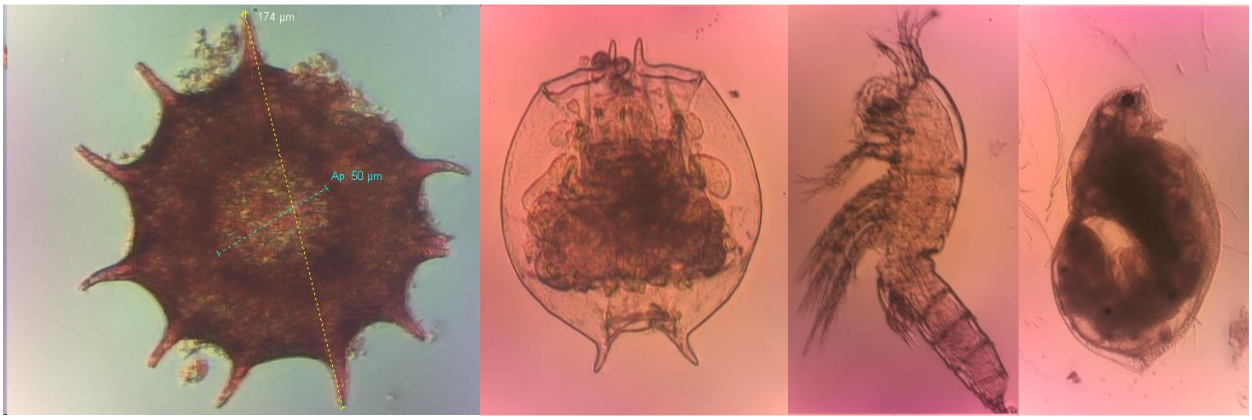
Zooplankton response monitoring: Lower Lakes, Coorong and Murray Mouth

October 2011 – April 2012

Russell J. Shiel & Lor-wai Tan



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

June 2013

THE UNIVERSITY of ADELAIDE

WRM Wetland Research & Management

Government of South Australia
Department of Environment, Water and Natural Resources

Acknowledgements

Samples reported here were collected, rain or shine, by Sorell Lock and support staff from DEWNR, S.A.

Multivariate analysis was performed by Jess Delaney of Wetland Research and Management, Burswood W.A.

Frontispiece: Protista: Rhizopoda: *Arcella dentata*; Rotifera: Brachionidae: *Brachionus* n. sp.; Copepoda: Harpacticoida; Cladocera: Daphniidae: *Daphnia* n. sp. from Lower Lakes/Coorong 2011-2012 samples.

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Executive summary

Following the wettest year on record in the Murray-Darling Basin in 2010, exceptional floods into Sth Australia from the Murray and Darling Rivers inundated the Lower Lakes and Coorong Lagoons through 2011. These were the first significant inflows after a decade of drought, during which the Lower Lakes and Coorong were salinizing. DENR-sponsored studies of the zooplankton communities of the Lower Lakes (Lock, 2011) and the Coorong Nth Lagoon (Shiel & Aldridge 2011) during the floods established that a rotifer-dominated (riverine) assemblage replaced the microcrustacean-dominated (estuarine) assemblage in the Murray Mouth and North Lagoon sites, with 70% of the zooplankton taxa recorded above the barrages in Lake Alexandrina or the Goolwa Channel. Freshwater assemblages also were documented in L. Albert after it refilled through Narrung Narrows, with some halotolerant survivors at its southern end, and in the Goolwa Channel from either the Finniss River or Currency Creek.

To monitor the effects of abating flows on the zooplankton assemblage, investigate the persistence of R. Murray microfauna in the Lower Lakes, and any potential recovery of estuarine microbiota below the barrages, a second round of sampling was undertaken by DEWNR staff at 14 sites in the CLLMM region: 27/28 Oct '11, 24/25 Nov '11, 28/29 Dec '11, 06/07 Feb '12, 27/28 Feb '12, 02/03 Apr '12 and 30 Apr/01 May '12.

Significant aseasonal rainfall in the northern catchments again produced high flows into the Lower Lakes during the 2011-2012 sampling period. A riverine rotifer-dominated zooplankton assemblage reconstituted that persisting in the Lower Lakes for the previous 12 mo., including most of the same species from the same source catchments. Evidence of local emergence from propagule banks in flooded riparian margins was provided by higher species richness at all sites in 2011-2012, however the total zooplankton/microfaunal biota identified was remarkably similar in the two years: 207 taxa in 2011-12, vs. 191 in 2010-2011 comprising Protista (51 [44] taxa) Rotifera (101 [102]) Cladocera (14 [15]), Copepods (16 [13]), Ostracoda (4 [5]), small macroinvertebrates (19 [13]) and fish fry. Total zooplankton recorded from each locality: 152 [144] taxa from L. Alexandrina, 70 [50] from L. Albert, 134 [109] from the Goolwa Channel and 117 [97] from Murray Mouth/North Lagoon sites. Approximately 85% of the zooplankton community in the 2011-12 series was freshwater in habit, vs. 70% the previous year, again reflecting prolonged inoculation of riverine biota into the Lower Lakes, and extended inundation of the CLLMM margins triggering propagule emergence.

Introduction

Following exceptional rainfall in the northern Murray-Darling Basin in late 2010, floodwaters into the Lower Murray and Lakes Alexandrina and Albert refilled the Lower Lakes, which had been drying/salinizing over a protracted drought. The floodwaters inundated margins which had been dry for ca. 10 yrs, potentially cueing propagules in riparian sediments. Significant barrage releases from Lake Alexandrina to the Murray Mouth and North Lagoon of the Coorong provided an opportunity to monitor the transfer of nutrients and biota, and to determine the impacts on the estuarine ecosystem. Responses of zooplankton assemblages to continued connectivity December 2010-April 2011 between the major waters of the Coorong, Lower Lakes and Murray mouth were reported by Lock (2011) and Shiel & Aldridge (2011).

In the context of the zooplankton, both reports described a largely freshwater assemblage, with only approximately 10% of the recorded zooplankton identifiably halotolerant or halophile, these primarily in the higher conductivities of L. Albert or the southern sites of the Coorong North Lagoon. A few halotolerant taxa were recorded in small numbers from around the L. Alexandrina margins, and in the Goolwa Channel. In effect, the unusually large (and unexpected) flooding had translocated zooplankton assemblages from the upper and middle reaches of both the Darling and Murray Rivers, a suite of freshwater species which was identifiable beyond the barrages into the Nth Lagoon of the Coorong, and even out into the Southern Ocean.

With high flows continuing from the northern Murray-Darling Basin beyond the conclusion of sampling in April/May 2011, the opportunity arose to study the effect of long-term inundation on the resident zooplankton assemblage, identify any recovery of estuarine communities with abating freshwater flows, and where possible, facilitate recognition of the contribution of resident egg-banks in the form of non-transported emergees among the zooplankton and littoral microfauna. Notably, further unseasonally high rainfall events occurred across the Darling and upper Murray catchments during Oct 2011-Apr 2012, such that flows to the lower R. Murray in SA were comparable to the high flows of the preceding summer.

Sampling was to be undertaken at 14 2010-2011 sites and one extra Coorong site (C-12) by DEWNR staff, the samples provided to Drs Shiel & Tan at the University of Adelaide, with the hypotheses and key questions in Table 1 below to be addressed for the zooplankton assemblages:

Table 1: Objectives, hypotheses and key questions for zooplankton monitoring

#	Monitoring Objective	Hypotheses	Key Questions	Rationale
1	To assess the Zooplankton to: A minimum of 1,000GL being released over the barrages in 2011-2012; The continued water availability following the recent drought	1. Zooplankton communities in the Murray Mouth and Coorong will be dominated by halophiles and communities will change along the salinity gradient; 2. Zooplankton communities in the Goolwa Channel and Lake Albert will be dominated by estuarine/halo-tolerant species whilst Lake Alexandrina will have a more lacustrine and freshwater community.	1. Will species be able to maintain any range increases observed in 2011-2012 2. Will further barrage flows in 2011-2012 maintain the presence of freshwater zooplankton in the Murray Mouth region, or will communities be dominated by more halophytic species? 3. Will continued flows be dominated by River Murray or Darling River communities and do they persist in the Lakes?	2009-2010 TLM Icon Site Condition Monitoring; CSIRO Coorong salinity modelling; 2010-2011 Barrage Flow monitoring

Sites

In order to quantify zooplankton abundance and diversity against that assessed in 2010/2011, the sites listed in Appendix 2 and shown in Fig. 1 were sampled on seven occasions by DEWNR staff from October 2011 to April/May 2012. Samples were provided to RJS/LWT as soon as possible following sample collection. Samples were collected using the same qualitative net tows and quantitative trap samples as used in 2010-2011 sampling methodology, summarized below.

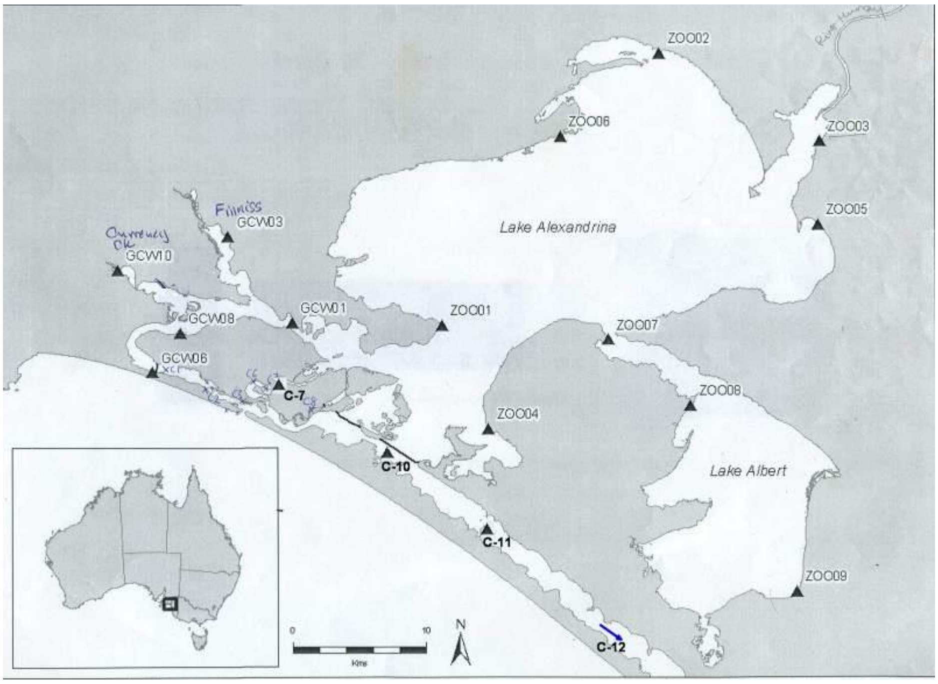


Fig. 1: DEWNR plankton-sampling sites, 2011-12, Lower Lakes, Goolwa Channel and Coorong Nth Lagoon.

Methods

Field

All sites were sampled from the shore, in open water, from wader depth, on 27/28 Oct, 24/25 Nov, 28/29 Dec (2011), 06/07 Feb, 27/28 Feb, 02/03 Apr and 30 Apr/01 May (2012).

Qualitative Sampling

Standard plankton nets of 230 mm aperture, 35 μm-mesh (Fig. 2a) were used to collect qualitative plankton samples by oblique hauls (3x5 m tows) from ca.1 m depth to the surface at each site.

Fig. 2a: Plankton net

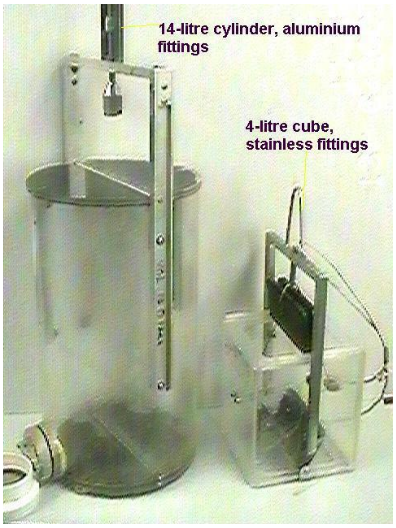


Fig. 2b: Perspex Haney plankton traps

Quantitative Sampling

To provide a measure of plankton density at each site both spatially and temporally, volumetric samples were collected with the 4-litre Haney trap on the right in Fig. 2b. Three 4-l trap samples were pooled by emptying the trap into a plankton net, concentrating 12-litres of filtrate.

All collections were fixed in the field with Lugol's iodine in 200 ml PET bottles and returned to the laboratory for sorting and enumeration. After sorting, samples were spiked with 20-50 ml of 90% ethanol in the laboratory to ensure preservation.

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. 3) for sorting and enumeration.

