the guts examined contained amphipods and 25% contained harpacticoids and *Capitella*. Other food items identified were ostracods, mysids and spionid worms, all at 10% occurrence. The most abundant items in hardyhead guts were amphipods (66.8 fish^{-1}) and harpacticoids1(3.6 fish^{-1}). Ostracods, mysids, *Capitella* and spionids were in low abundance. Amphipods were also the dominant item by biomass, with *Capitella* ranked second and only very small biomasses of harpacticoids, ostracods, mysids and spionids. This evaluation of the diet suggests that hardyheads forage in the water column and at the sediment-water interface on planktonic and epibenthic invertebrates.

The goby guts contained only amphipods, with 95% occurrence, and *Capitella* and spionids each at 5% occurrence. Amphipods were the highly dominant food item by number and biomass, showing that the gobies had an almost exclusively amphipod diet. This suggests the goby was an epibenthic forager. The other small fish, the juvenile mullet, had an exclusively polychaete diet of *Capitella* and *Phyllodoce* suggesting that juvenile mullet were benthic foragers.

Large adult mullet had a broad diet with nine different food items identified which included crustaceans, polychaetes, a bivalve and plant fragments. *Capitella* were the clear dominant by % occurrence and the number of items per gut. The number of nereids was only 4 fish^{-1} but the significant dry weight of these worms meant that they represented almost the same biomass as *Capitella.* The adult mullet foraged in the epibenthic and benthic habitats.

Mulloway was clearly the top predator with a diet of mullet, hardyheads, congolli and crabs. The numerical dominance was hardyhead, followed by mullet, crabs and congolli. Biomass of each species in the diet was not calculated because the wide size ranges did not allow estimation of an average weight per individual. However, the mullet ranged in size up to 300 mm TL while the hardyheads were all less than 50 mm TL, so mullet would have been the most important item by biomass.

The diet of this same suite of fish species was examined using C, N, and S stable isotopes by Lamontagne et al. (2007). This analysis could not unambiguously identify fish diet because the isotope signatures of most fish were outside those of any of the prey analysed. The C and N signatures did show that adult mullet had the least enriched N signature, the juvenile mullet, hardyheads and gobies were more enriched and the mulloway were clearly the most enriched. The degree of enrichment of the N signature shows the trophic level, and so these data imply that adult mullet may feed on a variety of sources including plant/algal material, the small mullet, hardyhead and gobies are second order consumers and the mulloway are third order consumers. This is consistent with the conclusions from diet analysis in the present study.

Table 8: Fish diets, showing % occurrence and mean number and biomass of food items per fish.

Diet	Fish			Crustacean					Polychaetes					Bivalve	Plant
	Mullet	Hardyhead	Congolli + Other	Harpactacoid	Amphipod	Crabs	Ostracod	Mysid	Nerids	Capitella	Arenicolodae	Phyllodoce	Spionods	Arthritica	
Hardyhead (20-50 mm)															
% Occurrence				25	65		10	10		25			10		
Mean No. of Animals/Fish				13.60	66.80		0.15	0.15		1.27			0.89		
Mean Biomass (mg dry wt)				0.016	3.34		0.001	0.009		0.14			0.07		
Goby (20-50 mm)															
% Occurrence					95					5			5		
Mean No. of Animals/Fish					15.95					0.2			0.15		
Mean Biomass (mg dry wt)					0.80					0.03			0.01		
Small Mullet (30-80 mm)															
% Occurrence										85		5			
Mean No. of Animals/Fish										16.0		0.05			
Mean Biomass (mg dry wt)										1.50		0.63			
Large Mullet (230-300 mm)															
% Occurrence					45	5	20		15	80	50		45	10	15
Mean No. of Animals/Fish					2.90	1.00	2.90		4.00	184.0	1.00		1.50	0.27	fragments/ phyto cells
Mean Biomass (mg dry wt)					0.15	3.90	0.01		16.88	17.30	10.0		0.02	0.68	
Mulloway (480-660 mm)															
% Occurrence	65	25	15			15									
Mean No. of Animals/Fish	1.00	2.76	0.17			0.58									
Mean Biomass (mg dry wt))	-	-	-			-									

