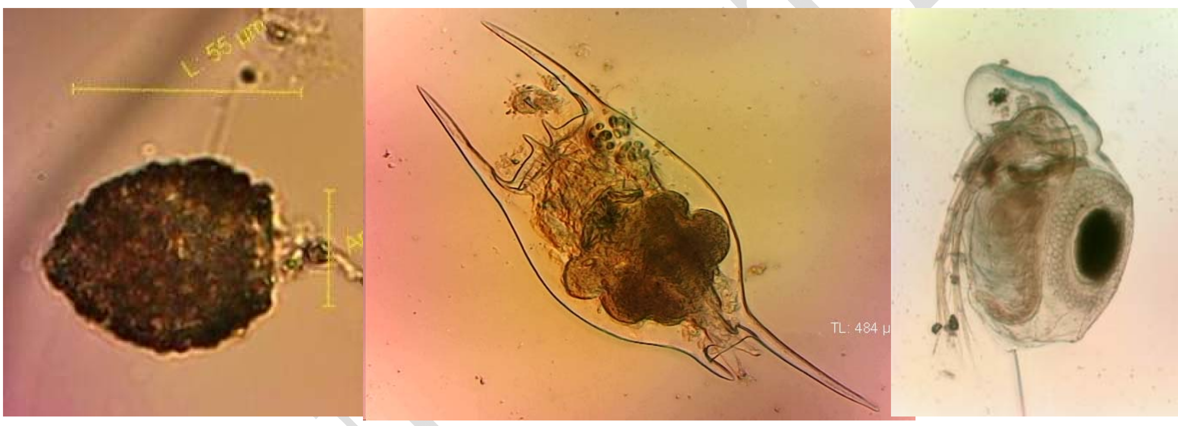
The response of zooplankton communities in the North Lagoon of the Coorong and Murray Mouth to barrage releases from the Lower Lakes, November 2010 – April 2011

Russell J. Shiel & Kane T. Aldridge



Final report prepared for the Department of Environment and Natural Resources and Department for Water, the Government of South Australia

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Frontispiece: Protista: Ciliophora: *Stenosemella lacustris*; Rotifera: Brachionidae: *Brachionus diversicornis*: Cladocera: Moinidae: *Moina micrura*; from Coorong 2010-2011 samples.

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Executive summary

Historically, Lower River Murray flows have transported a diverse zooplankton assemblage from the Murray and Darling catchments into Lakes Alexandrina/Albert. Since European settlement and impoundment the character of transported zooplankton communities from the upper Murray tributaries has likely changed from a riverine community to a lacustrine or reservoir community derived from the locks, weirs and reservoirs due to the restrictions to flow, while the relatively unimpounded Darling River has retained a riverine assemblage.

Characteristically, the plankton of lakes and other standing waters tends to be microcrustacean-dominated (Copepoda, Cladocera) with Rotifera, Protista and other groups seasonal. In comparison, the zooplankton community of rivers is primarily Rotifera-dominated, with microcrustaceans sparse or absent. This zooplankton community grazes resident phytoplankton

and bacterial assemblages in the river system and in turn is a primary food source for macroinvertebrates and fish.

In 2010 the Murray-Darling Basin experienced its wettest year on record, with high rainfalls continuing into 2011. Lakes Alexandrina and Albert received significant inflows following a decade of drought, with correspondingly large flows to the Murray Mouth/Goolwa Channel providing an opportunity to investigate inputs of zooplankton from the Lower Lakes. The zooplankton of the Lower Lakes and the Goolwa Channel upstream of the Goolwa Barrage was to be sampled concurrently by DENR staff, and is reported separately. Notably the three monitoring surveys are the first comprehensive study to date of the Lower Lakes, Goolwa Channel, Murray Mouth and northern Coorong zooplankton community. Only the assemblages downstream of the barrages are detailed here.

The objectives of this study were to document changes in the composition of the zooplankton community in the Coorong following barrage releases. Of particular interest was the survivability of freshwater zooplankton as well as enhanced productivity of estuarine species. The objective 'to assess any changes in diatom and other phytoplankton and zooplankton assemblages in the estuary in comparison to baseline (no-flow) conditions, in relation to Goolwa cockle food sources' was not pursued given that Goolwa cockles filter fine particulates and diatoms, and are not known to filter zooplankton.

It was hypothesised that high inflows would provide significant ecological benefits, particularly increased habitat availability, both areal and ecological (decreased salinity and stratification) and increased food availability (increased autochthonous productivity and allochthonous material) for aquatic organisms. Hypotheses were investigated by monitoring the zooplankton community on six occasions between November 2010 and April 2011 at 11 sites in the Northern Coorong, Murray Mouth and Southern Ocean.

High inflows from the Lower Lakes into the Murray Mouth and Northern Coorong prior to and during the sampling period flushed the estuarine microcrustacean zooplankton assemblage which had developed over the preceding protracted drought. The resulting low conductivities meant that the zooplankton community was replaced by a protist/rotifer dominated freshwater assemblage characteristic of the Lower Murray and Lake Alexandrina. Approx. 70% of zooplankton taxa recorded from the Murray Mouth and Coorong North Lagoon sites also were recorded above the barrages in Lake Alexandrina or the Goolwa Channel (DENR, unpublished). Species dominants downstream of the barrages differed significantly between sites and sampling dates, reflecting flows from disparate sources. More than 90% of recorded zooplankton are freshwater in habit. Only one species, an endemic freshwater testate ciliate, *Stenosemella lacustris*, occurred at all sites on most sampling occasions. Similarly, only one rotifer, the brachionid *Keratella tropica*, occurred at all sites on most sampling occasions. Two cladocerans, *Daphnia carinata s.l.* and *Moina micrura* occurred at most sites on approximately 50% of sampling dates, as did one copepod, the calanoid *Boeckella triarticulata*. Freshwater taxa occurred at all sampled sites, including the Southern Ocean adjacent to the Murray Mouth. Notably, halophile taxa were rare, usually singletons or in low numbers. Only 18 taxa of 187 recorded (<10%) across the Lower Lakes, Goolwa Channel, Murray Mouth and Coorong North Lagoon sites are halotolerant or halophile in habit (nine rotifers, eight copepods, one cladoceran). No barnacle or crab larvae were recorded and polychaete larvae were sparse, confined to easternmost sites C10 (Tauwitcherie) and C11 (Mark Point) in small numbers.

The number of zooplankton taxa per site recorded over the study (mean=12, N=66) varied from 0 (at C5, in the Murray Mouth in a zone of heavy wave action) to 28 (C10, Tauwitcherie). Densities (mean=1296 ind. l^{-1}, N=66) ranged from 14 ind. l^{-1} (C7, Mundoo) to 4,648 ind. l^{-1} (C11, Mark Point). At least four taxa of testate amoebae and five rotifers could not be allocated to known species, and apparently are undescribed. Several other brachionid rotifers were previously known only from tributaries of the Darling River in Queensland, or upper Murray billabongs, and are new to South Australia. Of the microcrustaceans, one, possibly two alonines (Cladocera: Chydoridae) and one *Ceriodaphnia* sp. (Cladocera: Daphnidae) appear to be undescribed. At least one species each in *Mesocyclops* (Copepoda: Cyclopoida) and *Mesochra* (Copepoda: Harpacticoida) could not be placed with certainty. These families/genera all require taxonomic revision for the continent.

There was a general trend of increasing diversity over the study period (November 2010 – April 2011), with compositional changes reflecting disparate sources, and responses to phytoplankton blooms carried by the outflows. Trophic responses are suggested by the presence of juvenile fish in plankton net hauls and volumetric trap samples. The estuarine zooplankton community was effectively ‘re-set’ into a more diverse freshwater assemblage by high flows and continued inocula from the 2010-2011 floods, which is likely to persist while high flows continue, preventing re-establishment of an estuarine community.

The implications of this system re-set operate at all levels of the aquatic ecosystem and have both negative and positive aspects – negative for the estuarine community, displaced by freshwater inflows and reduced salinity, and positive for the freshwater assemblages occupying new habitat, with accompanying phyto- and zooplankton providing cues to breeding and hence recruitment of macroinvertebrates, fish and birds. Future barrage releases, if timed to breeding cycles, could maintain ecosystem biodiversity – even small barrage releases have been shown to promote recruitment. Periodical monitoring of the biota coincident with barrage releases would be useful to establish response times missed by the unexpected timing and high flood levels during the 2010-2011 flood events. In the context of the zooplankton component, the significance of source populations, whether from Darling tributaries or Murray tributaries, the species composition, dietary significance in the trophic cascade, grazing impact on phytoplankton populations, fate, particularly persistence and emergence cues, of propagules deposited in the Lower Lakes, Murray Mouth and Coorong by the resident zooplankton, are questions which remain to be investigated.

Introduction

The Coorong, Lower Lakes and Murray Mouth – the region

On an evolutionary time scale, the Coorong has had a very long marine influence as sea level changes over millennia flooded interdune depressions along the coast. The Coorong has been isolated as a lagoon for about 3000 years (Geddes & Hall 1990). During this period it is likely that the ecosystem alternated between fresh and saline, subject to freshwater inflows from the Murray-Darling Basin or marine inflows through the Murray Mouth into the estuary – then comprising the Lower Lakes (Alexandrina and Albert), the Murray Mouth and Coorong Lagoons (Fig. 1).

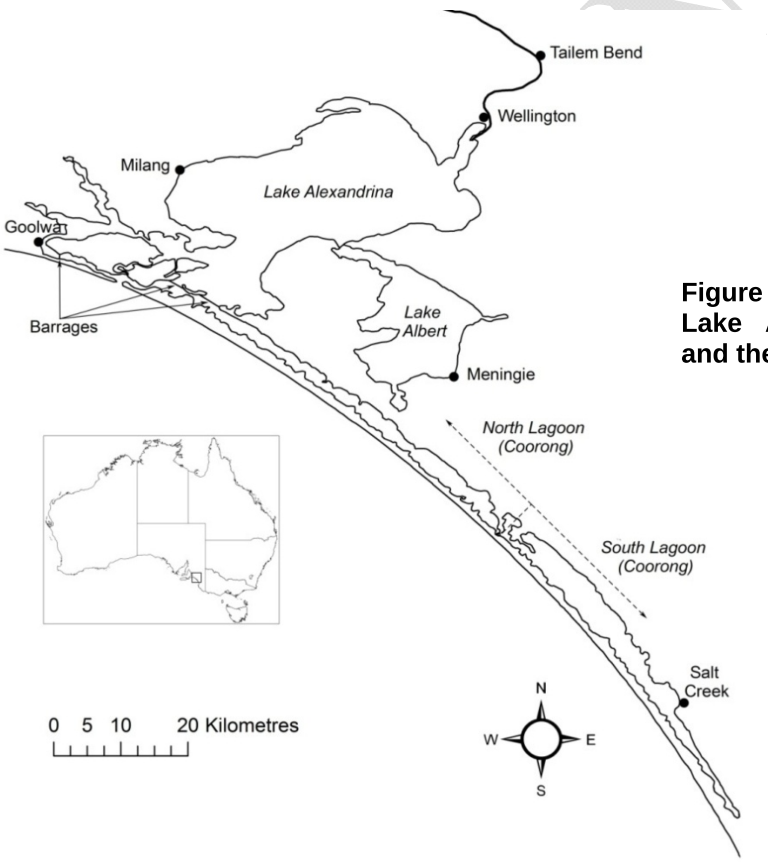


Figure 1. Lower River Murray, Lake Alexandrina, Lake Albert and the Coorong.

Following European settlement and management of the Basin, the area of the estuary was significantly reduced by construction of barrages across five channels connecting the Lower Lakes to the Murray Mouth (Fig 1). The Lower Lakes were effectively converted to freshwater ecosystems, with the Murray Mouth and Coorong the remnant estuarine ecosystem. The ecological heterogeneity across the region provided by fresh through to hypersaline salinity gradients, vegetated littoral, and extensive mudflats provided refugia, breeding/nesting sites and feeding habitat for a diverse suite of invertebrates, fish and birds. This diversity was recognized in 1985 when the region was declared a *Wetland of International Importance* under the Ramsar Convention (Aldridge & Brookes 2011).

From September 2001 to 2008 the Murray-Darling Basin experienced the second driest seven-year period in its recorded history (MDBC 2008). Combined with upstream abstraction and over-allocation of water within the Murray-Darling Basin, this resulted in no inflows to the Coorong in 2007-2009, following below average inflows from 1993 to 2007 (MDBA, unpublished). This has severely impacted upon the Coorong ecosystem due to elevated salinity (Brookes *et al.* 2009), the effects of which were compounded by drawdown, formation of acid-sulphate soils following exposure of previously submerged littorals, and intrusion of saline water into the lakes (Aldridge *et al.* 2009). Implications for the resident zooplankton community are considered below.