Fig. 3: Gridded Greiner tray used for sifting net tows.

Tray contents were sifted by row on a Zeiss SV-11 or Olympus SZH-10 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 in Figure 3), until 200-300 individuals had been encountered (Elliot 1977). 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 3) or a tungsten wire loop, transferred to a well-block containing 10% glycerol-H_2O for later HP examination.

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 an Olympus BH-2 compound microscope using Nomarski (DIC) optics.

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 dissecting and compound microscopes were fitted with high-resolution Logitech webcam digital cameras, used to catalog taxa encountered or provide a record of decision-points in taxonomic treatment, for example trophi (teeth) of rotifers, or significant appendages of microcrustaceans.

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). Triplicate subsamples taken during the 2010-2011 CLLMM sampling established that a single aliquot provided a density estimate ±2% of subsequent replicate aliquots from a volume sample. For the 2011-12 samples, the method below was used.

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 4a) 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. 4b), the coverslip placed, and the contents of the sub-sample enumerated on a compound microscope (BH-2) as noted earlier.

Fig. 4a: Gilson autopipette used to extract 1 ml from agitated trap sample

Fig. 4b: 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) was calculated.

Statistical Methods [by Jess Delaney, WRM]

Multivariate analyses

Multivariate analyses were performed using the PRIMER package v 6 (**P**lymouth **R**outines **i**n **M**ultivariate **E**cological **R**esearch; Clarke and Gorley 2006) to investigate differences in zooplankton assemblages amongst sites and sampling events. The PRIMER package, developed for multivariate analysis of marine fauna samples, has been applied extensively to analysis of freshwater invertebrate data.

Analyses applied to the data included:

Describing pattern amongst the zooplankton assemblage data using ordination and clustering techniques based on Bray-Curtis similarity matrices (Bray and Curtis 1957). The clustering technique uses a hierarchical agglomerative method where samples of similar assemblages are grouped and the groups themselves form clusters at lower levels of similarity. A group average linkage was used to derive the resultant dendrogram.

To examine whether there were any spatial or temporal differences in zooplankton assemblages, canonical analysis of principal coordinates (CAP) was undertaken within the PERMANOVA add-in in PRIMER. This test finds axes through the multivariate cloud of points that either (i) are the best at discriminating among *a priori* groups (discriminant analysis) or (ii) have the strongest correlation with some other set of variables (canonical analysis) (Anderson and Robinson 2003, Anderson *et al.* 2008). The CAP analysis produced an ordination and vectors corresponding to Spearman Rank Correlations >0.5 (i.e. individual species) were superimposed on this ordination.

Permutational multivariate analysis of variance (PERMANOVA) was undertaken (two-factor crossed design) to determine whether there was any significant difference in zooplankton assemblages between sites and sampling events (Anderson 2001a, b, McArdle and Anderson 2001, Anderson and ter Braak 2003, Anderson *et al.* 2008).

For sites which were sampled during the same sampling events for zooplankton and water quality (2011 and 2012 data), the relationship between environmental and biotic data was assessed in two ways:

Spearman Rank correlations were undertaken between zooplankton assemblages and water quality variables. Results with Spearman Rank correlations of >0.5 were overlain on the zooplankton ordination

The BIOENV routine was used to calculate the minimum suite of parameters that explain the greatest percent of variation (i.e. the parameters which most strongly influence the species ordination).

Results

Relative proportions of plankters varied widely between sites and dates. Appendix 1 provides a checklist of all taxa identified from the 2010-11 and 2011-12 samples. The 2011-12 series is summarized below, with comparisons from the 2010-11 series parenthesized where appropriate.

In total, 207 [191] taxa (Appendix 1) were recognized from net tows and trap volumes during October 2011-April 2012: 152 [144] from L. Alexandrina, 70 [50] from L. Albert, 134 [109] from the Goolwa Channel and 117 [97] from Murray Mouth/North Lagoon sites, comprising Protista (51 [44] taxa) Rotifera (101 [102]) Cladocera (14 [15]), Copepods (16 [13]), Ostracoda (4 [5]), small macroinvertebrates (19 [13]) and fish fry. Approximately 85% [70%] of zooplankton taxa recorded from the Murray Mouth/North Lagoon sites also occurred above the barrages in the Goolwa Channel or Lake Alexandrina. The same suite of halophile rotifers and microcrustraceans recorded in 2010-2011, ca. 18-20 taxa, or less than 10% of the recorded zooplankton assemblage, was again encountered, primarily in Coorong sites, with halotolerant rotifers and kinorynchs in L. Albert.

Zooplankton diversity, i.e. species richness, at all sites was higher, occasionally significantly so, than in the 2010-2011 series (Fig. 5). Similar trends of diversity are apparent. The 'upstream' R. Murray site (ZOO-03) and Narrung Narrows (ZOO-07), had the most speciose assemblages in both years.

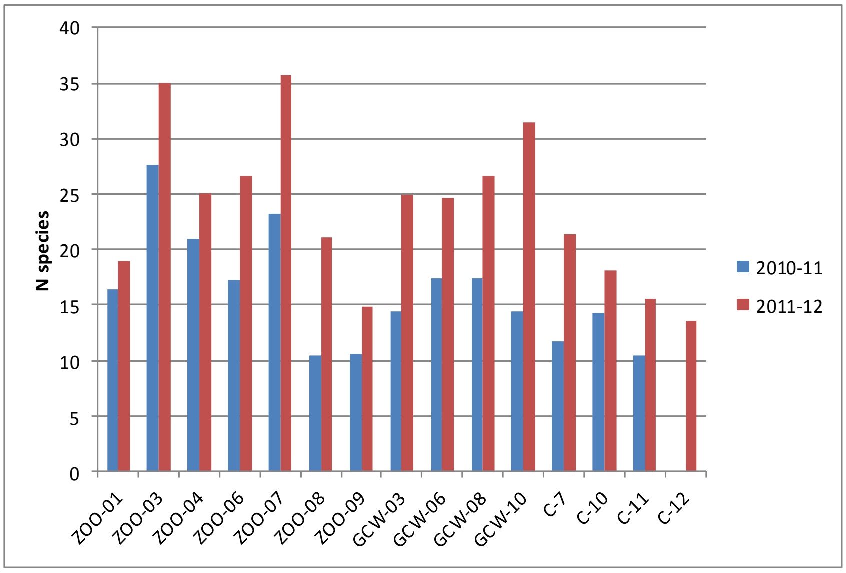


Fig. 5: Zooplankton species richness at all sites, 2010-11 and 2011-12. Note that C-12 was not sampled in the first series.

Mean zooplankton densities (individuals l^{-1}) for all sites are shown in Fig. 6.

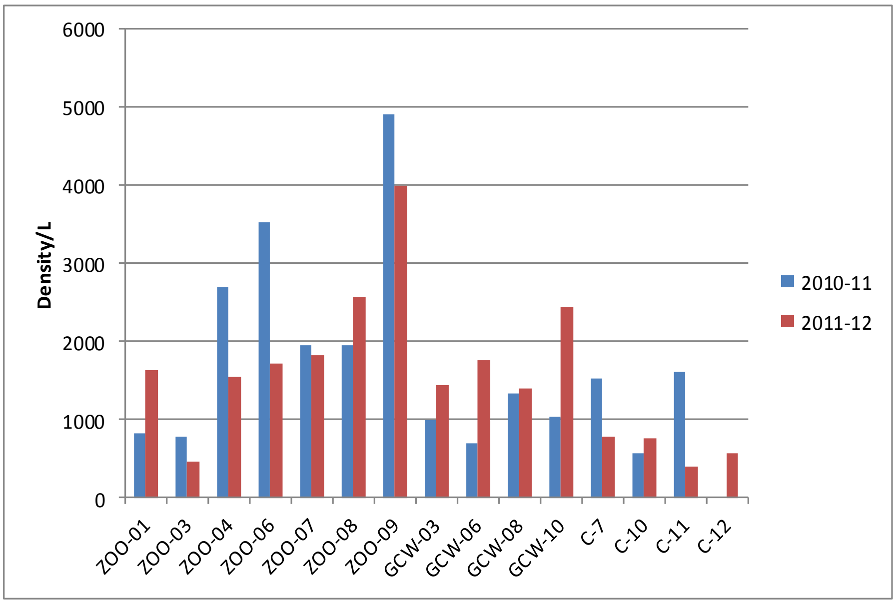
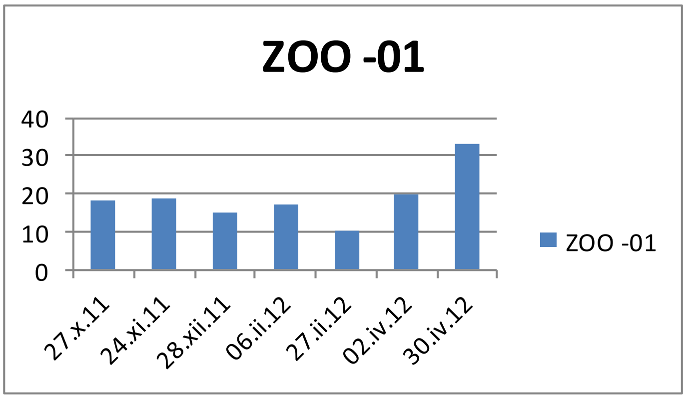


Fig. 6: Zooplankton densities at all sites, 2010-11 and 2011-12. Note that C-12 was not sampled in the first series.

In terms of zooplankton densities, L. Albert at the Meningie jetty (ZOO-09) had the most abundant zooplankton in both years – 4-5,000 ind/l. Early in the 2010-12 sampling the halotolerant *Hexarthra brandorffi* dominated, but with continuing inflow via Narrung Narrows, *Hexarthra* was replaced by a freshwater assemblage with the tintinnid ciliate *Stenosemella lacustris* and rotifer *Filinia pejleri* most abundant.

These two species also contributed to the significant 'spikes' at Loveday Bay (ZOO-04) and L. Alex/Tolderol (ZOO-06) in the 2010-11 samples. Other notable site-specific assemblage differences in Fig. 6 are seen at Currency Creek (GCW-10) with a pulse of *Filinia pejleri* and a suite of small rotifers occurred in the 2011-12 series, and C-11, where the notable 'spike' in the 2010-11 series resulted from a barrage release of small freshwater rotifers, dominated by *Proalides tentaculatus*.

Species richness and density plots for the 2011-12 sampling are provided below for all sites.



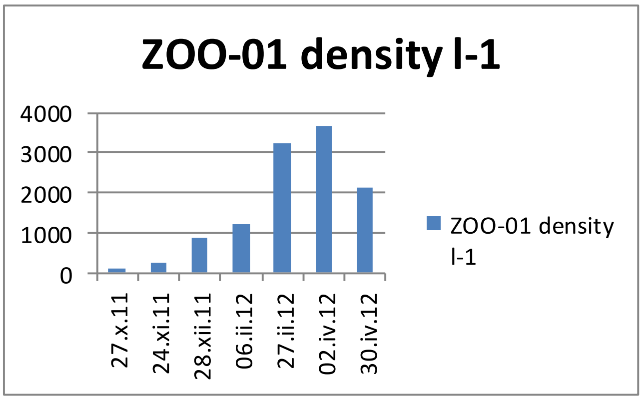
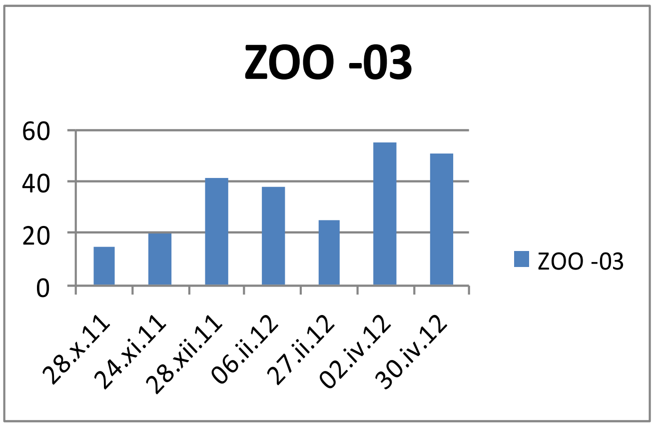


Fig. 7: ZOO-01, Lake Alexandrina at Point Sturt had <20 spp. until the last sampling event, when 33 taxa were recorded. The assemblage was dominated by microcrustaceans (*Ceriodaphnia, Daphnia* and *Boeckella* through the Spring samples (Oct-Dec), with only *Difflugia globulosa* reaching appreciable numbers. This testate was present throughout the sampling at this site, reaching nearly 1,500 individuals/litre at the Feb 27th sampling. Another protist, the endemic testate ciliate *Stenosemella lacustris*, had a gradual increase through the study, peaking at nearly 1,700/litre (Apr 2nd). A suite of protists and small riverine rotifers made up the balance of the zooplankton, generally in small numbers. Densities over the sampling ranged from 115-3,648/litre (mean: 1,634). .