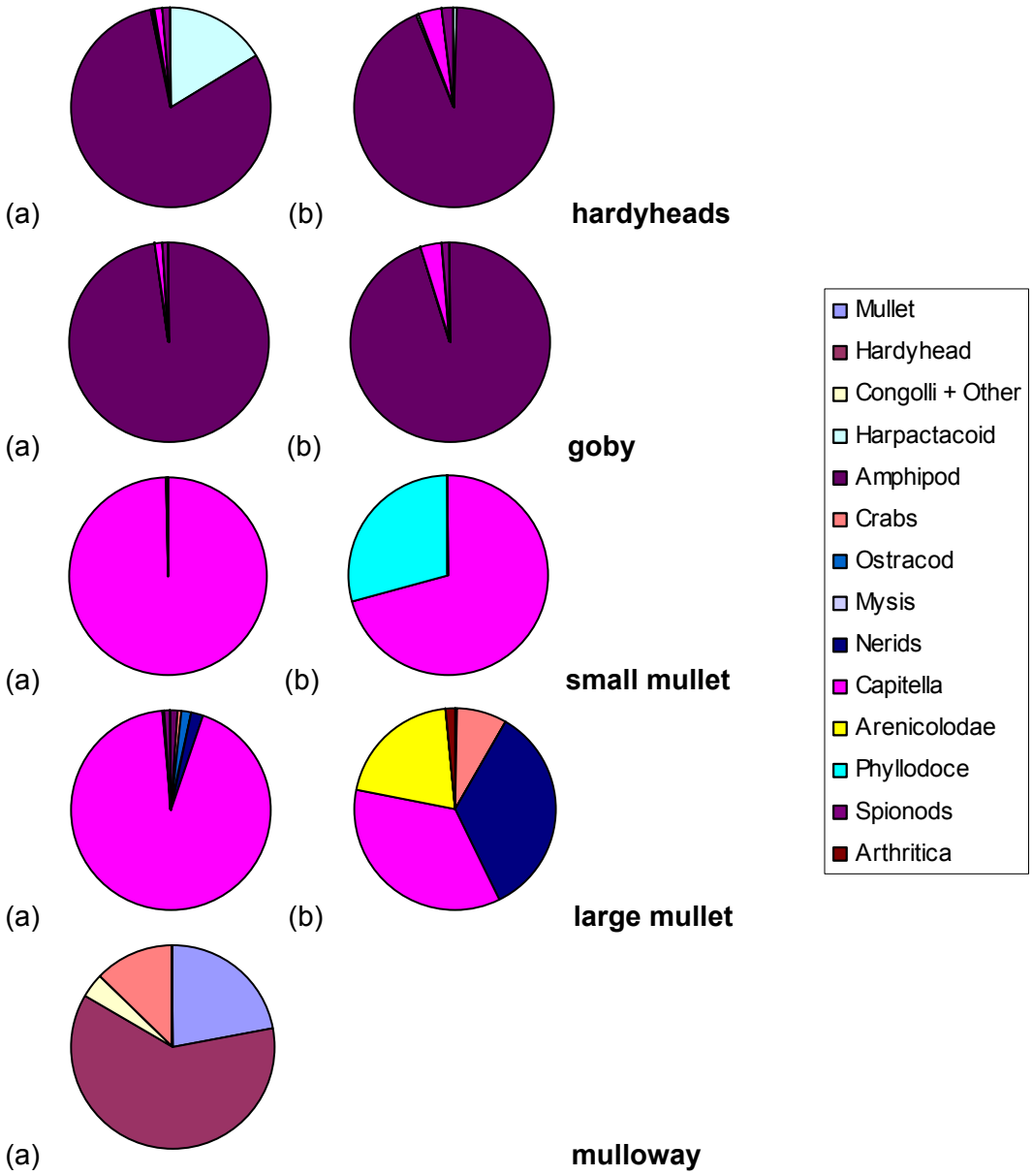

Figure 4: Composition of the diet of hardyheads, goby, mullet and mulloway (a) mean number of animals (b) mean biomass of animals

4 Food web

An indication of the food web operating at Pelican Point in March 2005 is given in Figure 5. The figure is arranged with primary producers along the base, then filter feeders and deposit feeders, opportunistic predators, obligate predators, predatory fish and the top fish predator mulloway. The size of each box is an estimate of the dry weight biomass of the food item. The biomass used is the mean of the two sites with the largest biomass for that species as presented in Table 7. A mean of two sites acknowledges that species are not likely to be at similar abundance across all ten sites and the three depth/habitat strata sampled, and emphasises the importance of patches of high abundance. For each item the darker boxes represent the total biomass from Table 7 and the lighter boxes inside them are the proportion of the food item that is epibenthic/nektonic, as estimated from the littoral epibenthos/nekton samples in Table 6. The smaller rectangular boxes are for species where there is no estimate of biomass (most of the primary producers, *Ficopomatus* and most of the fish). The diet of the four species, separating small and large mullet, is represented by the arrows with the width and darkness of the arrow representing the importance of the food item in terms of % biomass in the diet.