The zooplankton community

Zooplankton provide links in aquatic ecosystems between bacteria/algae and higher order consumers, such as macroinvertebrates and fish – they occupy an intermediate trophic level. As first feed for juvenile fish, zooplankton populations are vitally important in fish recruitment, which may in turn be queued to zooplankton recruitment. Zooplankton also are sensitive indicators of perturbation, and are widely used (in the northern hemisphere at least) as bioindicators – toxicological test organisms sensitive to minute changes in water quality, such as salinity, pH, pollutants. Zooplankton have also been utilized in biomanipulation – the control of problem phytoplankton blooms, particularly of cyanobacteria, by herbivorous zooplankton, after reduction or removal of zooplanktivorous fish from the target lake(s).

Zooplankton in Australian inland waters is less well-studied than that of northern hemisphere waters, with only a few reports on the zooplankton of reservoirs and rivers accessible from coastal population centres. Zooplankton of the Murray-Darling Basin was studied by Shiel (1981), and the zooplankton of the lower Murray in Sth Australia (at Mannum, 150 km upstream of the Murray Mouth) reported by Shiel *et al.* (1982).

In the context of the present study, it is pertinent to note that the two rivers transport different assemblages of zooplankton into the lower Murray and Lower Lakes: the Darling a warm-water rotifer-dominated *potamo*plankton (riverine), the Murray a cool-temperate microcrustacean-dominated *limno*plankton (lacustrine). Depending on the relative contributions from upstream rivers, a mixed assemblage of zooplankton would typically be expected to transit the lower Murray into Lake Alexandrina. When barrages are open this community could enter the estuarine Coorong/Goolwa Channel/Murray Mouth. Under estuarine conditions a freshwater zooplankton assemblage would be unlikely to survive, however may provide short-term food resources for, for example, estuarine macroinvertebrates or juvenile fish.

Low or no flows from the River Murray into the Lower Lakes during the protracted drought (September 2001 to 2008) reduced transport of zooplankton into the Lower Lakes, with reduction in resident zooplankton diversity and changes in species composition resulting from elevated salinity levels. The first documented report of Coorong and Murray Mouth zooplankton assemblages resulted from a small managed barrage release in Sept-Oct 2003, which created estuarine conditions in the Murray Mouth and contributed significant zooplankton numbers into the Murray Mouth and North Lagoon of the Coorong, stimulating fish movements and fish breeding (Geddes 2005). During this release few halotolerant/estuarine zooplankton were recorded, primarily the copepods *Gladioferens* and *Mesochra*, and *Synchaeta*, an estuarine rotifer. Estuarine meroplankton included barnacle larvae, polychaete larvae and crab larvae.

Subsequent small barrage releases into the Murray Mouth as the drought progressed documented reduced diversity of zooplankton in the receiving waters, attributed to elevated salinity. Limited survival of the freshwater L. Alexandrina zooplankton in the estuarine Goolwa and Tauwitcherie Channels was noted. The environmental benefits of the small releases were seen as short-lived and geographically limited.

Estuarine zooplankton

Studies on the zooplankton of Australian estuaries include that of the Brisbane River (Bayly 1965), Yarra/Port Philip Bay (Neale & Bayly 1974) and Swan Estuary (Griffin & Rippingale 2001). The first study of zooplankton of the Murray-Mouth/Coorong Estuary was Geddes' (2005) report on zooplankton responses to a small managed barrage release in Sept-Oct 2003. He recorded a freshwater zooplankton assemblage from Lake Alexandrina (rotifers, the calanoid copepods *Boeckella triarticulata/Calamoecia ampulla*) flushed into the Murray Mouth, whereas the salinized North Lagoon had an estuarine zooplankton: euryhaline rotifers and copepods, and meroplankton including crab larvae, barnacle nauplii, polychaete larvae and gastropod larvae at sites east of the Murray Mouth (Geddes *et al.* in MS).

This estuarine assemblage persisted in the Murray Mouth and North Lagoon through the protracted drought, with no flows from the Lower Lakes. Zooplankton collected from the North Lagoon during a trophic ecology study reported by Geddes & Francis (2008) contained the above estuarine assemblage, and the first record from the Coorong of the large estuarine calanoid *Labidocera cervi* (Kramer). Barnacle larvae, crab larvae and polychaetes were collected at Pelican Point and sites further east in the North Lagoon.

Exceptional rainfall in the northern Murray-Darling Basin in 2010, elevated flows to the Lower Murray, and significant barrage releases from Lake Alexandrina to the Murray Mouth provided an opportunity to monitor the transfer of nutrients and biota, and to determine the impacts on the estuarine ecosystem. Responses of the Coorong/Murray Mouth zooplankton assemblage are reported here. Appendix 1 includes a checklist of zooplankton recorded from the concurrent DENR sampling of the Lower Lakes and Goolwa Channel, and represents the first comprehensive monitoring of the zooplankton of the region.

Methods

Field

All sites sampled (Fig. 2, Appendix 2) were in open water. Sites C4 (Southern Ocean beach) and C5 (Murray Mouth) were sampled from wader depth from the shore. All other sites were sampled from a boat. Sampling dates were 01 November 2010, 27 November 2010, 05 January 2011, 31 January 2011, 28 February 2011 and 26 April 2011. The final field trip was delayed until late April in order to increase the temporal coverage.

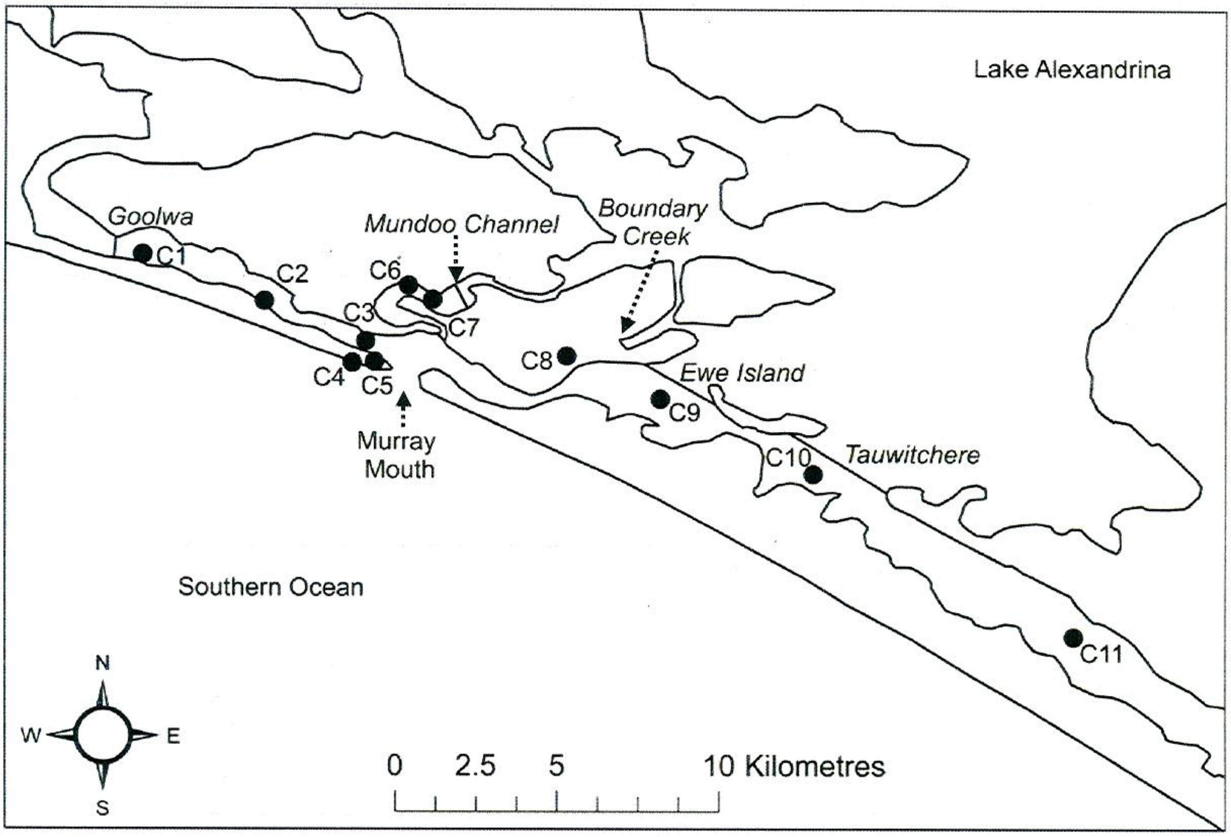


Figure 2. Map of sampling locations in the North Lagoon of the Coorong and Murray Mouth region. C1 – Goolwa Barrage Downstream; C2 – Half Way; C3 – Sugar's Beach; C4 – Southern Ocean; C5 – Murray Mouth; C6 – Hunter's Creek; C7 – Mundoo Channel; C8 – Boundary Creek; C9 – Ewe Island; C10 – Tauwitchere; C11 – Mark Point. Labelled in italics are barrages.

Qualitative Sampling

Standard plankton nets of 230 mm aperture, 35 μm-mesh (Fig. 3a) were used to collect qualitative plankton samples by oblique hauls (3x5 m tows) from approx. 1 m depth to the surface at each site. On occasion prevailing wind conditions prevented a clean throw of the net; in this event a 1 min tow was taken behind the boat at slow speed.

Fig, 3a: Plankton net

Fig. 3b: Perspex Haney plankton traps

Quantitative Sampling

To provide a measure of plankton density at each site both spatially and temporally, known volumes were collected initially using two closing perspex Haney traps (Fig. 3b). Although the larger volume 14-litre trap sample was desirable, filtering time through the bayonet mount 35 μm stainless mesh in highly turbid water was prohibitive, so subsequent trap samples were collected using the smaller and faster-emptying 4-litre trap. Multiple trap samples, usually 12-l, could be taken in the time taken for 1 x 14-litre sample. All collections were fixed with 90% ethanol in 200 ml PET bottles to a final concentration of approx. 75%, and returned to the laboratory for sorting and enumeration.

Laboratory

Qualitative Samples

Settled volumes were extracted *in toto* where possible using a 10-ml wide-bore pipette, then run into a gridded Greiner tray (Fig. 4) for sorting and enumeration.

Fig. 4: Gridded Greiner tray used for sifting net tows.

Tray contents were sifted by row on a Zeiss SV-11 dark-field dissecting microscope stage, using a fine sable brush or tungsten needle held in a pin-vice to separate particulates. Plankters were enumerated on a Micro-Professor multi-channel tally counter (to the left of stage shown in Figure 4), until 200-300 individuals had been encountered. The counter totals were then entered on an Excel spreadsheet, and the proportion of tray scanned noted as a coarse measure of density. Individuals which could not be identified in the Greiner tray were extracted during the scan using a bulbed microcapillary pipette (right of stage shown in Figure 4) or a tungsten wire loop, transferred to a well-block containing 10% glycerol-H_2O for later examination at higher magnification on an Olympus BH-2 compound microscope with Nomarski (Differential Interference Contrast) optics.

Highly turbid samples, whether abiogenic (e.g. montmorillonite clay suspensoids) or biogenic (algal blooms), could not be sifted in a sensible time frame in the Greiner tray. For these samples, 1 ml was extracted by Pasteur pipette, run into a 1-ml Sedgewick-Rafter cell, and the inhabitants counted on at 20X magnification on the BH-2 microscope.

For highly turbid samples, or samples with low density of plankters, a compromise was necessary when excessive search time was required to find 200 individuals. For such samples 60-90 min was the cutoff.

Both microscopes were fitted with high-resolution Logitech webcam digital cameras, used to catalog taxa encountered (e.g. Fig. 5a), or provide a record of decision-points in taxonomic treatment, for example trophi (teeth) of rotifers (Fig. 5b), or significant appendages of microcrustaceans (Fig. 5c).