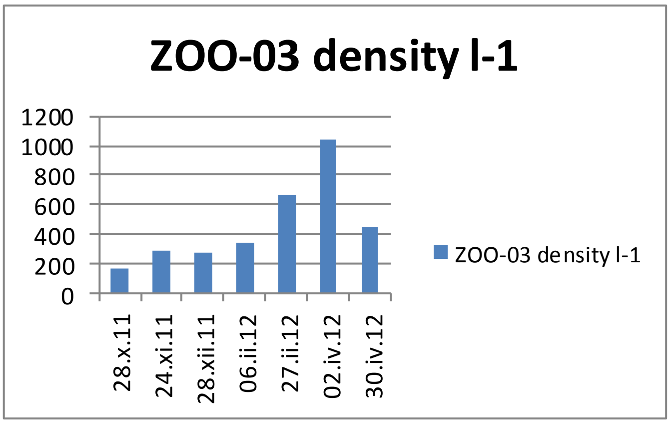
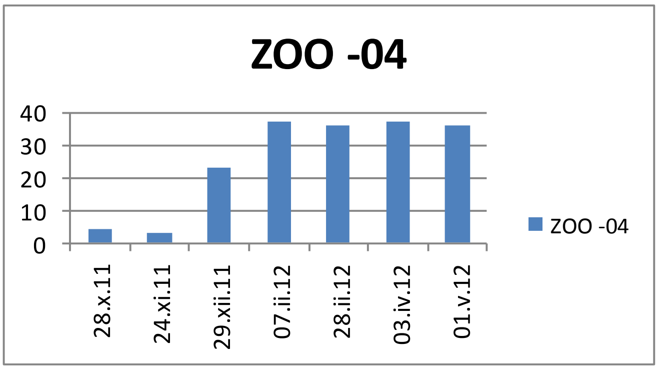


Fig. 8: ZOO-03 River Murray Jockwar Rd had a mix of copepods, primarily nauplii, with pulses of rotifers periodically, particularly synchaetids (*Polyarthra, Synchaeta*) and brachionids (*Keratella tropica*). *Stenosemella lacustris was* again the most abundant protist. Species richness was high (15-55 spp., mean 35). Density

generally was low, peaking at 1,036 individuals/litre on Apr 2nd (range 174-1,036, mean 461) declining thereafter.



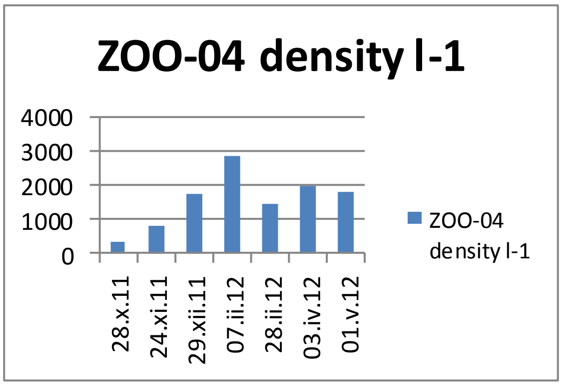
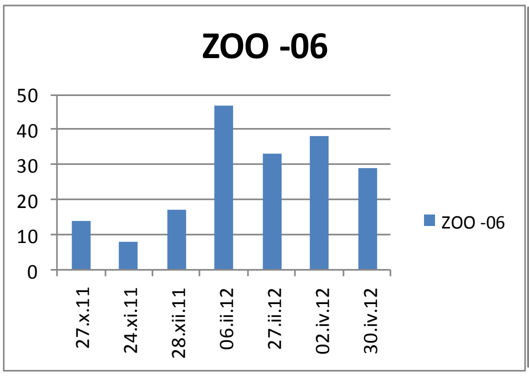


Fig. 9: ZOO-04, Lake Alexandrina –Loveday Bay – negligible plankton on the first trip, with the second trip net sample lost, not preserved in the field, decomposed by the time it was reached for processing. The trap sample (preserved) for Nov 24th indicates increasing density and diversity from the Oct 28th sample, which trend continued through Dec/Jan to an asymptote of 36-37 species for the duration of the study (mean 25 spp.). The assemblage was dominated by a diverse suite of rotifers, with dominants *Synchaeta* and *Filinia* species. As for the sites above, and in the 2010 samples, the two dominant protists were *Stenosemella lacustris and Difflugia globulosa* (*Difflugia* sp. C in the 2010-11 series). Densities ranged from 321-2,860, mean 1,558/l.



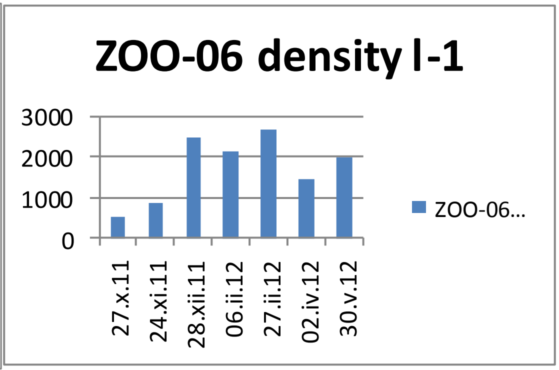
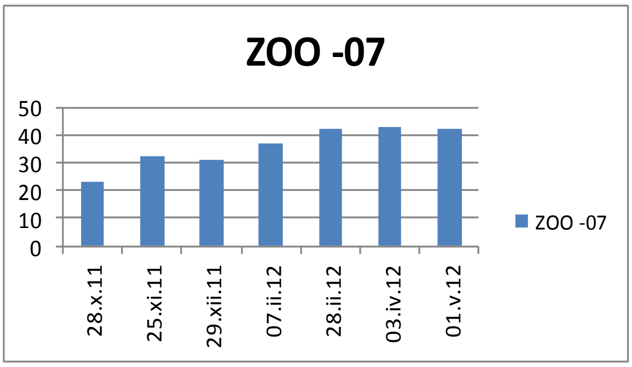


Fig. 10: ZOO-06, Lake Alexandrina - Tolderol had comparable low diversity to the above sites for the first three field trips, with a notable increase to 47 spp. on Feb 6th,

with 30+ spp per trip thereafter (mean 27 spp.). Microcrustaceans (cladocerans/copepods) dominated the first two trips, with a diverse suite of rotifers and protists, primarily *Stenosemella* and *Diflfugia globulosa,* as above, increasing steadily in the Dec-Apr samples. Densities ranged from 506-2,684, mean 1,719/l



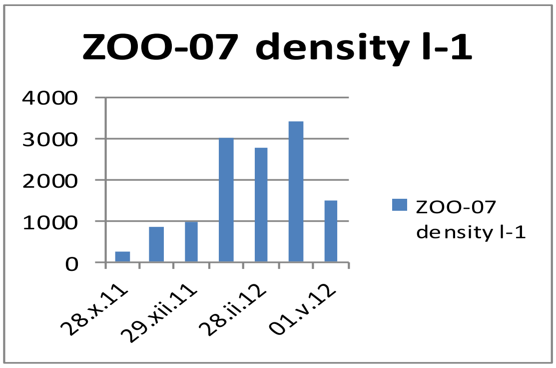
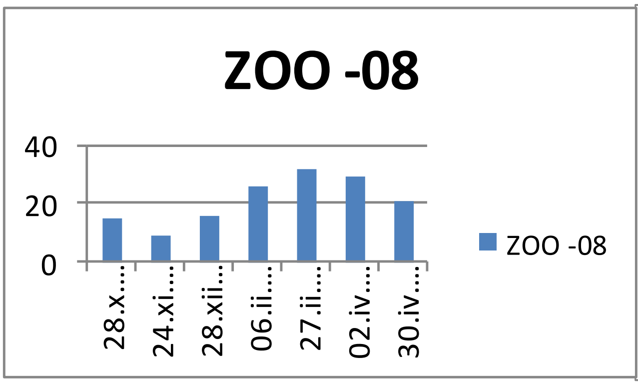


Fig. 11: ZOO-07, Narrung Narrows sampled from the jetty - diversity increased steadily from a low of 23 spp. on Oct 28 to 42-43 spp. Feb through Apr. Microcrustaceans were abundant only in the Oct sample, with rotifers 30+ spp. dominating therafter. Notable pulses of *Trichocerca pusilla* in Nov and *Filinia pejleri* in Feb. Again, *Stenosemella lacustris* reached significant numbers (1,400/l), with *Difflugia globulosa* the most abundant testate, present in small numbers on all occasions. Density: 224-3,402, mean 1,812/l.



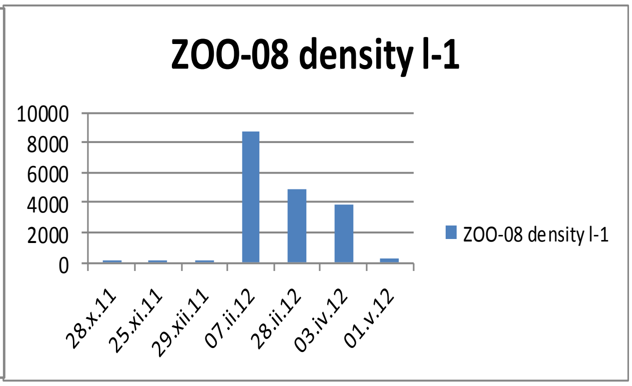


Fig. 12: ZOO-08, Lake Albert – with 9-32 spp, mean 21, the L. Albert plankton was dominated by copepods, primarily nauplii, on the first sampling, with a pulse of *Keratella australis.* Diversity increased to Feb 27th, declined thereafter. The abrupt

spike on the density plot Feb 7th is largely due to *Stenosemella lacustris*, which reached 6,800/l on that date. Pulses of *Filinia pejleri, Proalides tentaculatus, Keratella tropica* and *Synchaeta* n. sp .were notable in subsequent samples, but other rotifers were in low abundance. Notable also was the presence of kinorynchs (Dec. 28th), which are reportedly estuarine, not previously recorded from the Lower Lakes. Density: 13-8,732, mean 2,658.

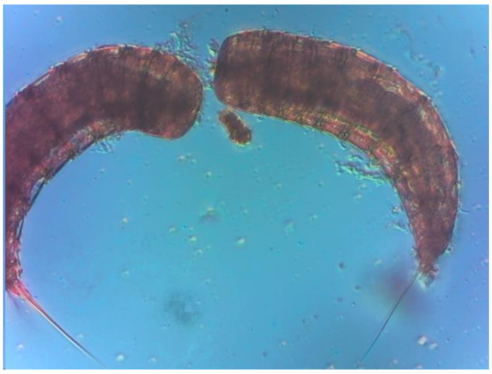
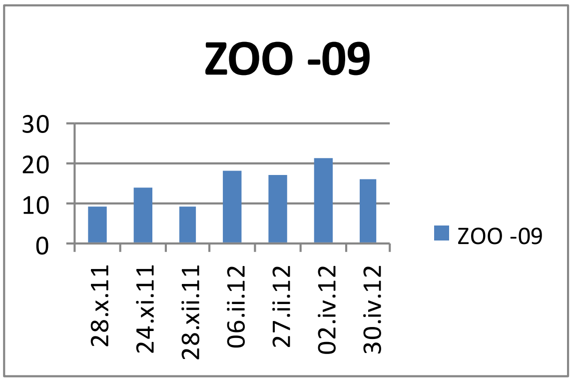


Fig. 13: Kinorhyncha, ZOO-09 06.ii.12



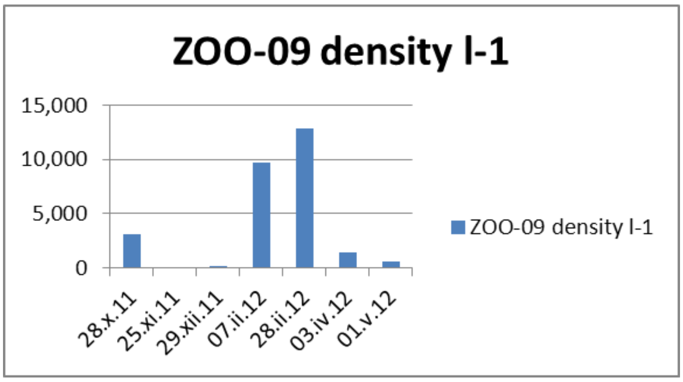
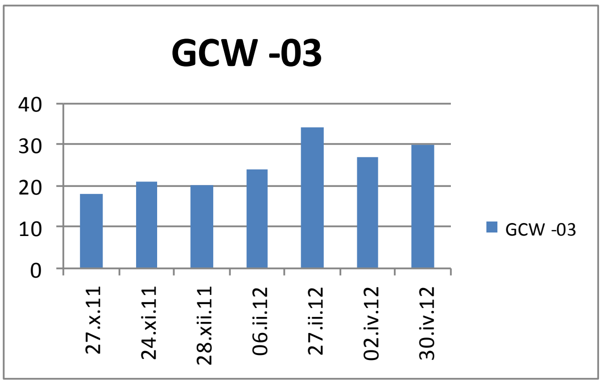


Fig. 14: ZOO-09, L. Albert, Meningie jetty boat ramp. Zooplankton diversity was low throughout the study (9-21 spp, mean 15), with 21 the highest recorded (Apr 2nd). Densities were only 100/l in the Nov/Dec samples. Notable was a spike of *Trichocerca* in the first sample (Oct 28th), and a pulse of cladocerans (*Daphnia/Ceriodaphnia*) and calanoid copepods on Nov 24th. The population peaks evident in the density plot above were due primarily to *FIlinia pejleri* and *Stenosemella lacustris* on both Feb. dates. Kinorynchs also recorded (Feb 6th). Densities 85-12,895, mean 4,001/l), the highest density across all sites in this study.