Among the possible primary producers at the base of the diagram only the phytoplankton biomass is estimated. The brown alga *Gracilaria* occurs only on hard substrate and this is rare in the area so the biomass is probably not large. Little work has been done on the microphytobenthos or the filamentous green algae, but they are likely to be important primary producers. *Ruppia megacarpa* was not found in this study, nor was it reported in an extensive literature survey by Nicol (2007).

Figure 5 shows that the species with the largest standing biomass are the bivalves *Notospisula* and *Arthritica*, the crab *Paragrapsis* and the polychaete *Nephtys*. In the case of *Arthritica* and the crab, the dry weight includes a large shell weight; the tissue dry weight is likely to be less than half of the dry weight shown here. For the worms and amphipods the dry weight shown will be close to the tissue dry weight. The values shown are for standing biomass and not for production. The zooplankton, amphipods and worms will have a faster turnover time than the crabs and bivalves and so will have a greater contribution to the productivity of the system. The zooplankton in particular seems to be under high predation pressure, as indicated by the lack of large specimens of copepods, and so does not achieve a substantial standing biomass. It is likely that zooplankton productivity is high in comparison to its biomass.

The bivalves *Notospisula* and *Arthritica* are filter feeders, as is the tubeworm *Ficopomatus*. The amphipod *Paracorophium* is also a filter feeder which, like other corophids, builds a tube of fine amphipod silk and filter feeds at the mouth of the tube. The other common amphipod, *Megamphopus,* is a deposit feeder, as are *Capitella* and the spionids (Hutchings 1982). It is likely that these deposit feeders utilize the microphytobenthos as well as detrital organic matter. The phyllodocid, *Phyllodoce novaehollandiae*, has no jaws on the pharynx but rather numerous papillae in longitudinal rows suggesting that it might be a deposit feeder or a micro-predator, although its feeding habits are unknown (Hutchings 1982). The nereid polychaetes *Simplisetia* and *Australonereis* are probably opportunistic predators, but they are flexible in their feeding mode and may also feed on algae, detritus and other organic matter

(Fauchold and Jumars 1979). *Australonereis ehlersi* has a short pharynx with a pair of distal jaws (Hutchings 1982), while *Simplisetia aequisetis* has an eversible pharynx with stout, curved jaws (Hutchings and Turvey 1982). *Nephtys* is a predatory polychaete that preys on other polychaetes and on amphipods as has been demonstrated for other species of *Nephtys* in Europe and North America (Redmond and Scott 1989; Schubert and Reise 1986). The crab *Paragrapsis gamardii* is a scavenger and omnivore.

The gut contents of the four fish species show that they did not prey upon many of the invertebrates with high biomass during the study period. Thus *Notospisula*, *Nephtys* and the tubeworm *Ficopomatus* did not occur in fish guts and *Arthritica* was only a small component of the diet of large mullet. The major components of the diet of the small fish, hardyheads, gobies and small mullet, were the amphipods, *Capitella* and the spionids. The hardyheads also ate zooplankton and the small mullet ate the polychaete *Phyllodoce*. The large mullet had a broad diet with the nereids and *Capitella* as major items but including detritus and plant matter. Mulloway was the top predator, with mullet, crabs and congolli likely to be important prey.

This diet study has been undertaken on a very limited scale with only four species of fish studied in one location at one time. It is likely that diets may change with time, especially for the higher trophic levels. Mulloway prey heavily on crabs at certain times, especially when soft crabs are abundant after moulting (Gary Hera Singh, pers com). Black bream is a major species in the Coorong and they can feed on *Notospisula* and the tube worms *Ficopomatus* (Gary Hera Singh, pers com).

The food web shows a high dependence of the small fish on amphipod crustaceans. In a major study of the diets of small fish in Western Port Bay, Victoria, crustaceans were the dominant component in the diets of most fish (Edgar and Shaw 1995). Among the crustaceans, copepods were the dominant diet for larval and small juvenile fish below 0.1 mg body weight, above this weight pericarids, amphipods, isopods and mysids became dominant and decapods were preyed upon by larger fish. Molluscs and polychaetes were sometimes important but generally supplied less than 25% of the food consumed. Edgar and Shaw (1995) suggested that the availability of high quality crustacean prey may limit fish production. A study of flounder in a bay in New York State found that amphipod crustaceans made up 99% of prey individuals (Franz and Tancredi 1992). The present study suggests that amphipods and other crustaceans are very important in the food webs to fish in the Coorong.