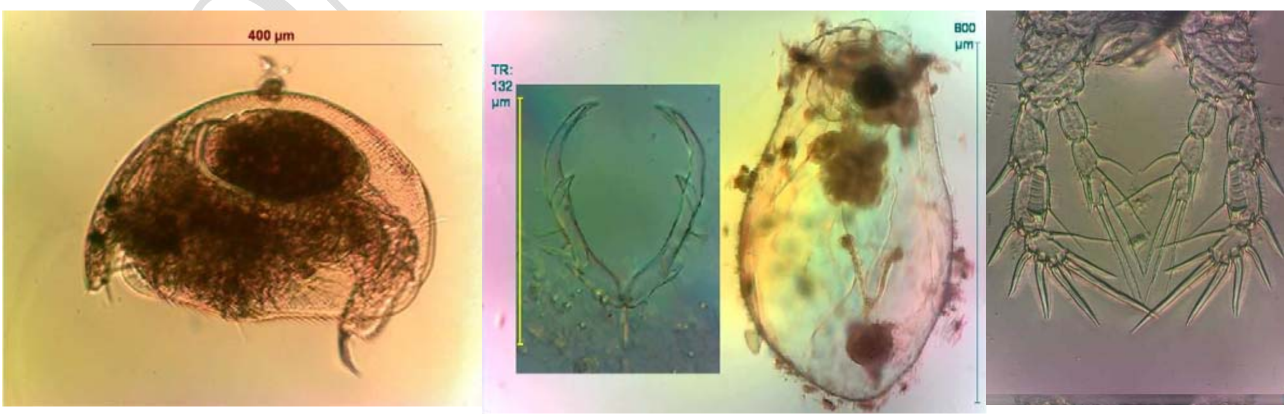


Fig 5a (left): *Alona* (Chydoridae) Mark Point, 01 November 2010; b (centre): *Asplanchna* (Rotifera) & trophi C2 05 January 2011; c (right): harpacticoid P3 C9 27 November 2010

Quantitative Samples:

Counts of trap samples in their entirety are generally time-consuming, not economic. Subsamples are a compromise, the efficiency of which can be estimated by taking three subsamples and calculating standard deviation (SD) and standard error (SE). Time constraints precluded three counts from Coorong traps in the reporting time frame – only a single count is reported from each date hereafter.

Trap samples were decanted, and the PET bottle flushed with ethanol, into a graduated measuring cylinder. The volume was recorded, the cylinder capped with Parafilm®, inverted three times to distribute the contents, and a Gilson 1-ml autopipette (Fig 6a) was used to extract 1 ml from approximately the centre of the cylinder. The 1 ml sub-sample was run into a 1 ml glass Sedgewick-Rafter cell (Fig. 6b), the coverslip placed, and the contents of the sub-sample enumerated on a compound microscope (BH-2 as noted earlier, or a Zeiss Laboval research microscope).

Fig. 6a: Gilson autopipette used to extract 1 ml from agitated trap sample

Fig. 6b: 1 ml glass graticule Sedgewick-Rafter cell

The count of plankters in the measured 1 ml sub-sample was multiplied by the overall sample volume to provide an estimate of the total plankters in the volume, from which the number of individuals/litre in the original sample (12-litres or, on one occasion, 20-litres) was calculated.

Results

Appendix 1 lists all zooplankton taxa recorded from the Lower Lakes, Goolwa Channel, Murray Mouth and Coorong North Lagoon sites. In summary, 187 zooplankton taxa were recorded across the study area: 144 from L. Alexandrina, 50 from L. Albert, 109 from the Goolwa Channel and 97 from Murray Mouth/North Lagoon sites. Relative proportions of plankters varied widely between sites and dates, reflecting different origins of water masses moving through Lake Alexandrina and the barrages into the Murray Mouth/North Lagoon. Approximately 70% of zooplankton taxa recorded from the Murray Mouth/North Lagoon sites also occurred above the barrages in the Goolwa Channel or Lake Alexandrina. Notably, only 18 taxa (less than 10% of the overall total) are recognized halophile or halotolerant estuarine or inland salt lake in habit. This total does not include the Protista, the ecology of which is poorly known in Australia. Some of the recorded protists, particularly from L. Albert and salinized margins of L. Alexandrina during the drought and drawdown are likely halotolerant.

Of the identified halophiles, nine are rotifers (*Brachionus* cf. *baylyi* n. sp., *B. nilsoni, B. plicatilis* s.l., *B. quadridentatus cluniorbicularis, Proalides tentaculatus, Hexarthra brandorffi, Lecane thalera, L. ludwigii* and *Colurella adriatica*) and eight are copepods (*Halicyclops ambiguus, Gladioferens pectinatus, G. spinosus, Sulcanus conflictus, Onychocamptus bengalensis, Mesochra parva, Mesochra* sp., and the halotolerant *Boeckella triarticulata*).

One cladoceran, *Daphnia carinata* s.l. is known to extend into slightly saline waters, and is likely tolerant of elevated salinities in the Coorong/Murray Mouth region. The name is applied with the reservation that '*D. carinata'* likely represents a species complex in Australia, the individual members of which may have different salinity tolerances which are not yet investigated or recognized. The remaining taxa listed in Appendix 1 are all primarily freshwater in affinity.

Appendix 1 includes a suite of species in all groups, but particularly Protista, identified only to genus, unavoidable in view of the poor resolution of protists in Australia generally. However, at least four testate amoebae appear to be undescribed (*Centropyxis* and *Difflugia* spp.), as do five species of Rotifera: two *Brachionus,* with a third species of *Brachionus* identified here as *B. plicatilis* s.l. resembling that halophile species, but below the size range of *B. plicatilis* s. str., therefore likely to represent an undescribed endemic species in the *B. plicatilis* complex, one *Cephalodella* and one *Synchaeta* sp. Only the *B. plicatilis* s.l. taxon has been recorded elsewhere – in salinized wetlands in the Wheatbelt of W.A. (Blinn *et al.* 2004).

Site diversity

Fig. 7 shows number of zooplankton taxa recorded per site for the sampling period, Fig. 8 the density of individuals per site from volumentric samples. The first samples were clearly of low density and generally lower diversity than on subsequent sampling dates. A general increase in diversity across the study period is evident for some sites, but not all. Except for sites 10 and 11,

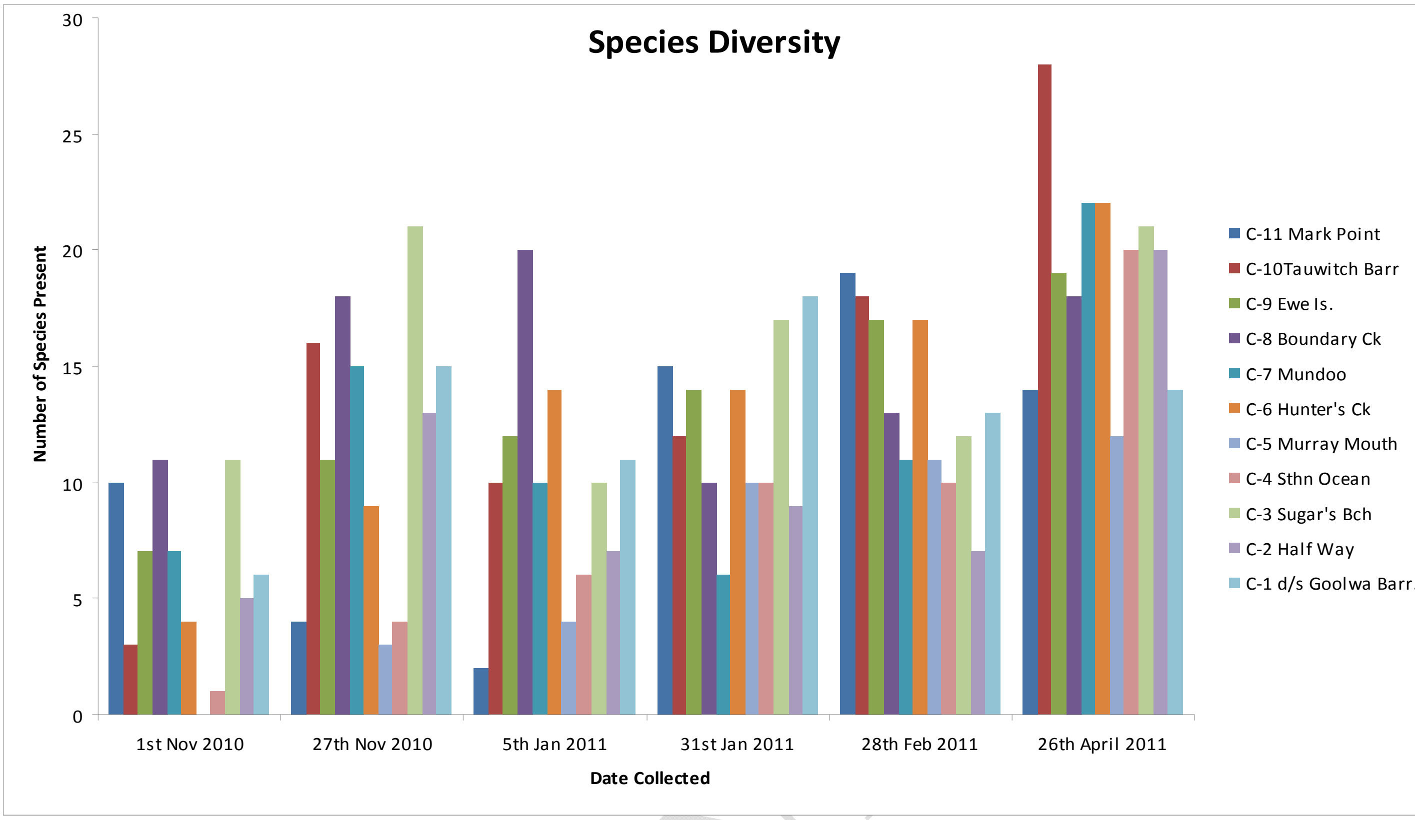


Fig. 7: Number of zooplankton species recorded from C-1 - C-11, Nov. '10 – Apr. '11

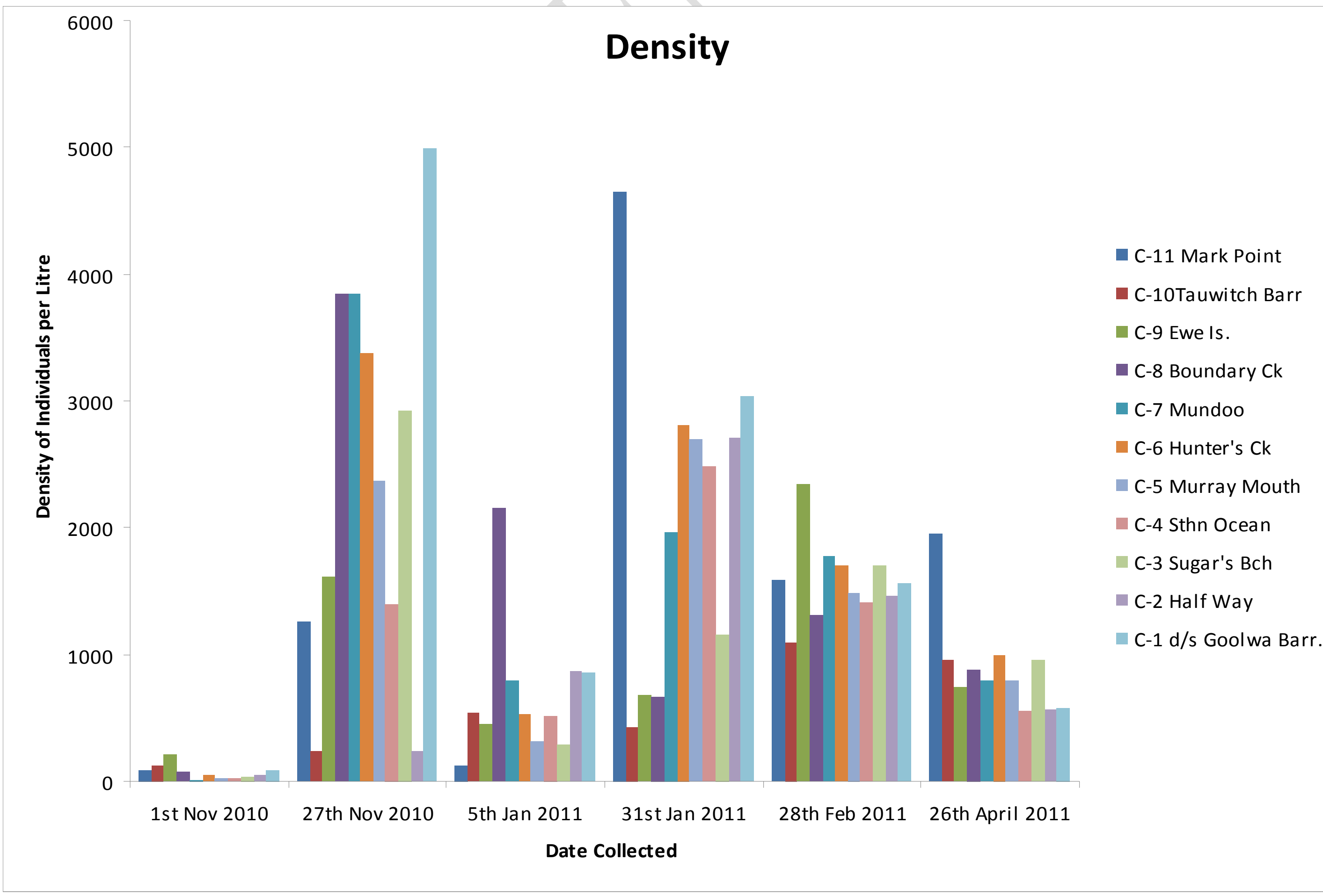


Fig. 8: Density of zooplankton (ind. l^{-1}) C1-C11 Nov '10-Apr. '11

there was high abundance on 27 Nov 2010 followed by a decrease in abundance on 5 Jan 2011. There was a decrease in abundance from 31 Jan 2011 at sites 1,2,4,5,6,7,11. At Site 11, diversity was lowest from Nov-Jan followed by an increase in diversity and abundance in 31 Jan 2011. Brief comments are given below on some site-specific events.