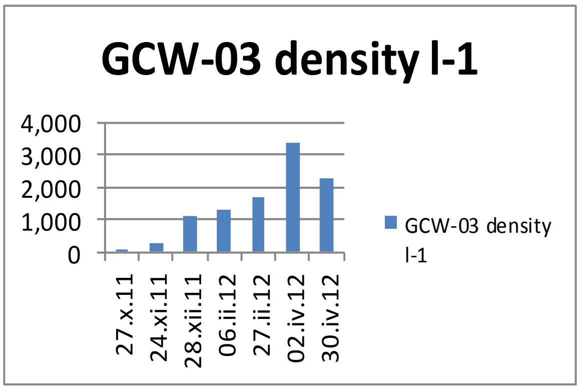


Fig. 15: GCW-03, Finniss River. Zooplankton diversity was moderate across the study period at this site, with a mean of 25 spp. (range 18-34). Different cladocerans predominated on each trip – *Ceriodaphnia* on Oct 27th, *Bosmina* & *Daphnia* on Nov. 24th, *Moina micrura* on Dec. 28th. Adult calanoids were abundant on Oct 27th, declining in subsequent trips, although copepodites and nauplii were numerous throughout. Interestingly, *Boeckella triarticulata* was abundant in the net tow, but not recorded in the pooled trap sample. Avoidance of traps has been reported for copepods. Cyclopoids also were numerous mostly as juveniles. Pulses of different species of rotifer were also apparent on each date: *Filinia australiensis on* Oct 27th, *F. pejleri* on Apr 2nd, *Hexarthra intermedia* on Oct 27th, *Keratella cochlearis* and *K. procurva* on Oct 27th, *K. tropica* on Apr 30th. A diverse array of other rotifer species occurred concurrently with the above pulses. *Stenosemella lacustris* was the only protist to reach reasonable densities - 595/l (Feb 6th). Zooplankton densities ranged from 108-3,340/l, mean 1,438.

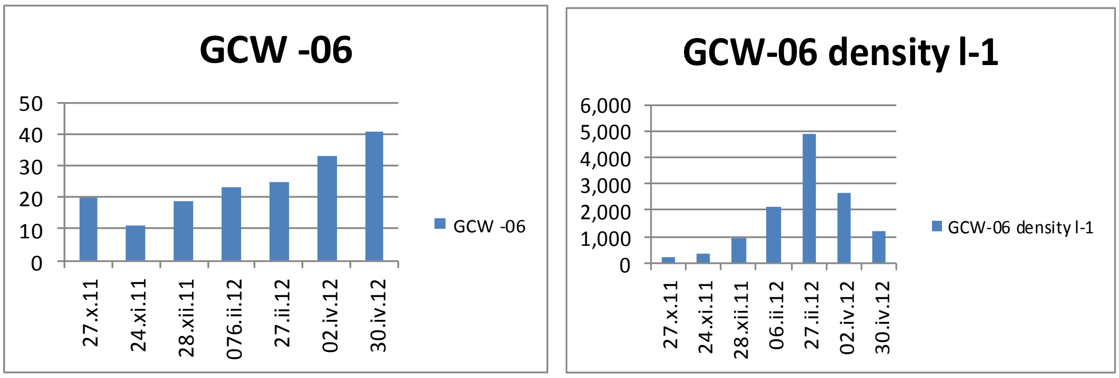
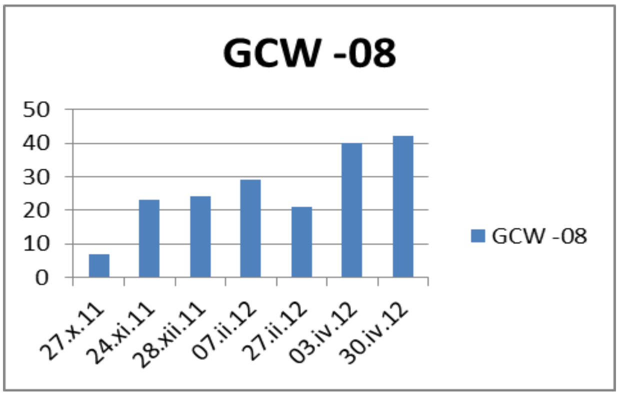


Fig. 16: GCW-06, Goolwa Barrage. Zooplankton at the barrage was 'moderately' diverse, with a mean of 24.6 spp. (range 11-41). Microcrustaceans, both cladocerans (particularly *Ceriodaphnia cornuta, Bosmina meridionalis*, *Daphnia carinata*) and copepods (*Boeckella triarticulata*), predominated on Oct 27th, declining thereafter. Pulses of different rotifer species occurred as floodwaters moved through the Goolwa Channel: notably, a Darling R. *Brachionus* on Nov 24th, *Filinia passa,* a floodplain species, on Dec 28th, tropical *Filinia pejleri* on Feb 6th, *Filinia grandis*, another Darling R. species, on Feb 27th, and *Keratella tropica/F. pejleri* on both Apr dates. Protists were noticeably sparse; only *Stenosemella lacustris* and *Difflugia globulosa* were present on each date. *S. lacustris* peaked at approximately 1,000/l on Apr 2nd, *D. globulosa* reaching nearly 1,200/l on Feb 27th. Sixteen rotifer species contributed to the population high on that date, notably *F. pejler* (1,660/l), *Synchaeta* n. sp. (537/l) and *Brachionus diversicornis* (391/l). Zooplankton density across the sampling period: 200-4,883, mean 1,759/l.



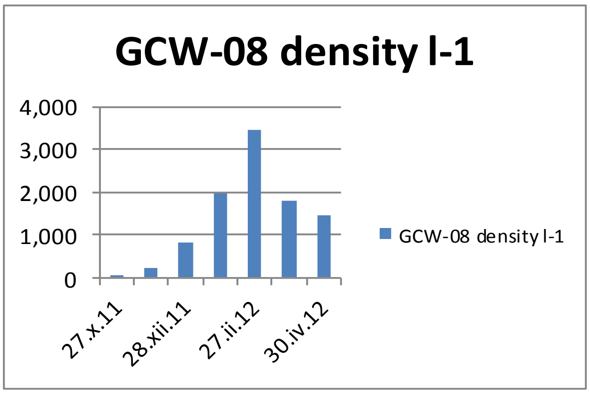
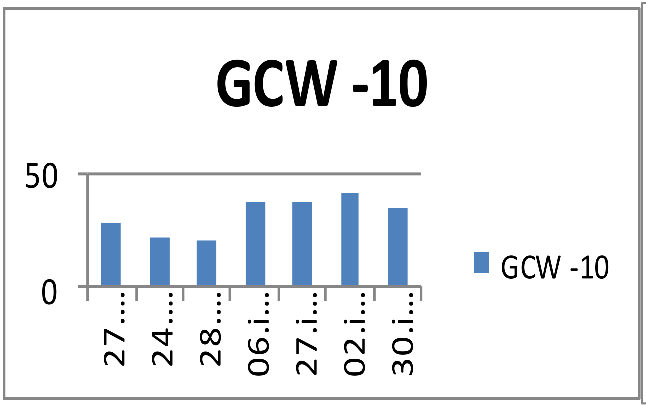


Fig. 17: GCW-08, Narnu, Hindmarsh Island. Moderate diversity, mean 26.6 spp, range 7-42. *Ceriodaphnia* dominated the net tow on Oct 27th, but the trap sample indicated only 2 *Ceriodaphnia*/litre, with low zooplankton densities persisting through the summer. Densities ranged from 10-3,456/l, mean 1,392. The pulse on Feb 27th was primarily *F. pejleri* (1,348/l), with *D. globulosa* the most abundant protist, contributing 760 individuals/l. Rotifers dominated the Apr samples.



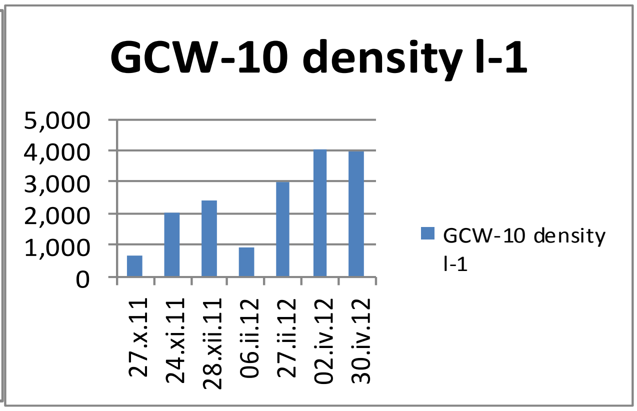
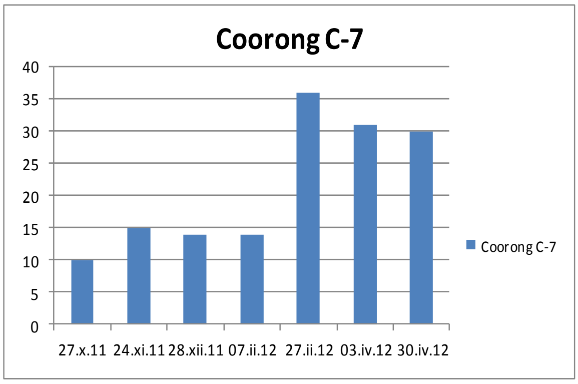


Fig. 18: Currency Creek, Ballast Stone Winery. Rotifers dominated throughout at this site. Copepod nauplii were present in small numbers on all dates. The only significant cladoceran populations were *Moina micrura* on Dec 28th (169/l) and *Daphnia lumholtzii* Apr 30th (120/l). *Filinia pejleri* was the most abundant rotifer at this site, peaking in Nov 24th (959/l) and declining in subsequent collections. Different rotifer species dominated on each date. The high of approximately 4,000/l in both Apr collections was composed of several species of rotifer (*Filinia, Polyarthra,*

Synchaeta, Hexarthra predominating). Diversity: 20-41 spp., mean 31.4. Density 685-4,063, mean 2,447/l



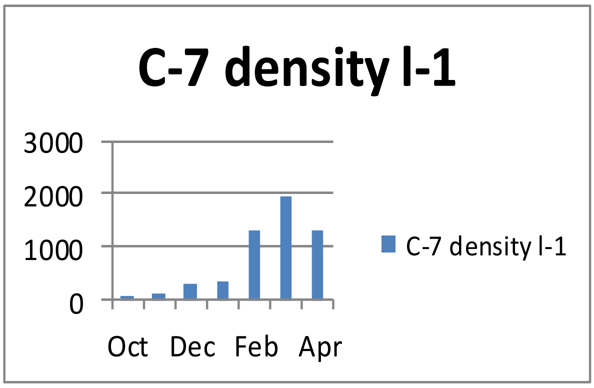
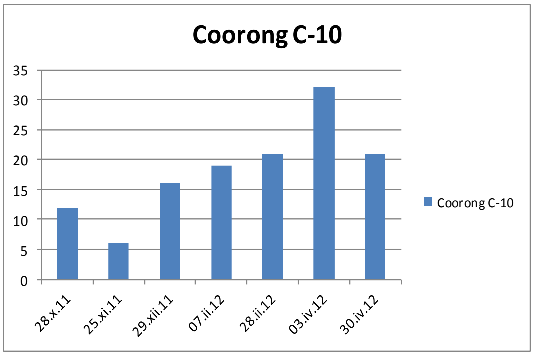


Fig. 19: C-7, Mundoo Channel. Low diversity and density of zooplankton were apparent through Spring/Summer (10-15 spp., densities 80-337/l). Halophile taxa were noted Feb 6th (crab larvae). A flush of freshwater rotifers and protists accounted for the fourfold increase in both density and diversity Feb 27th, with the subsequent population peak Apr 2nd comprised of *S. lacustris* (570/l), *F. pejleri* (806/l), *K. tropica* (197/l), and smaller numbers of various rotifers and protists. The only adult calanoid collected was a *Calamoecia ampulla* (Nov 24th), although calanoid nauplii were present in small numbers on each sampling date. Polychaete larvae and amphipods were noted in the Feb 27th sample. Diversity: 10-36 spp., mean 20. Density 81-1,967, mean 778/l.