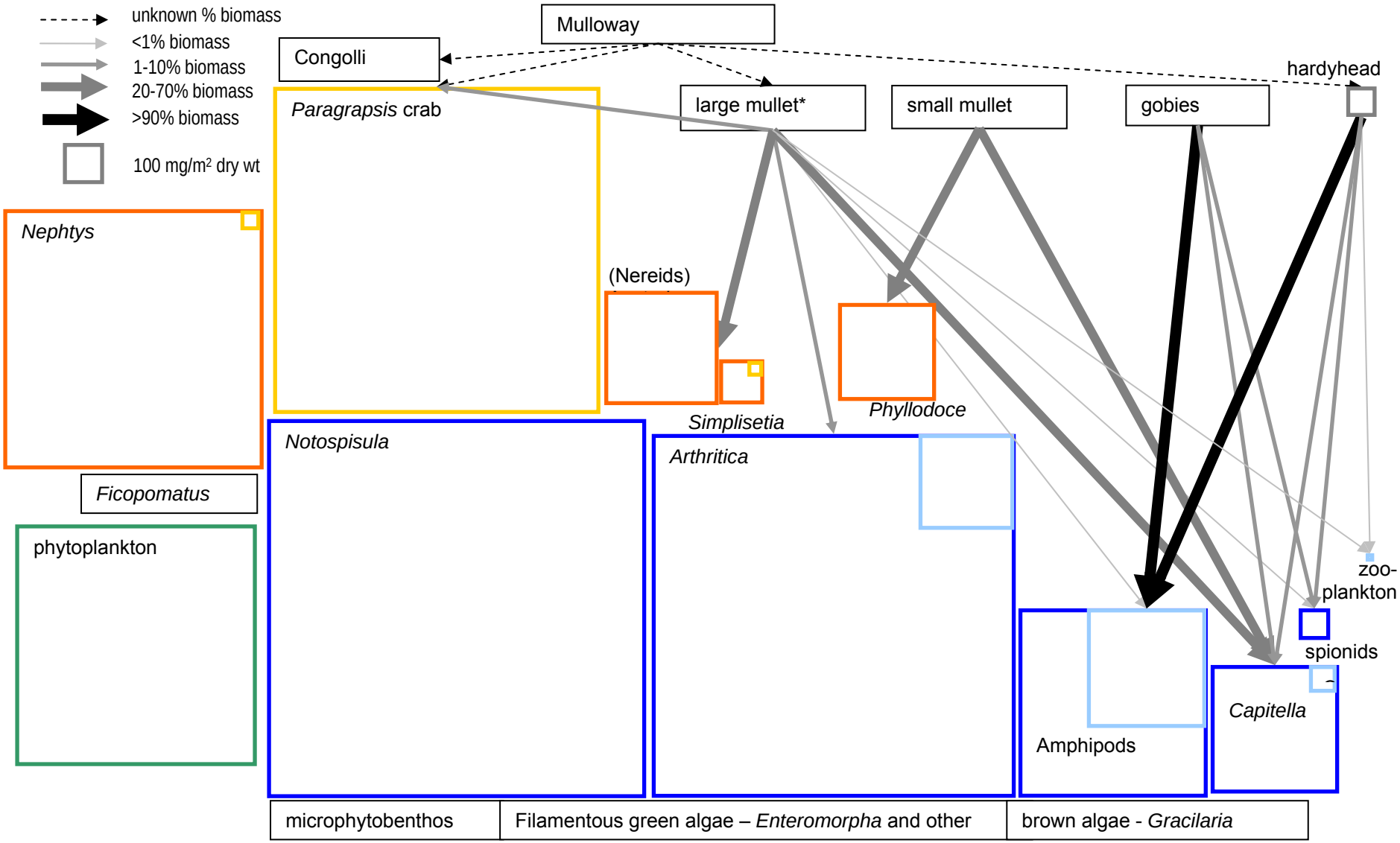

*Figure 5: Semi-quantitative foodweb structure for the Coorong at Pelican Point. Size of each box represents the biomass of the taxon (mg m^{-2} dry wt). Boxes in dark represent the total biomass and light coloured boxes are the proportion epibenthic, planktonic or nektonic. *Large mullet also ate arenicolid worms (20% biomass).*

5 Ecological character

The ecological character of the Coorong, Lower Lakes and Murray Mouth region has been extensively reviewed by Phillips and Muller (2006). Their work focuses on the Ramsar qualities and does not address the trophodynamics of the system. The ecological character considered here covers the diversity and abundance of organisms in the estuarine/marine component of the system at Pelican Point and the way in which production and food webs operate.