Figs. 9-20 summarize assemblages at each site during the study period. Plots are number of taxa (left) and densities (right).

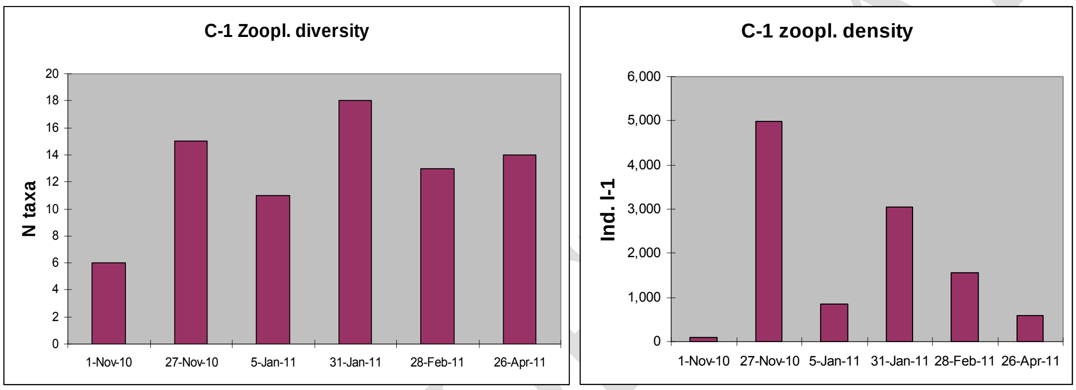


Fig. 9: Zooplankton density and diversity at C1, downstream of the Goolwa Barrage.

Both diversity and density were lowest at C1 on the 01 Nov ’10 sampling, with fewer than 100 individuals/litre, and only six taxa recorded (four rotifers, an alonine chydorid, and calanoid copepodites/nauplii). High turbidity was noted. In contrast, nearly 5000 individuals/litre were recorded from the second trip (27 Nov), attributed to a pulse of the ciliate *Stenosemella lacustris,* which persisted in C1 for the duration of sampling. Ten to fifteen other taxa were present in low numbers in later samples from C1. *S. lacustris* was the only plankter collected in appreciable numbers on Jan. 05, but by the end of January a population of another protist, *Difflugia* sp. C had developed, reaching comparable numbers to *Stenosemella.* Both protists are primarily bacteriovores, reflecting likely high bacterial levels at C1. No other zooplankters reached appreciable numbers at this site. The mean density of 1853 ind l^{-1} at this site reflects pulses of the two protists. Both were recorded in significant numbers in the Goolwa Channel samples; their occurrence at C1 likely reflects a combination of throughflow and recruitment.

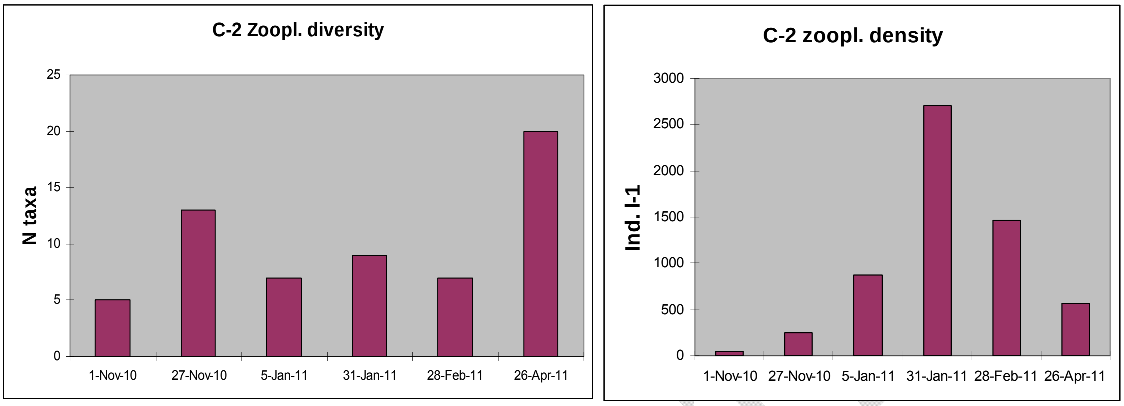


Fig. 10: Zooplankton density and diversity at C2, Half-way

The plankton assemblage at C2 was dominated by *S. lacustris* and *Difflugia* sp. C for the first five trips. Diversity was generally low. Only the last sample had a suite of rotifers, all in small numbers, with *Keratella tropica* gradually increasing in abundance. The population peak on 31 Jan was due almost entirely to *S. lacustris/Difflugia* sp. C dominating. Mean density across the sampling period was 985 ind. $l^{-1.}$

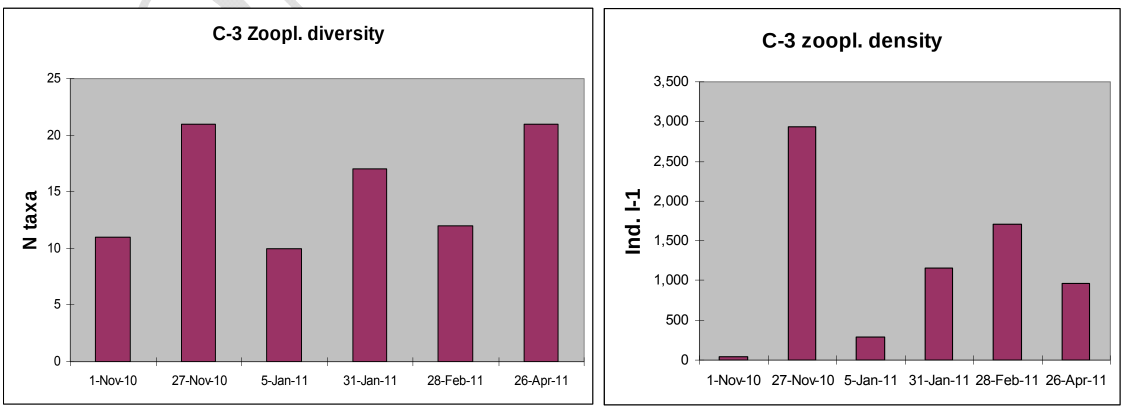


Fig. 11: Zooplankton density and diversity at C3, Sugar's Beach

S. lacustris again dominated across the sampling period at C3, Sugar's Beach, with nearly 3000 individuals/litre on 27 Nov. *Difflugia* C did not appear till the next sampling, 31 Jan, when it was co-dominant. C3 was the only site to have significant populations of microcrustaceans – as copepodites and nauplii in all samples, with *Moina micrura* (Cladocera) and *Boeckella/Calamoecia* (Copepoda) dominating on 05 Jan. Both taxa were found in L. Alexandrina, although not in comparable numbers on any sampling date. It is likely the population was flushed from an upstream inshore habitat prior to the sampling period, and was missed in transit. Both cladocerans and copepods declined thereafter. The population peaks on the last three trips comprised *S. lacustris*/*Difflugia* sp. C/*Keratella tropica.* Isolated bivalve larvae (27 Nov, 31 Jan), and a turbellarian (01 Nov), likely estuarine, were noted at C3. Mean density at C3 was 1182 individuals/litre.

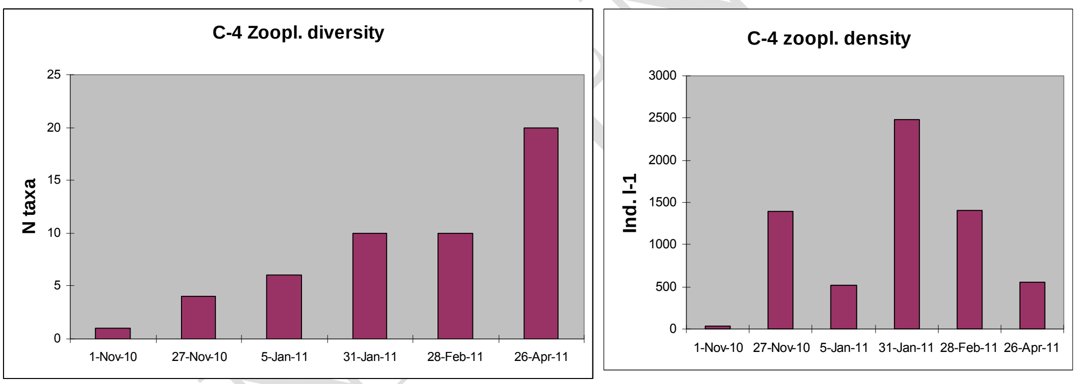


Fig. 12: Zooplankton density and diversity at C4, Southern Ocean

Samples were collected from wader depth at this site, usually in heavy wave action, likely underestimated the open-water zooplankton. Again, *S. lacustris* was the single most abundant plankter across the sampling period, with *Difflugia* sp. C co-dominant from 31 Jan. Diversity was low on all except the last field trip, when 20 species, including a suite of freshwater rotifers and estuarine copepods, were recorded. Density peaks on 27 Nov, 31 Jan and 28 Feb were due to *S. lacustris/Difflugia* sp. C. Marine foraminifera were recorded on every sampling date. Juvenile fish were present in trap samples

27 Nov, and net tows 31 Jan. Mean density of zooplankton at C4 across the sampling period was 973 individuals/litre.

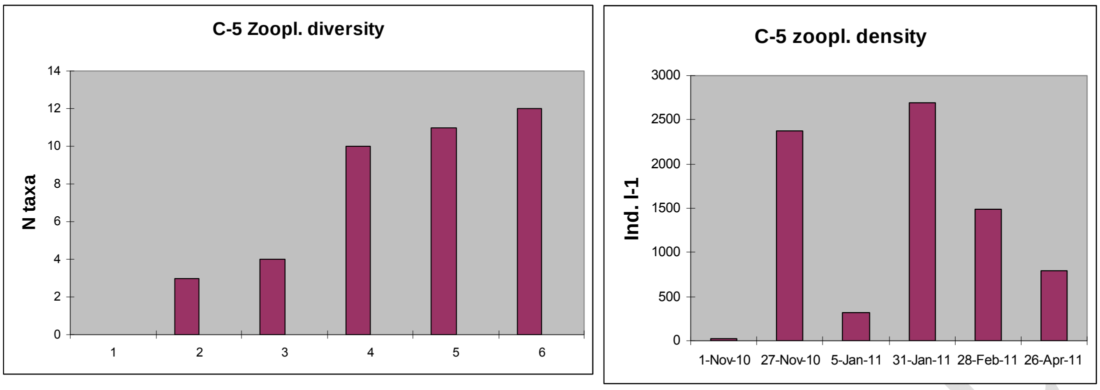


Fig. 13: Zooplankton density and diversity at C5, Murray Mouth

Samples at C5 also were collected from wader depth, subject to wave action and on occasion strong currents, so likely underestimate open-water plankton diversity/density. The first net sample contained only exuviae and macroinvertebrate exoskeletal material, and the trap volume only two copepod nauplii. On the second trip *S. lacustris* had reached the Murray Mouth, and was the dominant taxon (density peak 27 Nov. above). *Difflugia* sp. C was not apparent until 31 Jan, when it was co-dominant with *S. lacustris*, accounting for most of the 2694 individuals/litre. Diversity increases in the last three field trips were attributed to rotifers and microcrustacean moving through C5 in small numbers – with a corresponding decline in *S. lacustris/Difflugia* sp. C. Mean density at C5 across the sampling period was 1282 individuals/litre.