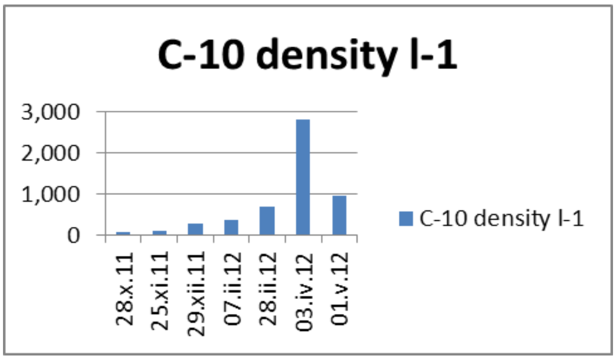
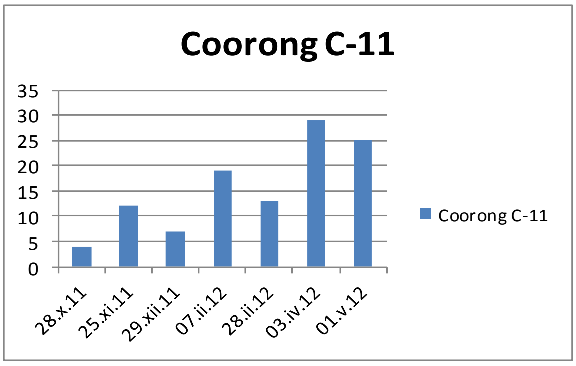


Fig. 20: C-10, Tauwitcherie Barrage, Coroong Nth Lagoon. Microcrustaceans dominated the Oct 28th sample *(Boeckella,* with nauplii the most abundant single group, *Bosmina, Ceriodaphnia).* The Nov. sample was depauperate,

microcrustaceans and rotifers were sparse, with only *Difflugia globulosa* abundant. Diversity increased thereafter, mainly consisting of freshwater rotifers, presumably from a barrage release. Halotolerant crustaceans were present on most dates – atyid shrimps, amphipods, crab larvae, isopods. Diversity: 6-32 spp., mean 18.1; density 78-2,817, mean 758/l. The spike on Apr. 3rd was largely *Stenosemella lacustris* and *Filinia pejleri* (986/l and 620/l respectively).



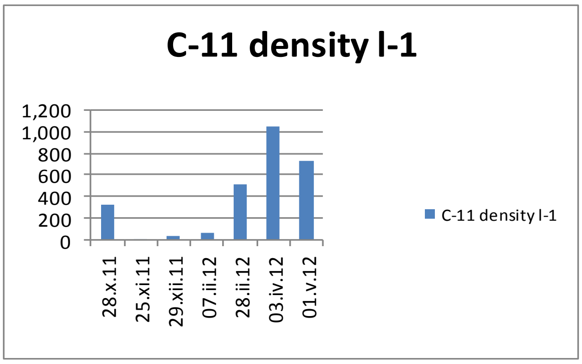


Fig. 21: C-11, Mark Point, Coorong Nth Lagoon. Diversity 4-29 spp., mean 15.6; density 9-1,042, mean 386/l, the lowest site density of this series. Estuarine protists (tintinnids) dominated the first three sampling dates, with calanoid nauplii the only other abundant taxon. A mixed assemblage of freshwater rotifers and estuarine or halophile copepods, with occasional bivalve larvae, atyids, crab larve, amphipods and isopods occurred on subsequent sampling dates. A small calanoid, a species of *Acartia,* resembles *A. fancetti,* known from Port Phillip Bay. A cercaria larva noted on Dec 28th was likely a bird fluke. The peaks in both diversity and density in the plots above (Apr 3rd) were composed of *Stenosemella lacustris* and a suite of freshwater rotifers, presumably from a barrage release.

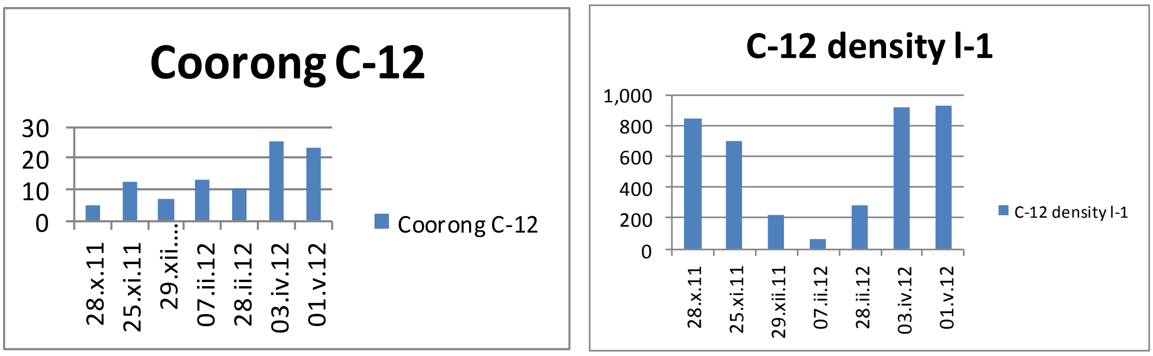
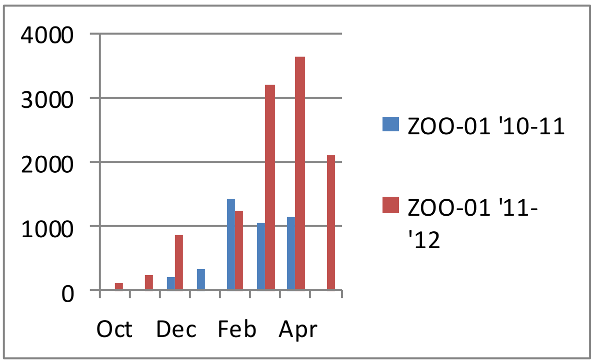


Fig. 22: C-12, Long Point, Coorong Nth Lagoon. Diversity 5-25 spp., mean 15.6, density 8-915/l, mean 566/l. A cased and presumably halophile ciliate resembling *Cothurnia* was the only abundant protist on the first two sampling dates (665/l on Nov 25th). As for C-11, a mixed freshwater/estuarine assemblage was present on subsequent dates. A few freshwater rotifers, e.g. *F. pejleri* persisted, but the most abundant rotifers were two or three species of halotolerant/estuarine *Synchaeta*, including *S. tremula* and *S. triophthalma.* The peak *Synchaeta* population was 428/l (Apr 1st). Calanoid nauplii were the only microcrustaceans on all sampling dates. A single ?*Acartia* subadult was noted in the Feb 28th net tow. No adults were found in the trap sample. The only macroinvertebrates recorded were polychaete larvae and nematodes (Dec 29th)

Density comparison, all sites, 2010-2011, 2011-2012

Comparative zooplankton densities from all sites are shown in Fig. 23:



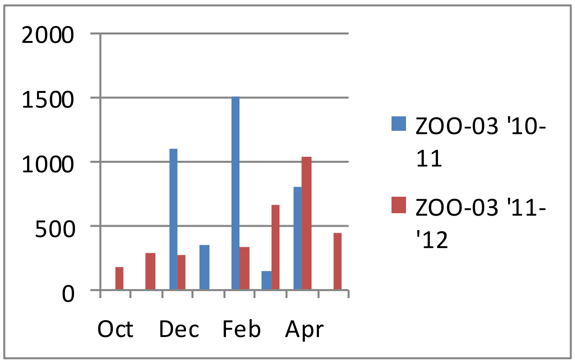
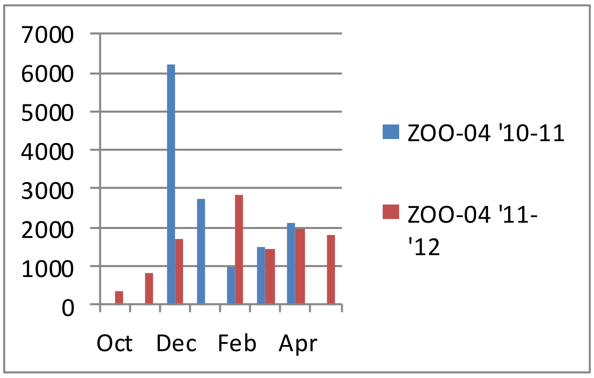


Fig. 23a ZOO-01: Mar/Apr ’12 peaks *S. lacustris/ D. globulosa*

Fig. 23b ZOO-03: Dec/Feb ’10 peaks *Polyarthra*



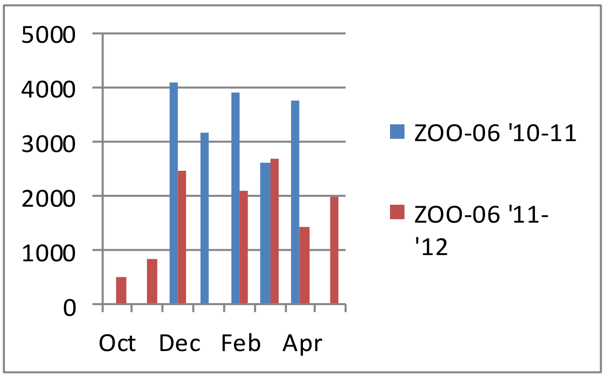
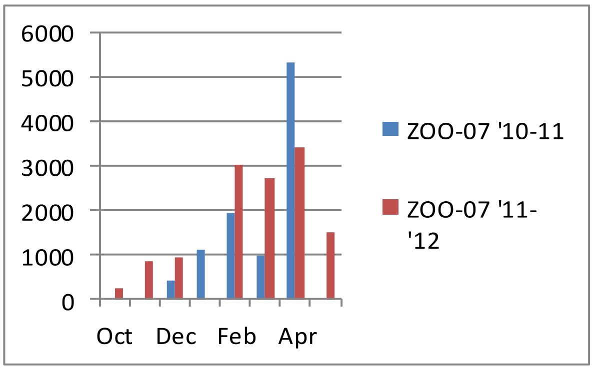


Fig. 23c ZOO-04: Dec ’10 peak *S. lacustris/F. pejleri*

Fig. 23d ZOO-06: All peaks *S. lacustris*



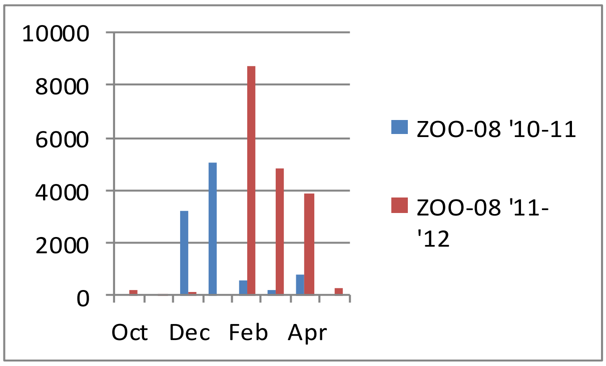


Fig. 23e ZOO-07: Apr ’11 peak *S. lacustris*

Fig. 23f ZOO-08: Feb ’12 peak *S. lacustris*

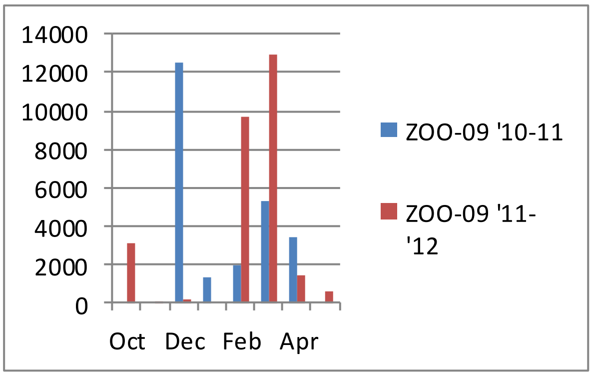


Fig. 23g ZOO-09 : Dec ’10 peak *H. brandorffi*, Feb/Mar ’12 peaks *S. lacustris/F. pejleri*