The species diversity recorded here for the Murray Mouth and Coorong is low and dominated by polychaetes, amphipods and molluscs, a pattern that is similar for most Australian estuaries (Hutchings 1999). Samples of estuarine macro-fauna from southern NSW and Victoria at 90 sites across 28 estuaries were studied by Hirst (2004). This study showed salinity, longitude and estuarine morphology were important in the distribution of estuarine infauna and it emphasised the continuity of estuarine benthic macrofaunal structure on a broad spatial scale in south-eastern Australia. The following 10 taxa were among the 23 most commonly collected in grab samples: *Simplisetia* was collected at 48 sites, *Arthritica* at 40 sites, *Megamphopus* (*Gammaropsis*) at 33 sites*, Nephtys* at 30 sites *Paracorophium* at 27 sites, *Melita* at 23 sites, *Prionospio* at 21 sites, *Australonereis* at 19 sites, *Notospisula trigonella* at 17 sites and *Macrobrachium intermedium* at 10 sites. These ten taxa are among the most common in the Murray Mouth and Coorong area. This set of estuarine taxa is also common in Tasmanian estuaries (Edgar et al. 1999). It is interesting that *Capitella* were not common in these studies while it is often among the most abundant species in the Coorong. This may reflect the eutrophic nature of the Murray Mouth and Coorong.

The infauna in the Swan-Canning estuary was also dominated by *Arthritica*, *Ceratonereis (Simplisetia), Capitella, Paracorophium, Prionospio, Boccardiella, Melita,* and *Tellina* (Kanandjembo et al. 2001). The mean abundances in that study were 2,990 m^{-2} for *Arthritica* and 1,780 m^{-2} for *Simplisetia* (*Ceratonereis*). By comparison the abundance of *Arthitica* and *Simplisetia* were 5,750 and 140 individuals m^{-3} in the present study. Biomass comparisons made in Dittmann et al. (2006) suggest that the biomass of macro-fauna in the Coorong is low compared to other estuarine and coastal lagoon mudflats.

The food web presented here (Figure 5) shows a rather simple trophodynamic system. The primary production supposedly occurs in the phytoplankton, the microphytobenthos and the filamentous green algal mats. The relative importance of these carbon sources is unknown. The bivalves *Notospisula* and *Arthritica* and the serpulid tube worm *Ficopomatus* may filter feed on the phytoplankton. However there is little connection between these species and higher trophic levels suggesting that the phytoplankton-filter feeder-higher trophic level pathway is limited. The zooplankton which also may feed on the phytoplankton represents a very small biomass. Although the zooplankton will be important in the diet of larval and juvenile fish it may not represent a major carbon pathway. The amphipods *Paracorophium* and M*egamphopus*, and the polychaetes *Capitella,* the spionids, the nereids and *Phyllodoce* appear to provide the major pathway to the higher trophic levels. It is likely that these species use detrital matter in their diets. The microphytobenthos is probably also important. Thus it appears that under present conditions in the Murray Mouth and Coorong, organic matter on the sediment surface is the major carbon source being transferred throughout the system.

This present food web contrasts with the food web that might have operated in this region in the early 1980s (Geddes and Butler 1984, Geddes 1987). At that time the macrophytes *Ruppia megacarpa*, *Lepilaena* and *Zostera muelleri* were all common in the system. *Ruppia megacarpa* was abundant on the landward side of the North Lagoon along all of its length. *Zostera muelleri* and *Lepilaena* were common in the northern parts of the Lagoon. Beds of filamentous algae comprised of *Cladophora, Enteromorpha* and *Oscillatoria* covered much of the bottom of the lagoon. The macrophyte beds provided a resource for the amphipod *Melita*, the snail *Hydrobia* and the shrimp *Macrobrachium*. *Melita, Hydrobia* and *Macrobrachium* were extremely abundant in the macrophyte beds (Geddes and Butler 1984). These species were collected in the present study, but in very low numbers. They belong to a feeding guild of scrapers gathering food from the macrophytes and their epiphytes. That habitat and its associated trophodynamic pathway is not available in the Coorong now.