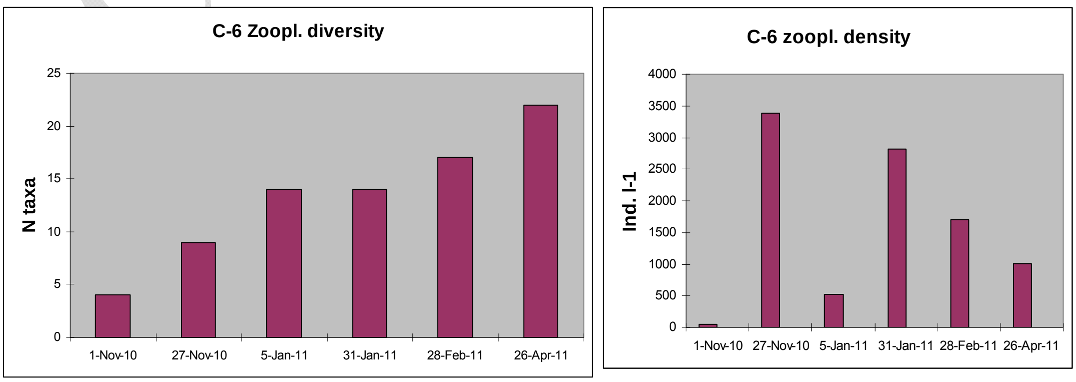


Fig. 14: Zooplankton density and diversity at C6, Hunter's Creek

Diversity at C6, Hunter's Creek, increased from 4 to 22 species over the sampling period, with all taxonomic groups represented. *S. lacustris* was abundant throughout, with a peak on 27 Nov. *Difflugia* sp. C appeared in low numbers 05 Jan, was dominant by Jan 31, declined thereafter. Notable was a 'pulse' of *M. micrura/B. triarticulata*, (525 individuals/litre) on 05 Jan. *S. lacustris/Difflugia* sp. C persisted as dominants, with rotifers in small numbers, to the end of sampling. Mean density at C6 across the sampling period was 1578 individuals/litre.

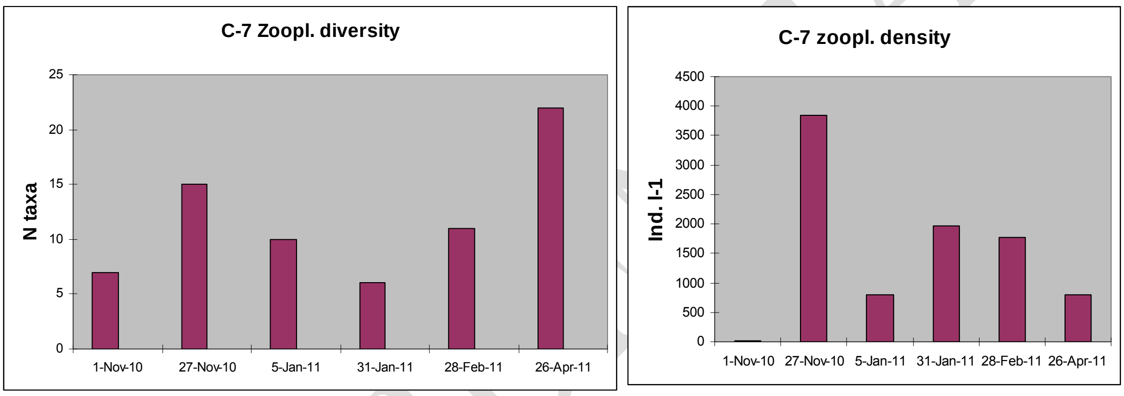
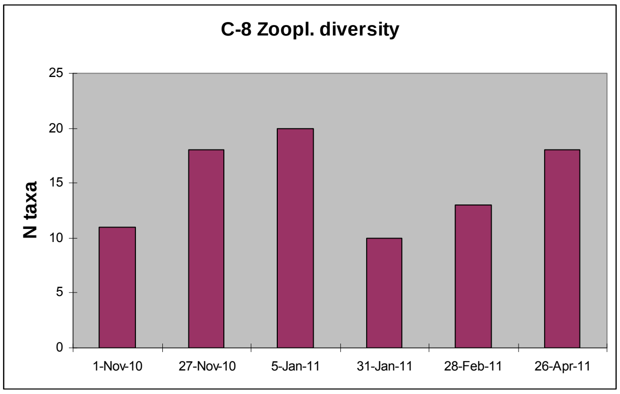


Fig. 15: Zooplankton density and diversity at C7, Mundoo Channel

As at C6, *S. lacustris* accounted for the density peak on 27 Nov, while the diversity increase was due to a suite of rotifers, *Brachionus calyciflorus* and *Keratella tropica* most abundant. The 05 Jan pulse of microcrustaceans *M. micrura/B. triarticulata* also occurred at C7, and also at low density. The diversity peak of 22 spp. on 26 Apr was predominantly a mix of testate amoebae, likely flushed from vegetation or littoral surfaces, and rotifers, only one of which, *Keratella tropica* was present in appreciable numbers. The estuarine calanoid, *Gladioferens pectinatus* was present in small numbers 28 Feb and 26 Apr. Mean density at C7 across the sampling period was 1532 individuals/litre.



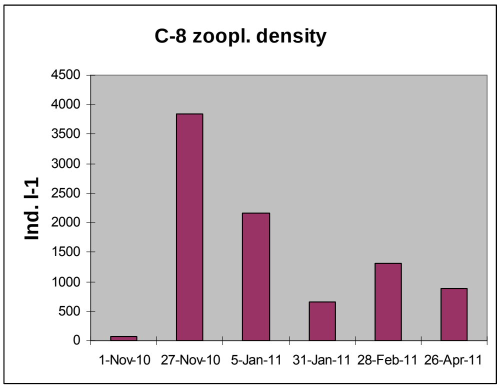


Fig. 16: Zooplankton density and diversity at C8, Boundary Creek

Daphnia carinata was the most abundant plankter in the first net sample (01 Nov) from C8, comprising more than 70% of the community. Another 20% consisted of the epibenthic/littoral alonine, *Alona* cf. *rectangula* (Chydoridae). No *Daphnia* were present in the aliquot taken from the 01 Nov trap volume, and only one *Alona*, suggesting that patchiness in the habitat, e.g. clumping or swarming by *Daphnia,* was picked up by the net, but missed by the trap, and that the net may have passed through the submerged vegetation such as *Myriophyllum* preferred by alonines, selectively sampling a microhabitat which also was missed by the trap. These are methodological variables which have to be taken into account when sampling, both qualitatively and quantitatively, shallow vegetated habitats. In any event, *Daphnia* had gone by the second sampling date, and only isolated *Alona* were collected. The most abundant cladoceran by 27 Nov was the planktonic *Bosmina meridionalis,* accompanied by a suite of rotifers dominated by *Brachionus calyciflorus/Keratella australis.*

The density peaks on 27 Nov/05 Jan were primarily *S. lacustris,* with a small contribution by microcrustaceans (*M. micrura/B triarticulata*) on the latter date. Mean density at C8 across the sampling period was 1490 individuals/litre.

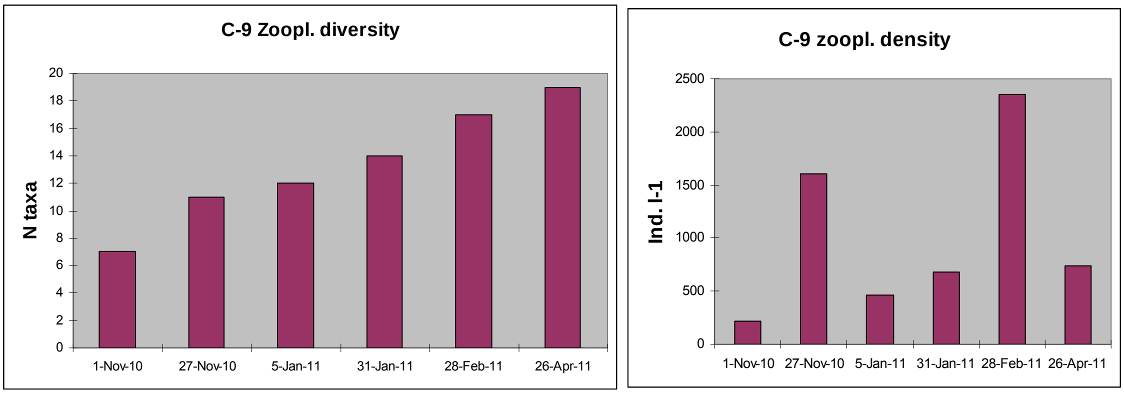


Fig. 17: Zooplankton density and diversity at C9, Ewe Island

As at C8, the 01 Nov net sample from C-9 was dominated by *D. carinata*, but apparently at low densities (22 l^{-1}). *Alona* cf. *rectangula* also was subdominant at C9, and also occurred at low densities (33 l^{-1}). Diversity increases thereafter were attributed to rotifers, with a single pulse of microcrustaceans (*Daphnia, Moina, Boeckella*) 05 Jan. The density peak 28 Feb was primarily *S. lacustris*, with *Difflugia* sp. C. subdominant. Mean density at C9 across the sampling period was 1008 individuals/litre.

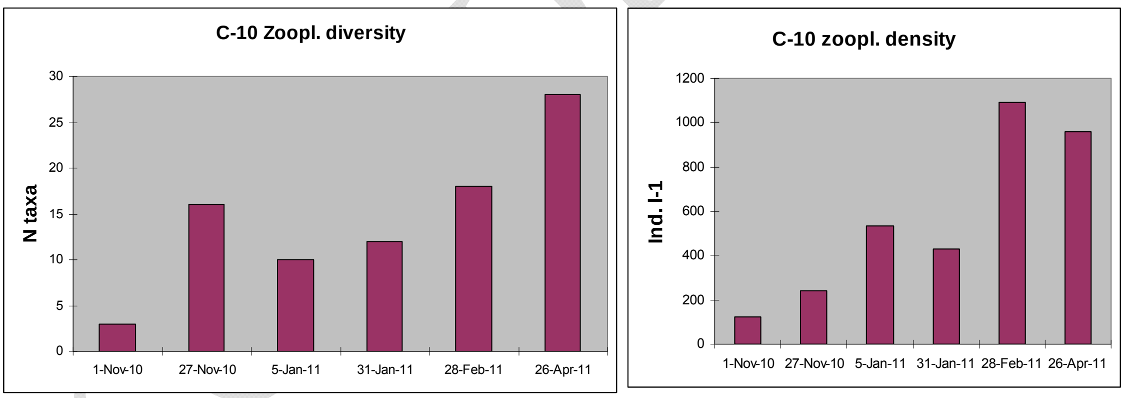


Fig. 19: Zooplankton density and diversity at C10, Tauwitcherie

As at C9, the zooplankton assemblage at C10 on 01 Nov was dominated by *D. carinata* at low densities (19 l^{-1}) with *B. triarticulata* also present in low numbers. No rotifers were recorded from the net tows, but one *Proales daphnicola* and two *Synchaeta* n. sp. were found in the trap aliquot. The former species is an epizoite on *Daphnia*, and is commonly found with that cladoceran. Both diversity and density increased by the 27 Nov sampling, with a suite of rotifers and copepodites/nauplii at C10. The latter were likely *B. triarticulata*, which was the only adult calanoid found. The peak on 05 Jan was due to a pulse of *M. micrura/D. carinata/B. triarticulata*, with rotifers in low numbers. Diversity increased in subsequent samples with influx of protists (*S. lacustris/Difflugia* sp. C in particular) and rotifers accompanying a dense algal bloom. The 28 Feb and 26 Apr samples were most diverse, protist/rotifer dominated (18 & 28 spp respectively), with microcrustaceans present as copepodites/nauplii. Mean density at C10 across the sampling period was only 564 individuals/litre.