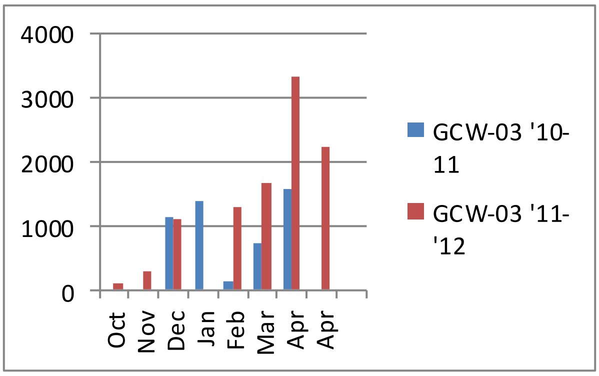


Fig. 23h GCW-03: Apr peak *Keratella*

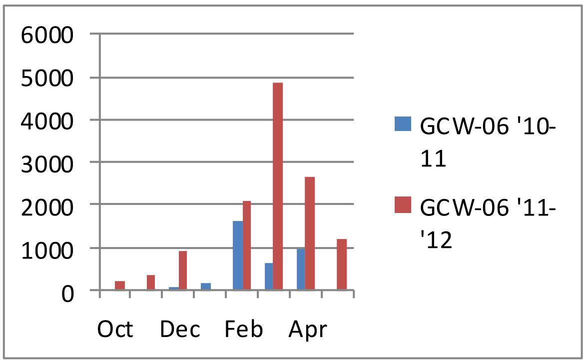


Fig. 23i GCW- 06: Mar ’12 peak *D. globulosa/F. pejleri*

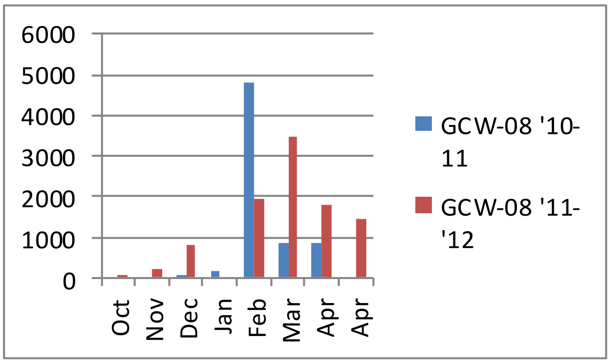


Fig. 23j GCW-08: Feb. ’11 peak *S. lacustris/D. globulosa*

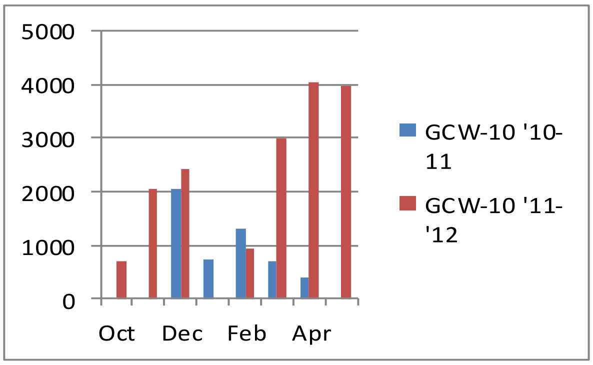


Fig. 23k GCW-10: Apr ’12 peaks *Filinia/ Polyarthra/ Synchaeta/Keratella*

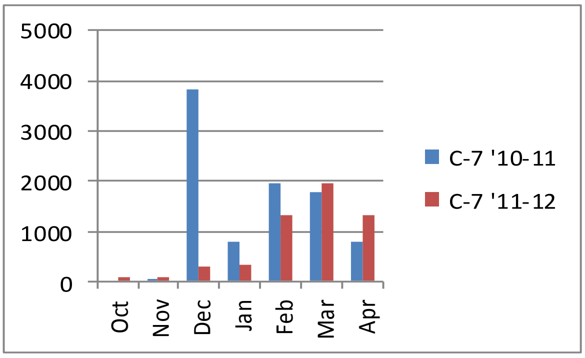


Fig. 23l C-7: Dec ’10 peak *S. lacustris*

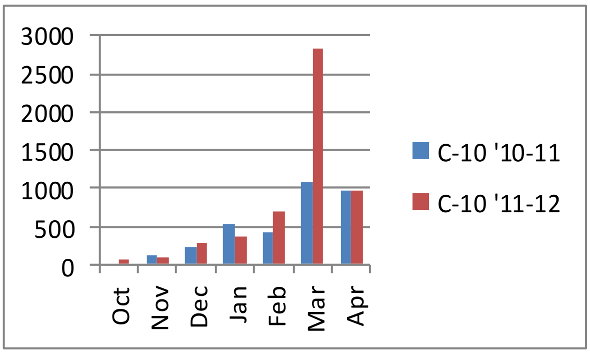


Fig. 23m C-10: Mar ’12 peak *S. lacustris/ F. pejleri*

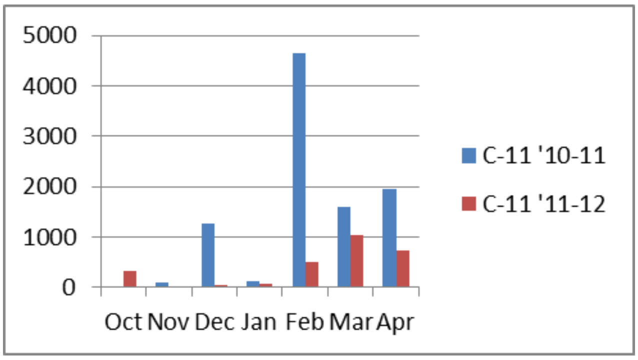


Fig. 23n C-11: Feb ’11 peak *P. tentaculatus*

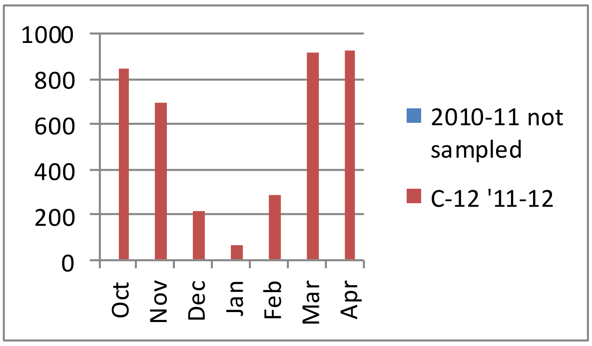


Fig. 23o C-12: Mar/Apr ’12 peaks *Filinia/Synchaeta/Keratella*

Fig 23a-o: comparative zooplankton densities all sites, both years. Dominant zooplankters are identified in the captions.

With one exception, all the population ‘spikes’ above during both sampling periods were of freshwater bacteriovorous/detritivorous protists, *Stenosemella lacustris/ Difflugia globulosa,* or one or more of a suite of small freshwater rotifers known to be bacteriovorous or herbivorous on small chlorophytes. Barrage releases account for their appearance in the Coorong sites. Exceptionally, *Proalides tentaculatus* (Fig. 23n, with a peak in Feb ’11 in C-11) is known to occur in ‘brackish’ waters, 5-6 °/oo, and is halotolerant, if not a halophile (Koste 1978).

Multivariate analysis [JESS DELANEY, WRM]

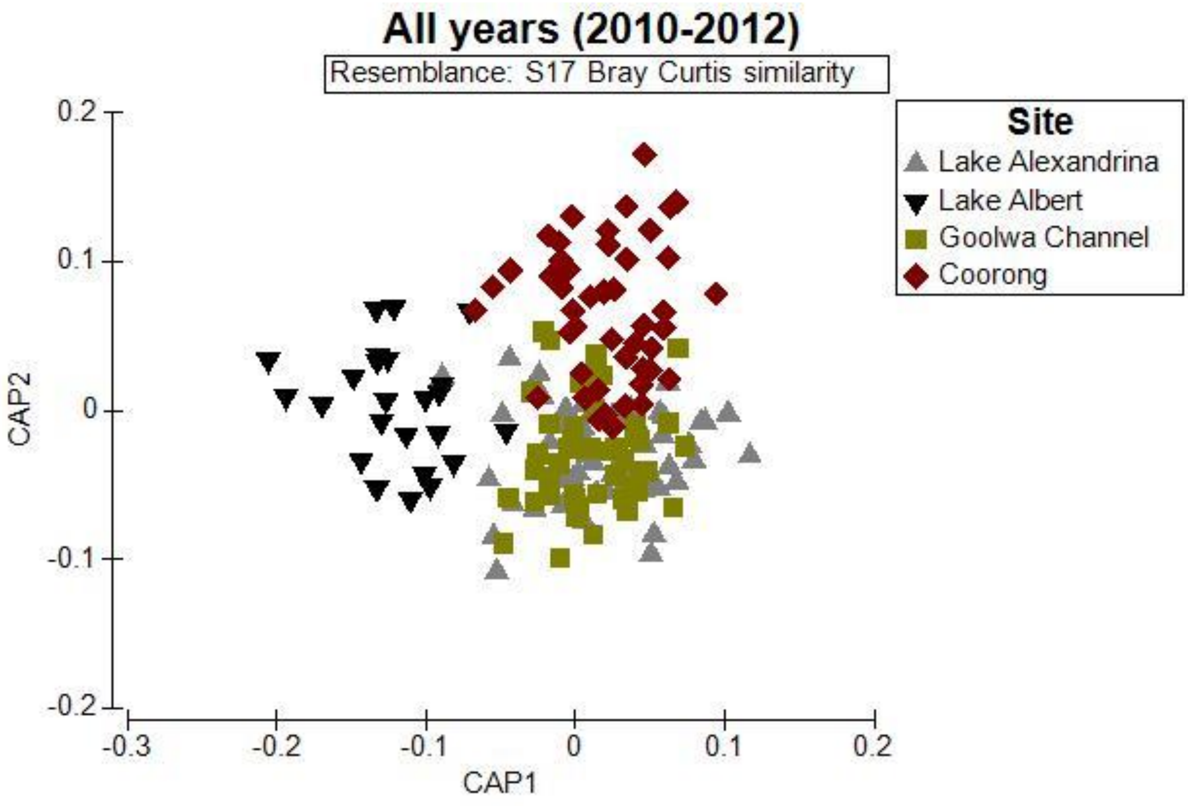


Figure 24. Constrained CAP plot comparing zooplankton assemblages between sites.

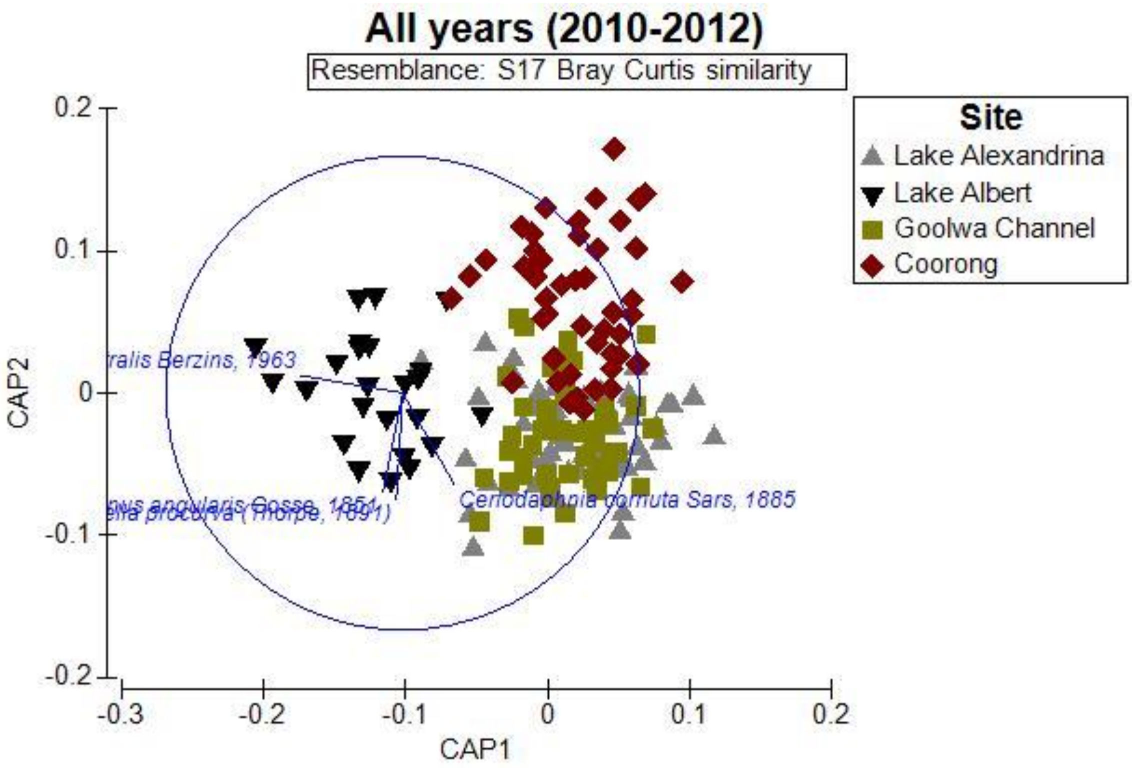


Figure 25: Constrained CAP plot comparing zooplankton assemblages between site. Vectors of Spearman rank correlations >0.5 are overlain on the ordination.