Trophodynamics in estuaries are driven by inflows of water from the rivers and lakes in their catchments. The large flows of over 1,000 GL/month in July-October 1983 and August-September 1984 would have provided a washout of phytoplankton and zooplankton from Lake Alexandrina that could enter the food web. The nutrients provided could promote primary production. Flows are also important in the life history of estuarine species and the outflows in 1983 led to *Ruppia megacarpa* flowering profusely in October 1983 (Geddes 1987).

Thus, considering the trophodynamics we see a major change from what may have been a macrophyte dominated system in the 1980s to one based on phytoplankton, microphytobenthos and detritus in the present study. In the 1980s the trophodynamics may have had three carbon sources, phytoplankton, microphytobenthos and macrophytes. These would all have contributed to the detritus/dead organic matter pool. It is likely that the macrophytes would have made a major contribution there. In the present study, the food web relies heavily on the organic matter pool, which is likely to be less abundant and diverse than in the 1980s. As well as being a food source, the macrophytes would have provided habitat for the macro-invertebrates and small fish. Thus they would have promoted both biodiversity and productivity in the system.

6 Conclusions

It should be noted that this is a pilot study and that the estimates of several parameters are likely to involve some error. While the field sampling for sediment characteristics, phytoplankton, zooplankton, and littoral and benthic macro-invertebrates was relatively robust, the biomass estimates of the macro-invertebrates were made from limited data and the phytoplankton and zooplankton biomasses were calculated from literature values. The study was undertaken over a one km wide strip across the Coorong Lagoon south of Pelican Point over a three day period and so has limited spatial and temporal scale. Some cautious conclusions about the trophodynamics of the region can be made.

- The sediment analysis showed that the particle size was dominated by fine sands of about 150-200 µm particles, the nutrient content of N and C was low, but increased in sediments at greater depth.
- The macro-invertebrates showed a pattern with increasing depth. In particular *Australonereis* and *Hydrobia* were only found in the littoral zone to a depth of 0.5 m, and *Simplisetia* also had its highest abundance there, the amphipods and *Nephtys* had their highest abundance at the mid-depths, and only *Nephtys*, *Phyllodoce*, *Prionospio*, *Capitella* and the amphipods were collected in either of the two deepest samples.
- The sources of carbon production in the system are the phytoplankton, microphytobenthos and filamentous algae. The production may be consumed directly or may enter the foodweb via the detrital pathway. It is likely that the detrital pathway is important in the system as it now operates. The absence of macrophytes, limits productivity and removes macrophyte production from the detrital pathway. It means there is no habitat or food source for invertebrate grazers and scrapers. It is likely that both the direct and indirect provision of carbon by macrophytes was a major feature of foodwebs in the 1980s.
- The pathway from primary producers and detritus to higher trophic levels depends on a few species of filter feeders and detritivores. The amphipods *Paracorophium* and *Megamphopus,* and the polychaete *Capitella,* are key species in this trophic transfer.
- The study of the fish diets showed that the small fish species, hardyheads and gobies, feed primarily on crustaceans, especially amphipods, yellow eye mullet have a broad range of food items, and mulloway are the top predators, taking fish and crabs.
- The food web operating at Pelican Point in 2005 was rather simple. There were limited sources of primary production and a limited number of pathways to higher levels and one top predator. Other fish were not studied and the food web may be shown to be more complex when species such as black bream and flounder are included.
- The trophodynamics of the system in 2005 was very different from what it had been in the 1980s. The major difference is the absence of carbon production from macrophytes. Macrophytes and their epifauna would also have provided a direct food source for grazers and scrapers. Species that occupied these niches include the amphipod *Melita,* the snail *Hydrobia* and the decapod shrimp *Macrobrachium*. All of these species are now in very low abundance in the system.

7 Acknowledgements

This study was funded by DEH with major input from Brenton Grear and Russell Seaman. The project was managed by Dr Jason Tanner of SARDI Aquatic Sciences. The sediment grain size and chemical results were provided by Dr Milena Fernandes of SARDI Aquatic Sciences. Some of the fish diet work was undertaken by Matt Pellezzari from SARDI Aquatic Sciences and some by Dr Russell Shiel of the University of Adelaide. Nadine Kilsby, University of Adelaide, did the final presentation and formatting of the report.

Thanks to the three reviewers from SARDI Aquatic Sciences who improved the manuscript.

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