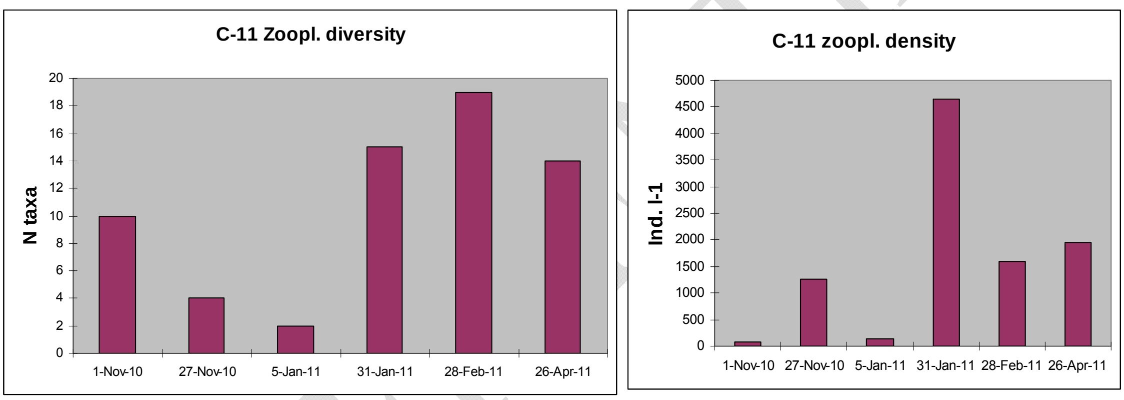


Fig. 20: Zooplankton density and diversity at C11, Mark Point

Copepodites/nauplii dominated the 01 Nov sample at C11 (75% of the assemblage), with *D. carinata* present in low numbers. Diversity declined on 27 Nov and 05 Jan, likely a result of higher salinities than at any other site (to approx 24 mS cm^{-1}). Polychaete larvae occurred on both dates, with a pulse of *Synchaeta* n. sp. accounting for the small density increase on 27 Nov (almost 1000 individuals/litre), suggesting that this species is halotolerant, in accord with the observations of Geddes (2005) who noted populations of *Synchaeta* at Coorong North Lagoon sites east of Mark Point, the easternmost sampling site in the present study. *Synchaeta* persisted at C11 for the duration of sampling, with a peak of approx. 1070 l^{-1} on 26 Apr. The diversity increases from 31 Jan were due to a suite of rotifers, notably the small *Proalides tentaculatus*, which peaked on 31 Jan (over 3000 l^{-1}). This species also appears to be halotolerant.. It was reported from 'Brackwasser' (5-6 $^{o}/_{oo}$) in Europe by Koste (1978). Freshwater protists and rotifers accounted for the higher diversity in the last two samples (28 Feb, 26 Apr), but with the exception of the above *Synchaeta,* were in low numbers. Mean density at C11 across the sampling period was 1609 individuals/litre.

Major components of the Coorong zooplankton

Protista: Although the sampling method was not designed to sample the protist component of the system, protists were occasionally the most abundant plankters at some sites, particularly the endemic R. Murray ciliate *Stenosemella lacustris* Foissner & O'Donoghue (frontispiece). This protist occurred at all sites, with 'pulses' to ca. 4-5,000 l^{-1} (e.g. C1, C7 27 Nov 10). Also abundant at most sites was a small testate amoeba resembling *Difflugia gramen* Penard, but distinct from that species, with which it co-occurred on occasions. It could not be placed satisfactorily into a known species, is likely undescribed, and remains as *Difflugia* sp. **c** in Appendix 1. It reached densities of more than 1,400 l^{-1} at C6 (31 Jan 11). Other testates in the genera *Arcella, Centropyxis, Cyphoderia* (Fig. 21)*, Difflugia* (Fig. 21)*, Zivkovicia, Lesquereusia, Netzelia* and *Trinema* were singletons or sparse. All are primarily benthic, freshwater in habit. Estuarine/marine protists (Foraminifera) were noted in appreciable numbers at only two sites, C4 and C5 (Southern Ocean and Murray Mouth).

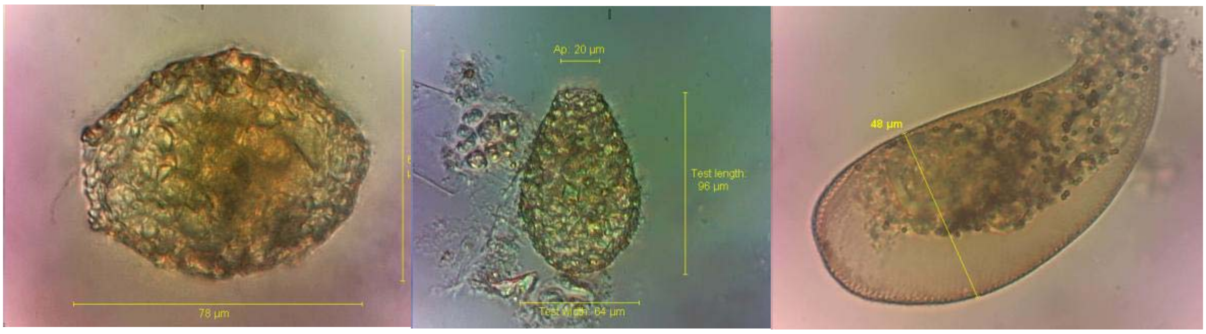


Fig 21: testate amoebae *Difflugia ampullula* C1 (left), *Difflugia* cf. *bryophila* C10 (centre), *Cyphoderia ampulla* C2 (right).

Rotifera: Of approx. 50 taxa of rotifers identified from Coroong sites, only half a dozen reached appreciable numbers at any site. An undescribed small species of *Synchaeta* dominated at C11 (27 Nov 10) along with a *Proalides* also at C11 (31 Jan 11). This *Synchaeta* sp. apparently is halotolerant, occurring across a salinity range of 2-17 mS (it occurs in L. Alexandrina). Brachionidae was the family with the most species or subspecies. represented (21), albeit generally in low abundances. An undescribed species of *Brachionus*, the pancontinental *Keratella australis* and cosmopolitan *K. tropica* were the only brachionids reaching significant numbers. The trochosphaerid genus *Filinia* occurred at all sites after 31 Jan, but generally in low numbers, except for a pulse of *F. pejleri* at C11 on 31Jan 11. Sites C4 and C5 were depauperate for rotifers throughout the period. With the exceptions of *Synchaeta* and *Proalides* noted above, the rotifer assemblage was freshwater in habit, recorded from L. Alexandrina and the upstream R. Murray. Representative rotifers are shown in Fig. 22.

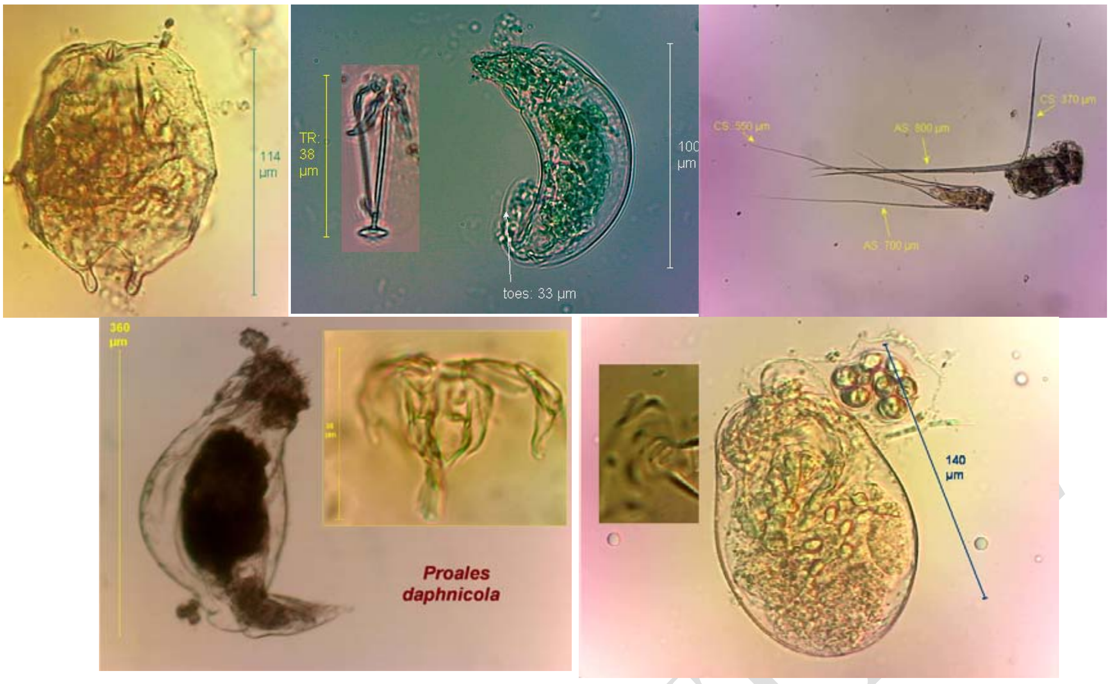


Fig. 22: (Top) *Brachionus angularis* (left) C1; *Trichocerca obtusidens* (centre) C8; endemic *Filinia* species (right) *F. australiensis* (right), *F. grandis* (left C8. (Bottom left) *Proales daphnicola* C11 (inset: trophi (teeth)); (bottom right) *Synchaeta* n. sp C1.

Cladocera: Cladocerans, which are much more visible than rotifers, larger (to 2-3 mm), and significant fish food, were notably sparse at most sites. Only two taxa were recorded in significant numbers: *Daphnia carinata* s.l. at C8, C9, C10 and C11 on 01 Nov 10, and *Moina micrura*, which reached a peak at several sites on 05 Jan 11 but was sparse thereafter. Brief ‘pulses’ of *Alona*/*Anthalona* (Chydoridae) were noted at C7/C8 01Nov 10. A few cladocerans – *Bosmina, Alona, Daphnia* (Fig. 23), and *Moina*, were noted at C4 and C5. With the exception of *Daphnia carinata* noted above, all cladocerans recorded are freshwater in habit.

Fig. 23: *Bosmina meridionalis* (left) C4; *Alona* cf. *rectangula* (centre) C9; *Daphnia carinata. S.l.* (right) C10

Copepoda: Of the eleven species of copepod recorded, six (*Boeckella triarticulata, Calamoecia ampulla, Australocyclops* sp., *Mesocyclops* cf. *notius, Microcyclops* sp. and *Thermocyclops* sp.) are known from the R. Murray and Lower Lakes (Shiel *et al*., 1982; Geddes 1984) and are primarily freshwater in habit, but tolerant of slight salinity increases. *Gladioferens spinosus* (a few ind. at C3 and C8) and *Halicyclops ambiguus* (a single individual at C9 27 Nov 10) are both halophile/estuarine in habit, known previously from the Coorong North Lagoon (Geddes 2005) and Goolwa Channel (R.J. Shiel, unpublished, DENR unpublished). *Gladioferens pectinatus*, a juvenile of which was misidentified as *G. inermis* (Shiel 2011) was sparse at most sites. It is a halophile, also known previously from the Coroong. The halophile harpacticoid, *Mesochra* sp., was noted by Geddes (2005) and again in plankton tows collected in 2007 and 2008 (Geddes & Francis (2008). The Coorong species are likely the canthocamptid *Mesochra parva* Thomson and laophontid *Onychocamptus bengalensis* Sewell, which occurred in the Goolwa Channel during the study period (DENR unpublished). Notably, the halophile calanoid *Sulcanus conflictus* Nicholls, which also was recorded from the Goolwa Channel during the study period, was not recorded from C1-C11.

Ostracoda: Ostracods are benthic in habit, rarely collected in open-water plankton. A few individuals in at least four taxa recorded in net tows from several Coorong sites were likely dislodged from substrata or submerged vegetation during increased flows.

Macroinvertebrates: Twelve taxa of juvenile or small adult macroinvertebrates were noted in net samples. Some are freshwater in habit, flushed into the Murray Mouth with high volume flows (e.g. flatworm, naidid oligochaetes, and two taxa of freshwater shrimps). The rest are likely estuarine, persisting from the salinized phase (e.g. polychaete larvae, limpet, chironomids).

Fish: Juveniles of at least two fish species were recorded from net tows or trap samples at C4 27 Nov 10 & 31 Jan 11. They were less than 1 cm and were not identified.