Lake Albert retained a discrete cluster in both years (Figs 24-25), with a slight overlap with Lake Alexandrina reflecting input of the latter's zooplankton assemblage via the Narrung Narrows. Most of the Coorong sites also clustered out from the dense and overlapping cluster of L. Alexandrina/Goolwa Channel sites, with a greater degree of overlap evident above reflecting the movement of water from L. Alexandrina through the Goolwa Channel into the Murray Mouth and North Lagoon.

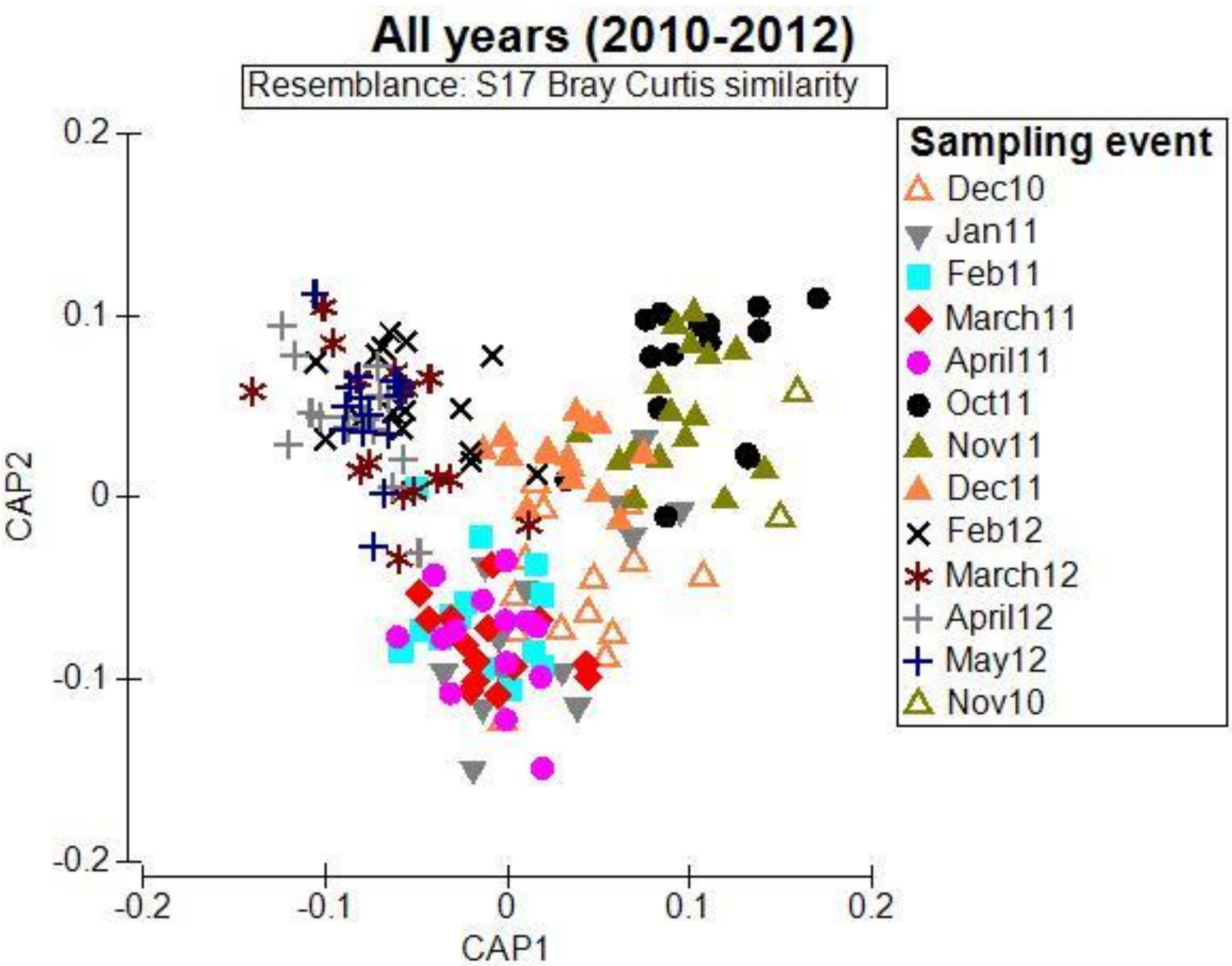


Figure 26: Constrained CAP plot comparing zooplankton assemblages between sampling events.

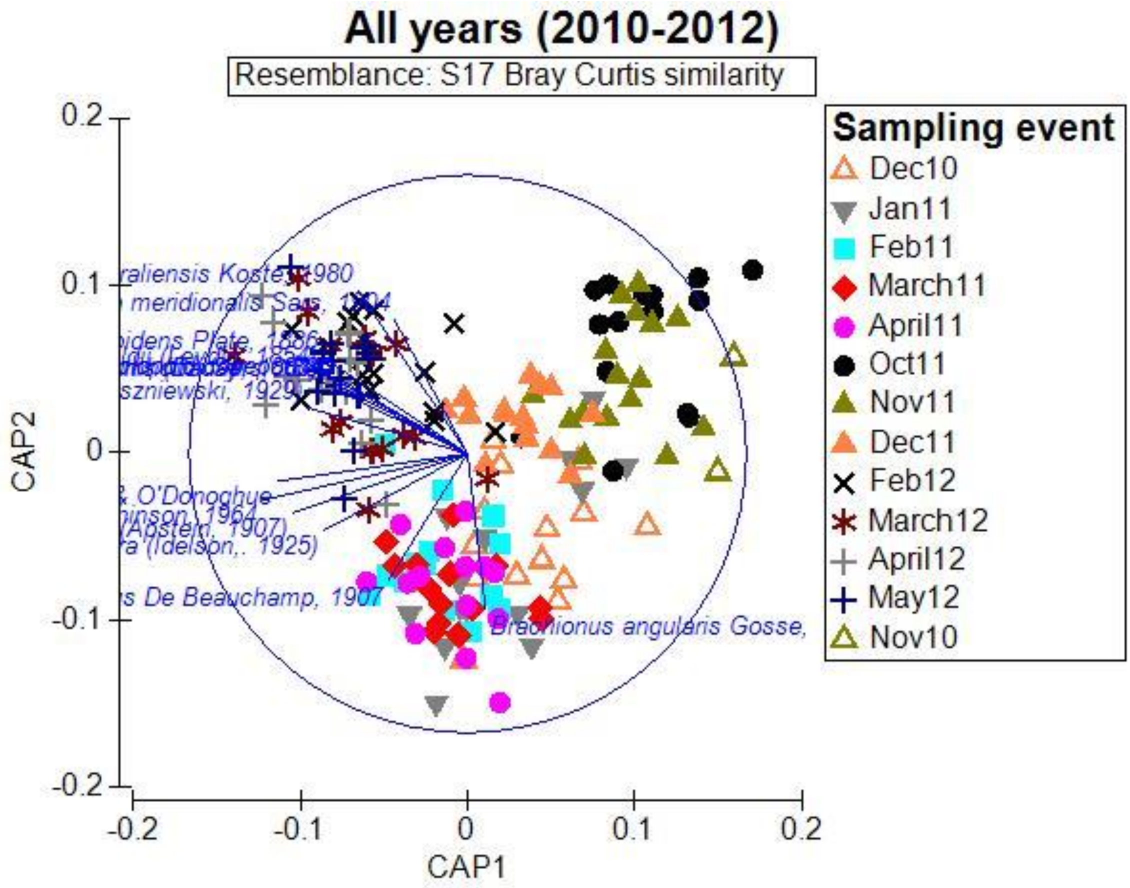


Figure 27: Constrained CAP plot comparing zooplankton assemblages between sampling event. Vectors of Spearman rank correlations >0.5 are overlain on the ordination.

Zooplankton assemblages were significantly different between site and sampling event (see Table 2). However, post-hoc tests showed that not all sampling events were significantly different from each other. Sampling events which recorded statistically similar zooplankton assemblages were:

Nov10 and Dec10
Jan11 and Feb11
Jan11 and Nov10
Feb11 and March11
Feb11 and April11
March11 and April11
Oct11 and Nov11
Oct11 and Nov10
Nov11 and Nov10
Dec11 and Nov10
Feb12 and March12

Source	df	MS	Pseudo-F	p-stat
Site	3	10932	6.01	0.001
Sampling event	12	9200.2	5.05	0.001
Site*Sampling event	33	2653.4	1.46	0.001
Residual	129	1820.4		
Total	177			

Table 2: Two-Factor PERMANOVA results comparing zooplankton assemblages between site and sampling event.

2011 & 2012 to assess influence of water quality

BIOENV found that water quality variables which contributed to differences in zooplankton assemblages were electrical conductivity and pH. Although, the correlation was not particularly high (BIOENV; Rho = 0.44, p = 0.0001). Overlaying water quality variables with a Spearman Rank Correlation greater than 0.5 indicated that Lake Albert zooplankton assemblages separated from other sites based on the lower EC characteristic of this site (Figure 28). Furthermore, the sampling event ordination was shown to be influenced by pH and water temperature; the zooplankton assemblages of 2012 were influenced by slightly higher pH, whilst assemblages from December 2011 were influenced by higher water temperatures (Figure 29).

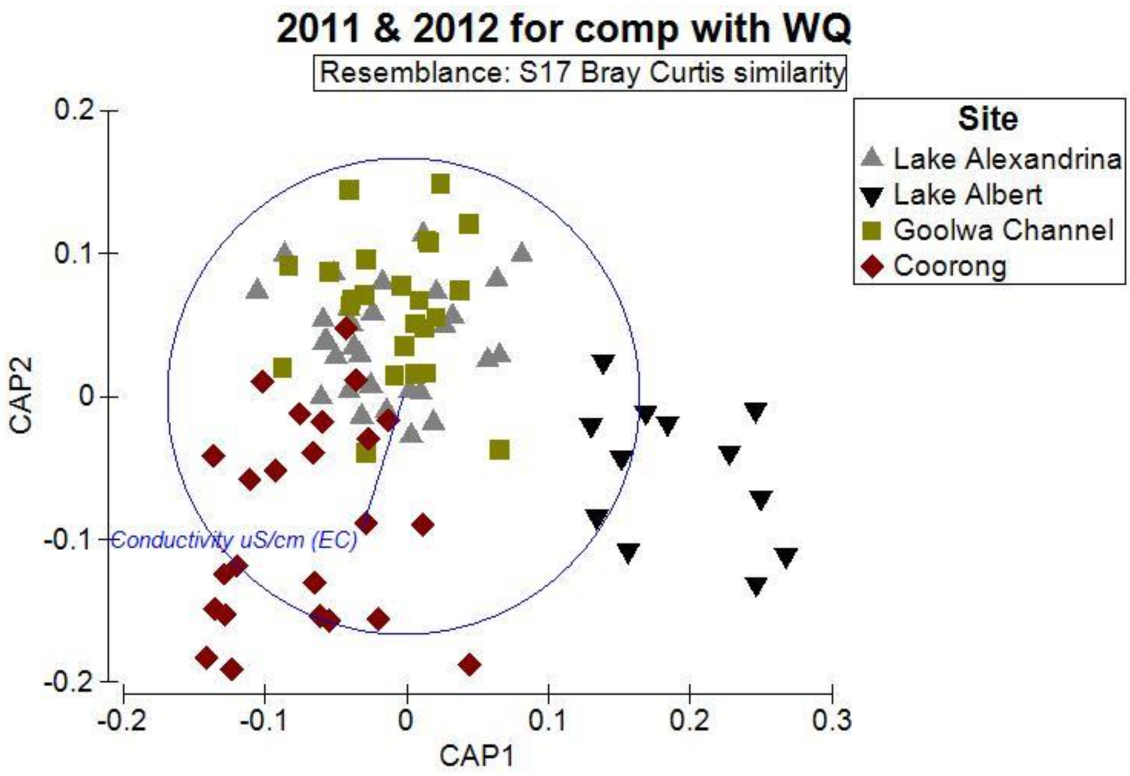


Figure 28: Constrained CAP plot comparing zooplankton assemblages between sites. Vectors of water quality variables with Spearman Rank Correlations >0.5 are overlain on the ordination.