Ordination of diversity data (net tows) against phys-chem data is shown in Fig. 24 and against algal data in Fig. 25. Ordination of the density (abundance) data (traps) is shown in Fig. 26. Fig 24 shows oxidised nitrogen (NOx) was in high concentrations at the start of the project, pH decreased through the sampling period, filterable reactive silica (FRSi) was in very low concentrations at the start of the project. Fig 25 indicates *Cryptomonas* present on first trip later disappeared, while *Planctonema had* high abundance throughout but increased through time and peaked during Jan-Feb 2011 and then fell to April 2011). *Staurosira* was absent at the start but increased

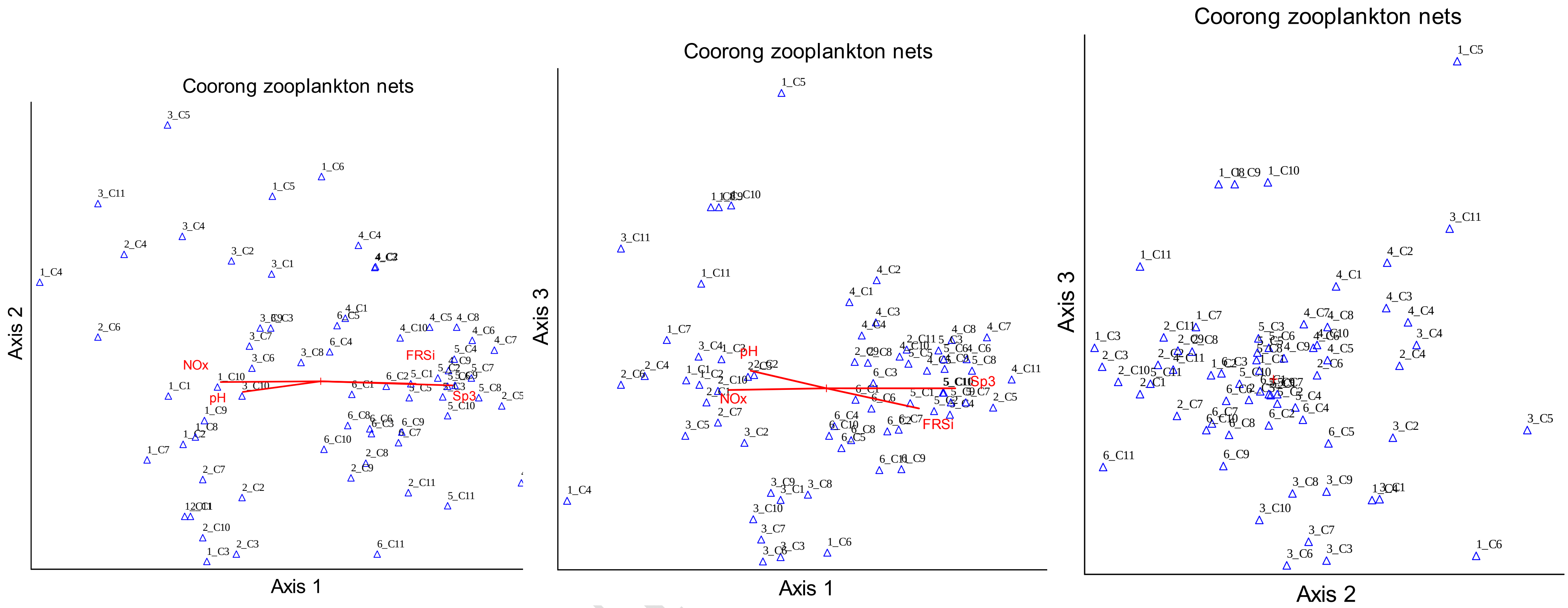


Fig. 24: NMS Ordination (Sorenson) of changes in Coorong zooplankton Nov '10-Apr '11. Blue triangles represent trip # and site ID. Vectors show major drivers of change in the zooplankton community.
Successful 3D ordination (nets/phys-chem) with stress of 17.6, r2 of 0.3 displayed on graph for vectors.
Abbreviations:
NOx = oxidised nitrogen
pH = pH
FRSi = filterable reactive silica
Sp3 = *Stenosemella lacustris*

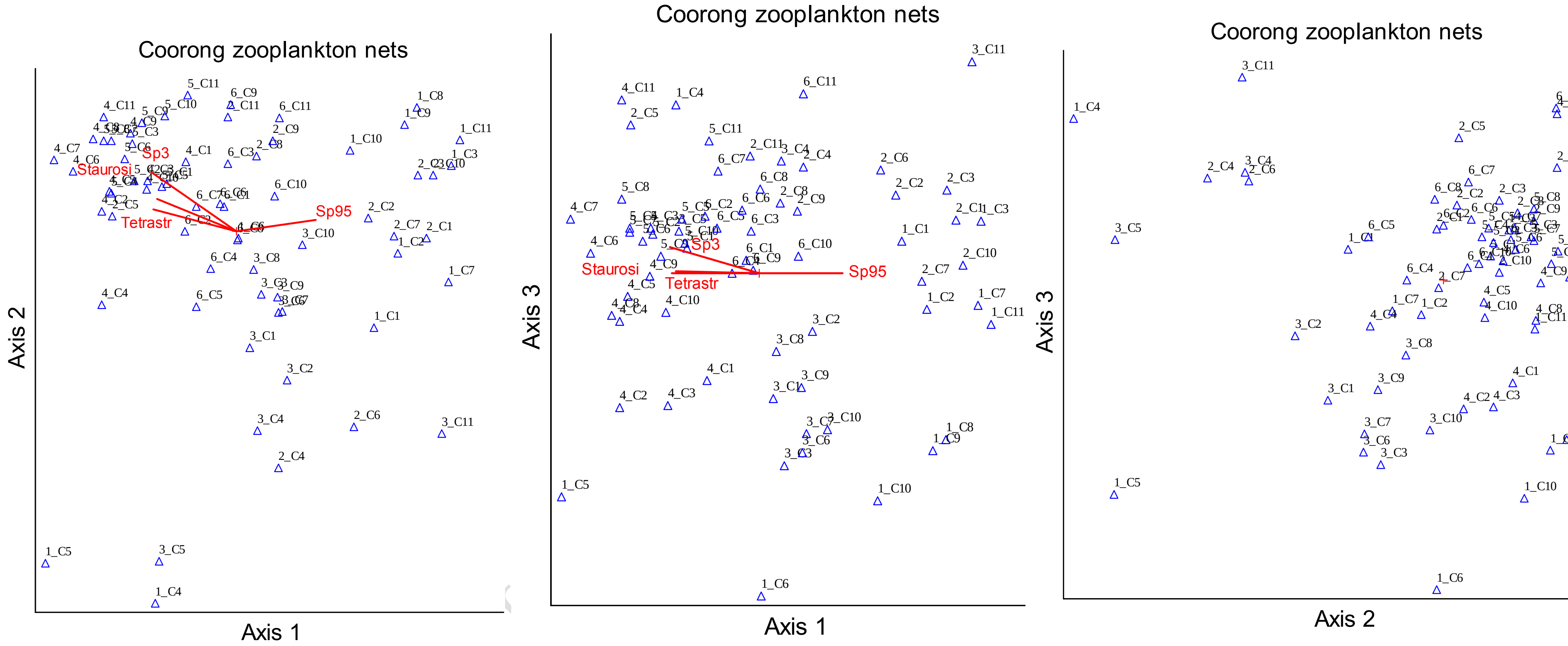
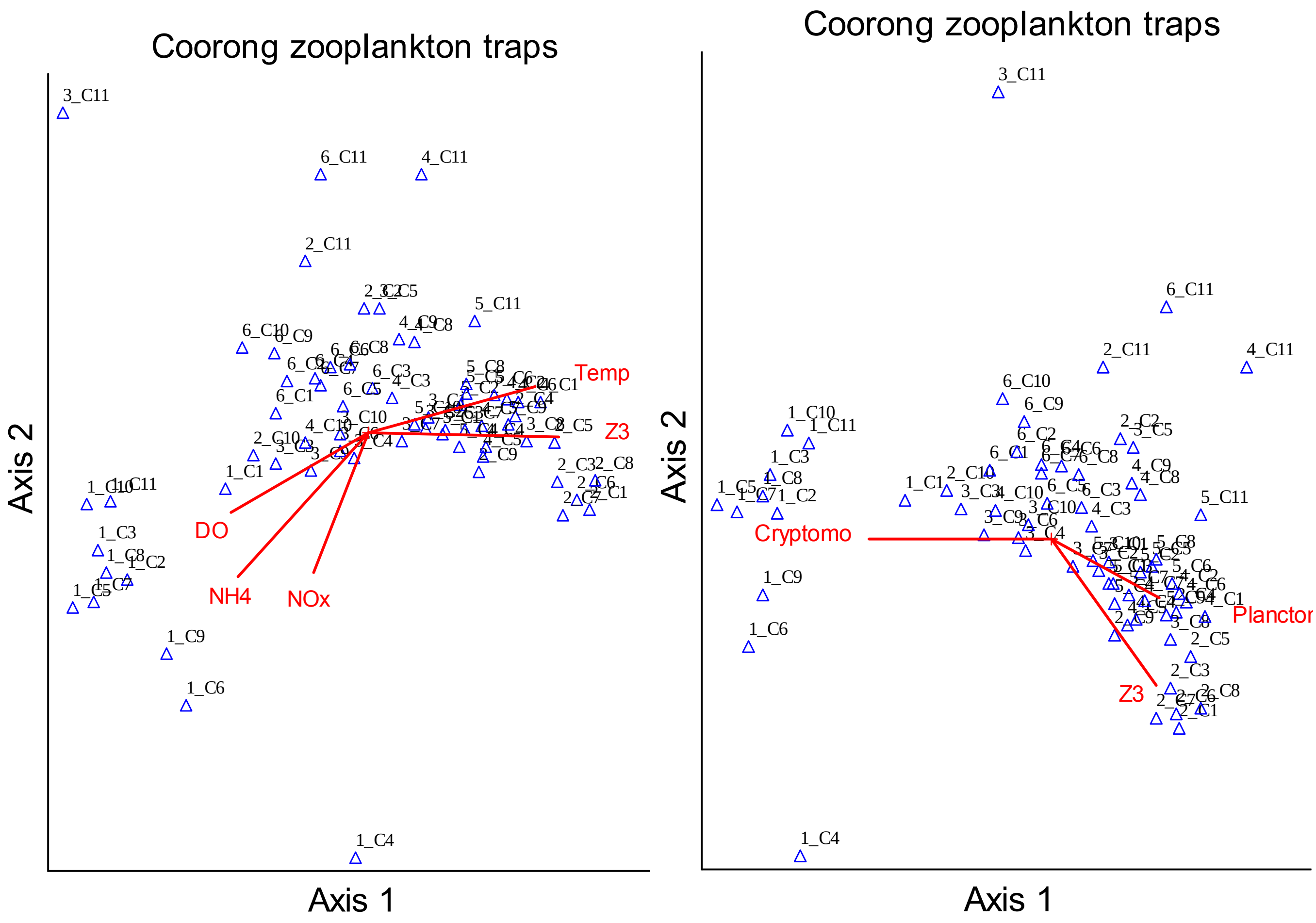


Fig 25: Ordination as for Fig. 10 (zoopl nets/phyto)
Successful 3D ordination with stress of 15.7, r2 of 0.3 displayed on graph for vectors.
Abbreviations:
Staurosi = *Staurosira* (diatom)
Tetrast = *Tetraspora* (green)
Sp3 = *Stenosemella lacustris*
Sp95 = nauplii (labelled after copepodites)



a **b**

Fig 26 a: Zoop traps - phys chem. Successful 2D ordination with stress of 14.9, r2 of 0.3 displayed on graph for vectors.
Abbreviations:
DO = dissolved oxygen
NH4 = ammonium
NOx = oxidised nitrogen
Temp = water temperature
Z3 = *Stenosemella lacustris* (ciliate);
b: Zoop traps – phytoplankton
Successful 2D ordination with stress of 14.8, r2 of 0.3 displayed on graph for vectors.
Abbreviations:
Cryptomo = *Cryptomonas* (cryptophyte)
Plancto = *Planctonema* (green algae)
Z3 = as above

through time to be most abundant diatom. *Tetraspora* was present only on very last trip in relatively high abundance. Most obvious from Fig 26 is the separation of the 01 Nov 2010 samples from subsequent samples. DO, NH_4

and NOx differentiate the zooplankton community of the 1st sampling event from later sampling events. Later sampling events were differentiated/driven by temperature and high densities of the protist *Stenosemella lacustris* (Fig 26A).

Discussion

The initial objective to document the species composition of the Coorong zooplankton and changes therein after barrage releases were met for the extant community at the time of sampling. Sampling began on 01 Nov 2010, however first releases through the barrages occurred in September 2010. The initial zooplankton community and response to flows was not assessed in this study. The freshwater plankton assemblage present at the Coorong North Lagoon and Murray Mouth sites in early November 2010 had already replaced much of the estuarine assemblage known (historically) to occur there. It could well have been a depauperate plankton assemblage after the long drought – certainly all zooplankton had disappeared from the hypersaline South Lagoon prior to the 2010 flood events (M. Geddes, pers. comm.), and it is likely that more saline-sensitive taxa in the North Lagoon also were lost during this period.

The changes in water quality and phytoplankton shown by the ordinations, together with the microcrustacean zooplankton evident at C6-C11 on the 01 Nov sampling suggest that the initial flood pulse moving into and through L. Alexandrina pushed the residual (i.e. surviving after the drought) lacustrine or standing water community through the barrages into the Murray Mouth and North Lagoon sites. The heterogeneity of this assemblage is likely a result of mixing of plankton from littoral areas with distinct communities. Some halophiles had avoided the initial floodwaters, possibly in refugia afforded by tributaries (e.g. Currency Creek, Finniss R., Boundary Creek) or backwaters around the L. Alexandrina littoral zone, and continued to appear in net and trap samples, albeit in small numbers, in the early collections. This mixed halophile/freshwater assemblage is a likely explanation for the heterogeneity evident in the ordinations of both tow and trap samples. Over the study period the zooplankton assemblage became more 'freshwater' (and homogeneous) in character as flood inocula from barrage releases continued.

The source of the freshwater assemblage in the first instance was Lake Alexandrina, but a significant component of the rotifer plankton in particular originated in the Darling River, or a northern tributary. Species such as *Filinia opoliensis*, *Filinia australiensis, Filinia grandis* and some of the brachionids are known only from the Darling River system. Some of the microcrustaceans also are likely Darling River system 'transportees', for example *Thermocyclops*, a warm-stenothermal cyclopoid, and the primarily tropical cladoceran, *Ceriodaphnia cornuta.*. Most of the remaining freshwater taxa are known from the Lower R. Murray, or elsewhere in the Murray-Darling Basin (Shiel *et al*, 1982). Four taxa of testates and five rotifers (in the genera *Brachionus, Cephalodella* and *Synchaeta*) could not be placed in known species, and apparently are undescribed, at present known only from the Coorong/Lower Lakes.Three cladocerans and two copepods also require more intestive investigation, are likely undescribed.

In terms of impact of the changed conditions on the resident (estuarine) plankton assemblage, obligatory halophiles or halobionts may have been flushed from the system, moved east into the higher conductivities east of Mark Point, or succumbed in the fresh water if not mobile. Their resting eggs, ephippia or other propagules likely remain in the Coorong sediments awaiting a system re-set, cued by appropriate salinities, so the species bank is not lost. Such a system re-set will not occur during prolonged flood conditions, but it is likely that the longevity of the propagule bank is greater than the flood frequency of the Lower Murray/Lower Lakes/Coroong Lagoons.

There was already evidence of trophic responses early in the study period, with juvenile fish caught in plankton samples. Significant increases in secondary productivity are a likely consequence of barrage releases carrying a diverse plankton assemblage into the Murray/Mouth Coorong, the effects of which extended far out into the Southern Ocean during the study period.

Conclusions

Large inflows from the Lower Lakes between Nov. 2010 and Apr. 2011 effectively flushed the estuarine plankton assemblage out of the Murray Mouth and west end of the North Lagoon. Mark Point was the furthest east samples were collected, so it is not evident how far east the freshwater plankton assemblages intruded into the North Lagoon. The freshwater zooplankton assemblage is likely to persist, and the estuarine assemblage not re-establish, while high flows through the system continue. Rapid changes in zooplankton assemblages are likely, dependent on sources of the outflows. Influx of zooplankton into the Murray Mouth and Coorong is likely to stimulate secondary consumers such as planktivores, such as juvenile/small-bodied fish, mactoinverebrates, therefore creating positive food chain effects.

Recommendations

- The 2011 floods will continue beyond the time frame of current sampling. Some measure of system re-set later in the year would be useful, if outflows are declining. A set of samples in Spring, say Sept. or Oct. 2011 may be instructive. Or in 2012 if high flows are protracted.
- The onset of current floods was missed by this sampling program. Some means of rapid response to future unpredicted events would fill help fill gaps in analyses/interpretation.
- Research into food web interactions at all trophic levels is lacking for the Lower Lakes and Coorong. Life cycles and population events of zooplankton may be highly significant to higher order consumers (macroinvertebrates, fish and birds) whose own life cycles and population events may be cued to them.

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APPENDIX 1: Zooplankton species recorded from Lakes Alexandrina & Albert, Goolwa Channel, Murray Mouth and North Lagoon of the Coorong.

Species	L. Alex.	L. Albert	Goolwa Channel	MM/NL
Protista				
Ciliophora				
Didinium sp.			+	+
Epistylis sp.	+			
Euplotes sp.	+	+	+	+
Halteria sp.	+		+	
cf. *Opercularia* sp.			+	
Paradileptus sp.			+	
Stenosemella lacustris	+	+	+	+
Stentor sp.	+	+	+	+
tintinnids	+	+		
indet. spher. ciliate	+	+	+	+
Rhizopoda				
Arcellidae				
Arcella bathystoma	+		+	
Arcella discoides	+	+	+	+
Arcella cf. *gibbosa*	+			
Arcella hemisphaerica	+		+	+
Arcella megastoma	+			
Arcella sp. **a**	+	+	+	
Arcella sp. **b**	+		+	+
Arcella sp. **c**	+			
Centropyxidae				
Centropyxis aculeata	+			+
Centropyxis ecornis				+
Centropyxis sp. **a**	+	+		
Centropyxis sp. **b**	+		+	
Centropyxis sp. **c**	+			
Centropyxis sp. **d**	+			
Cyphoderiidae				
Cyphoderia ampulla	+	+	+	+
Difflugiidae				
Difflugia ampullula				+
Difflugia gramen	+	+	+	+
Difflugia lanceolata			+	
Difflugia limnetica	+		+	
Difflugia sp. **a**	+			+
Difflugia sp. **b**	+			+

Difflugia sp. **c**	+		+	
Difflugia sp. **d**	+			

Appendix 1 (cont.)

Difflugia sp. **e**	+			
Difflugia sp. **f**	+			
Difflugia sp. **g**	+		+	
Zivkovicia sp.	+			
Euglyphiidae				
Euglypha sp.	+		+	
Lesquereusiidae				
Lesquereusia spiralis	+			
Netzelia tuberculata		+	+	
Trigonopyxidae				
Cyclopyxis sp.	+			
Trinematidae				
Trinema sp.	+			
Foraminifera				
Indet.				+
Indet. protists	+	+		
Rotifera				
Bdelloidea				
Philodinidae				
Philodina alata	+			
Philodina sp.	+			
Rotaria neptunia	+			
indet. bdelloid **a**	+		+	
indet. bdelloid **b**	+	+	+	+
Monogononta				
Asplanchnidae				
Asplanchna brightwellii	+	+	+	+
Asplanchna priodonta	+	+	+	
Asplanchna sieboldii	+	+		
Brachionidae				
Anuraeopsis coelata	+		+	
Anuraeopsis fissa	+		+	
Brachionus angularis	+	+	+	+
Brachionus cf. *baylyi* **n. sp. b**		+		
Brachionus bennini	+	+	+	
Brachionus bidentatus	+			+
Brachionus budapestinensis	+		+	
Brachionus calyciflorus calyciflorus	+			+
Brachionus calyciflorus amphiceros	+	+	+	+
Brachionus cf. *calyciflorus* **n. sp. a**	+		+	
Brachionus caudatus austrogenitus	+	+		

Brachionus dichotomus reductus	+			
Brachionus diversicornis	+		+	+

Appendix 1 (cont.)

Brachionus falcatus	+			
Brachionus lyratus	+		+	
Brachionus nilsoni	+		+	+
Brachionus plicatilis s.l.	+	+		
Brachionus q. quadridentatus	+			+
Brachionus q. cluniorbicularis			+	+
Brachionus rubens	+	+		+
Brachionus urceolaris	+		+	+
Brachionus sp.	+	+		+
Keratella australis	+	+	+	+
Keratella cochlearis	+			
Keratella procurva	+	+	+	+
Keratella quadrata	+	+	+	+
Keratella slacki	+			
Keratella tropica	+	+	+	+
Keratella sp.			+	
Plationus patulus	+			+
Collothecidae				
Collotheca pelagica	+	+	+	
Conochilidae				
Conochilus dossuarius	+			
Conochilus sp.	+		+	+
Dicranophoridae				
Dicranophorus cf. *epicharis*	+			
Encentrum cf. *saundersiae*	+			
Encentrum sp.	+		+	+
Epiphanidae				
Microcodides sp.	+			
Proalides tentaculatus	+	+	+	+
Euchlanidae				
Euchlanis sp.			+	
Flosculariidae				
Indet. flosculariid			+	
Gastropodidae				
Ascomorpha cf. *ovalis*	+			
Gastropus sp.			+	
Hexarthridae				
Hexarthra brandorffi	+	+		
Hexarthra intermedia	+		+	
Hexarthra mira	+			+
Lecanidae				
Lecane bulla	+		+	

Lecane closterocerca	+		+	
Lecane curvicornis	+			

Appendix 1 (cont.)

Lecane hamata	+	+	+	
Lecane ludwigii	+		+	
Lecane stenroosii	+			
Lecane cf. thalera			+	
Lecane sp.				+
Lepadellidae				
Colurella cf. *adriatica*	+	+		+
Colurella uncinata bicuspidata		+		
Colurella sp.			+	
Lepadella sp.			+	+
Mytilinidae				
Lophocharis sp	+		+	
Notommatidae				
Cephalodella forficula			+	
Cephalodella gibba	+		+	+
Cephalodella megalocephala				+
Cephalodella cf. *ventripes*	+			
Cephalodella sp. **a**	+		+	
Cephalodella sp. **b**	+			
Cephalodella sp. **c** [n. sp. nr *C.eva*]				+
Eosphora anthadis	+		+	
Notommata cerberus	+			
Notommata sp.	+			+
Proalidae				
Proales daphnicola				+
?Proales sp.	+	+	+	
Synchaetidae				
Polyarthra dolichoptera	+	+	+	+
Synchaeta pectinata	+	+		
Synchaeta **n. sp.**	+	+	+	+
Synchaeta sp. **a**	+	+	+	+
Testudinellidae				
Pompholyx complanata			+	
Trichocercidae				
Trichocerca obtusidens				+
Trichocerca pusilla	+	+	+	+
Trichocerca rattus carinata			+	
Trichocerca similis	+		+	
Trichocerca similis grandis	+	+	+	
Trichocerca sp. **a**	+			
Trichocerca sp. **b**	+			

Trichocerca sp. **c**	+			
Trichocerca sp. **d**	+	+	+	

Appendix 1 (cont.)

Trochosphaeridae				
Filinia australiensis	+		+	+
Filinia brachiata	+			
Filinia grandis	+		+	+
Filinia longiseta	+	+	+	+
Filinia opoliensis	+		+	+
Filinia passa	+		+	
Filinia pejleri	+	+	+	+
Filinia sp.			+	+
indet. rotifer	+		+	+
Cladocera				
Bosminidae				
Bosmina meridionalis	+		+	+
Chydoridae				
Alona sp. a cf. *rectangula*		+	+	+
Alona rigidicaudis	+			+
Alona sp. b. **n. sp.**			+	+
Anthalona sp.				+
Chydorus sp.	+			
Pleuroxus inermis	+			+
Daphnidae				
Ceriodaphnia cornuta	+		+	+
Ceriodaphnia **?n. sp.**	+		+	+
Daphnia carinata	+		+	+
Daphnia lumholtzi	+		+	+
Ilyocryptidae				
Ilyocryptus sp.	+		+	
Moinidae				
Moina micrura	+		+	+
Copepoda				
Cyclopoida				
Australocyclops sp.				+
Halicyclops ambiguus			+	+
Mesocyclops cf. *notius*	+			
Mesocyclops sp.			+	
Microcyclops varicans	+		+	+
Copepodites	+	+	+	+
Nauplii	+		+	+
Calanoida				

Boeckella triarticulata	+	+	+	+
Calamoecia ampulla	+		+	+

Appendix 1 (cont.)

Gladioferens pectinatus	+		+	+
Gladioferens spinosus			+	+
Sulcanus conflictus			+	
Copepodites	+	+	+	+
nauplii	+	+	+	+
Harpacticoida				
Onychocamptus bengalensis			+	+
Mesochra parva			+	+
?*Mesochra* sp.	+			+
Copepodites			+	+
Nauplii			+	+
Ostracoda				
Australocypris sp.	+			
cf. *Cypretta*				+
Limnocythere sp.	+		+	
cf. *Sarscypridopsis* sp.	+			
indet. juvenile	+	+	+	+
Macroinvertebrates				
Nematoda				+
cf. Polyzoa			+	
Turbellaria cf. *Mesostoma*			+	+
Mollusca: Gastropoda				+
Mollusca: Bivalvia				+
Mollusca: limpet				+
Oligochaeta: Naididae	+		+	+
Polychaeta: larvae				+
Tardigrada	+			
Diptera: Chironomidae: larva	+	+	+	+
Crustacea: Amphipoda: *Australochiltonia*	+	+	+	+
Crustacea: Decapoda: *Macrobrachium*	+			+
Crustacea: Decapoda: crab larvae			+	
Arachnida: ?oribatid mite	+			
Vertebrates				
Pisces: juv.	+		+	+

Appendix 2: Site coordinates. Geodatic data used was WGS 84.

Site reference	Site description	Longitude (°E)	Latitude (°S)
C1	Goolwa Barrage Downstream	138.81737	35.52718
C2	Half Way	138.85110	35.54021
C3	Sugar's Beach	138.87921	35.55139
C4	Southern Ocean	138.87552	35.55749
C5	Murray Mouth	138.88164	35.55720
C6	Hunter's Creek	138.89107	35.53571
C7	Mundoo Channel	138.89784	35.53969
C8	Boundary Creek	138.93509	35.55551
C9	Ewe Island	138.96111	35.56748
C10	Tauwitchere	139.00363	35.58852
C11	Mark Point	139.07573	35.63423