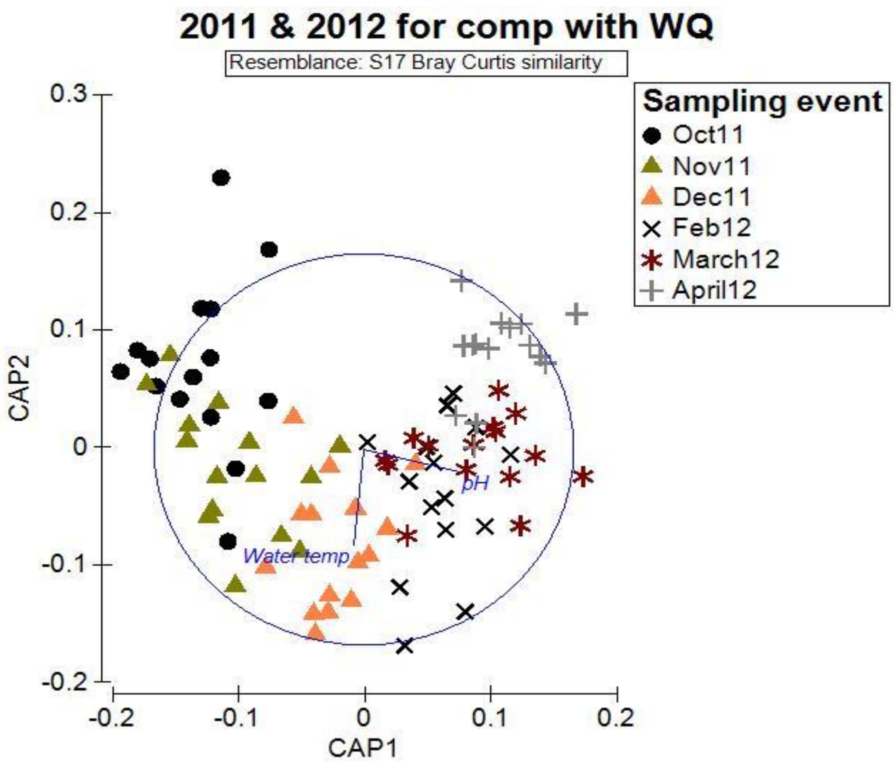


Figure 29. Constrained CAP plot comparing zooplankton assemblages between sites. Vectors of water quality variables with Spearman Rank Correlations >0.5 are overlain on the ordination.

Discussion

As noted in the 2010-2011 report (Shiel & Aldridge 2011) that sample series was taken from exceptionally high flows following a protracted drought. Coincidentally, significant rainfall events towards the end of 2011 also resulted in high flows into Sth Australia – 20-50,000 Ml/day over Lock 1 during Feb-Apr (DEWNR 2012). The 2011-12 floods also derived from the same upper basin catchments as the preceding year, potentially transporting a similar Spring/Summer zooplankton assemblage into the Lower Lakes. These similar assemblages were identified by the PERMANOVA (Table 3) and ordinations above, *viz.* Oct11 and Nov10, Nov11 and Nov10, Dec11 and Nov10. Consecutive sampling events also had statistically similar species assemblages, *e.g.* Mar/Apr ’11, Feb/Mar ‘12

The contrast between the high flow events is that the 2010-2011 floods inundated the salinizing Lower Lakes, filling them, submerging long-dry margins, whereas the 2011-12 flows, although abating through 2011, increased to flood levels through Spring 2011, and flowed into an already-full L. Alexandrina/L. Albert. A short residence time in Lake Alexandrina is suggested by the persistence of a riverine, rotifer-dominated assemblage at all the L. Alexandrina sites *after* the first (Oct) sampling trip. Calanoids had time to establish by October as floodwater abated, but with increasing flows through Nov-Dec, were present only as nauplii, and the L. Alexandrina zooplankton was primarily rotifer/protist dominated. This is the assemblage flushed into the Goolwa Channel, Murray Mouth and Coorong North Lagoon with barrage openings.

The ordinations above show that both L. Albert and the Coorong sites maintained discrete zooplankton assemblages during the sampling period, despite intrusion of R. Murray water via, respectively, the Narrung Narrows, and barrage releases. L. Albert, with a mix of microcrustacean, rotifer and protist plankton, had a Spring zooplankton reminiscent of that described from L. Alexandrina by Geddes (1984). Longer retention time over the preceding months had given copepods and cladocerans time to complete life cycles, however increasing flows, further dilution, and introduction of riverine assemblages were identified by the ordinations above. *Brachionus angularis*, *Keratella australis, K. procurva,* and *Ceriodaphnia cornuta*, identified in Fig. 25, are riverine 'transportees' (Shiel *et al.* 1982).

New records for the CLLMM region were the meiobenthic Kinorhyncha (Fig. 13) from both ZOO-08 and ZOO-09. These 'mud dragons' or spiny-crown worms are reportedly marine, inhabiting mud or sand. They may have been translocated from the Coorong during an estuarine phase, possibly vectored by birds, or may be a relict population in L. Albert from a pre-barrage estuarine period.

The superimposition of L. Alexandrina and Goolwa Channel assemblages evident in the ordinations reflects the flow from the former through the latter. Contributing to the rotiferine L. Alexandrina assemblage, the Spring samples from both the Finniss R. and Currency Ck contributed microcrustaceans, which had time to reach maturity in the preceding low-flow months. As summer (and flows) progressed, the rotifer/protist assemblage again predominated. Also likely to mitigate against large-bodied microcrustaceans, favouring the smaller rotifers and protists, is small fish and macroinvertebrate predation, a subject for later study. Evidence of an estuarine biota in the Goolwa Channel was provided by the halophile calanoid *Gladioferens,* amphipods and crab larvae recorded at Narnu, GCW-08,

The Coorong sites were variable, subject to barrage releases and tidal influences, such that a freshwater assemblage on one trip would be replaced by an estuarine assemblage on another. Approximately 85% of the zooplankton species recorded were freshwater in habit, derived from L. Alexandrina. Estuarine tintinnids, copepods, amphipods, crab larvae and isopods were among the halophile biota recorded. Notable was a small estuarine calanoid, *Acartia* sp., known also from Port Philip Bay, Vic. (McKinnon *et al.* 1992), recorded at C-11 and C-12.

In the context of the hypotheses (Table 1):

3. Zooplankton communities in the Murray Mouth and Coorong will be dominated by halophiles and communities will change along the salinity gradient;

Communities did change along the salinity gradient, as indicated by the strong influence of conductivity (Fig. 28) for the Coorong sites. However in view of the exceptional flooding and subsequent barrage releases again recorded for the sampling period, as noted above, the zooplankton was not dominated by halophiles in the Murray Mouth and Coorong. Halophiles were present, but generally were sparse.

A large halophile synchaetid recorded from C-12 is *S. triophthalma*, a new record for Australia, and probably resident in the Coorong, but not previously identified.

4. Zooplankton communities in the Goolwa Channel and Lake Albert will be dominated by estuarine/halo-tolerant species whilst Lake Alexandrina will have a more lacustrine and freshwater community.

Again, only partly supported. Lake Alexandrina had a riverine rather than a lacustrine assemblage, derived from upstream flows, with some evidence of local/littoral contributions – all sites had higher species richness than in the previous year, likely reflecting emergence from seedbanks. Several testate amoeba (littoral incursions), and several epiphytic/epibenthic rotifers, were recorded for the first time (Appendix 1: species of *Arcella, Centropyxis, Difflugia, Nebela,* two species of *Encentrum*, two species of *Eosphora*)*.* Both the Goolwa Channel and Lake Albert were dominated by riverine incursion species, but halotolerant species were collected in small numbers from both, likely flushed out of Currency Creek, in the case of the Goolwa Channel, or saline pools in 'backwaters' or littoral margins of L. Albert. It is unlikely that halophile taxa would be queued to emerge from riparian sediments by fresh water flows. Higher conductivities of receding water levels during a drying phase would be more likely triggers for this suite of species.

And key questions:

3. Will species be able to maintain any range increases observed in 2011-2012

Most of the recorded zooplankton from the 2010-2011 sampling series were encountered again, including novel species from the earlier survey (Appendix 1). New finds for the 2011-2012 series were generally littoral/epibenthic taxa, probably local respondees to the protracted riparian flooding. All of the freshwater species are sensitive to salinity increases beyond approximately 4-5 ppt, are unlikely to maintain populations in the Murray Mouth/Coorong Nth Lagoon due to marine water intrusions during reduced river flows. Halotolerant taxa, e.g. *Boeckella, Daphnia* may survive into 'brackish' concentrations, although breeding may be impaired.

4. Will further barrage flows in 2011-2012 maintain the presence of freshwater zooplankton in the Murray Mouth region, or will communities be dominated by more halophytic species?

Barrage flows released into the Murray Mouth are subject to saline intrusions during high tides, seiches, stratification (freshwater overlying saline layers). Freshwater assemblages will only persist if flow volumes are sufficient to keep conductivities within their tolerance(s). High freshwater flows are inimical to the halotolerant taxa, which will migrate, if possible, further east into the North Lagoon, out the Murray Mouth if open, or die if unable to osmotically regulate in fresh water.

5. Will continued flows be dominated by River Murray or Darling River communities and do they persist in the Lakes?

In both sampling years riverine assemblages identifiable from either upstream river catchment predominated. No sampling was undertaken in the intervening period (autumn/winter), so it is not possible to state that they persisted throughout. It is, however, likely during low/medium flow periods that the riverine assemblage is reconstituted, with larger zooplankton reproducing in sheltered marginal waters, reedbeds, e.g. Finniss/Currency catchments, Lake Albert, where they would be subject to predation by small fish, macroinvertebrates.

There is some evidence that the population pulses or peaks evident in the density plots (Fig. 23) were associated with algal blooms. As these move downstream into the Lower Lakes, accompanying bacteriovores, e.g. *Stenosemella lacustris, Difflugia globulosa, Filinia* spp., take advantage of senescent algae and organic breakdown products. Although *S. lacustris* was described from L. Alexandrina, it probably originated from upstream. It has been recorded at Lock 1 (SARDI, unpublished), and all of the *Filinia* species, and other small bacteriovorous rotifers associated with algal blooms, are known from both the upper Murray and Darling catchments. All apparently do well in the Lower Lakes.

Conclusions

As for the 2010-2011 high flow period, large inflows into the Lower Lakes between Oct. 2011 and Apr. 2012 resulted from flooding in the northern Darling/Murray catchments. Lake Alexandrina retained a riverine, rotifer-dominated zooplankton community. The largely freshwater assemblage which had resulted from the prolonged flooding over the previous year was reconstituted in the Murray Mouth and west end of the Coroong North Lagoon. Estuarine plankton was sparse in the Murray

Mouth region, increasing along the salinity gradient to Long Point. This region provided more heterogeneous conditions and rapid changes in plankton composition than did the Lower Lakes. Positive food chain effects are likely from the influx of freshwater zooplankton, particularly to small-bodied fish, macroinvertebrates, and thence up food chains.

Recommendations

•High flows in both sampling years leaves a gap for identifying changes in plankton assemblages with declining flows – significant in the context of food web interactions. Reference samples during low-flow periods would be useful.

•Food web interactions in general at this level are still a black box for the Coorong/Lower Lakes. The prevalence and relatively high density of bacteriovores periodically is of particular interest. A preliminary study of bacteriovory in the Upper Murray catchment demonstrated that rotifers were significant grazers of bacterioplankton (Boon & Shiel 1990). Intuitively, pulses of bacteriovores were likely to be following algal blooms/breakdown products of bloom senescence as water masses moved downstream. It is also likely that decomposition products from inundated riparian margins contributed to bacterial production. The significance of such trophic coupling of bacteria/rotifers to higher levels of CLLMM food webs is unknown.

•Zooplankton/juvenile fish interactions remain poorly researched. Environmental flows may be released at an inappropriate time for fish spawning, zooplankton production, etc. More information on the local time frame(s) of these events would facilitate appropriate basin-wide responses.

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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	
	2010-'11	**2011-'12**	2010-'11	**2011-'12**	2010-'11	**2011-'12**	2010-'11	**2011-'12**
Protista								
Ciliophora								
Cothurnia		+		+		+		+
Didinium sp.					+		+	
Epistylis sp.	+							
Euplotes sp.	+		+		+		+	
Halteria sp	+	+			+			
cf. *Noctiluca* sp.								+
cf. *Opercularia* sp.					+			
Paradileptus sp.		+			+	+		
Stenosemella lacustris	+	+	+		+		+	
Stentor sp.	+	+	+		+	+	+	
Tintinnids							+	+
Indet. spherical ciliate	+		+	+	+		+	
Indet vasiform ciliates								+
Rhizopoda								
Arcellidae								
Arcella bathystoma	+	+		+	+	+		
Arcella dentata						+		
Arcella discoides	+	+	+		+	+	+	+
Arcella cf. *gibbosa*	+							
Arcella hemisphaerica	+				+		+	+
Arcella megastoma	+							
Arcella vulgaris		+						
Arcella sp. **a**	+		+		+	+		
Arcella sp. **b**	+	+			+	+	+	
Arcella sp. **c**	+							
Centropyxidae								
Centropyxis aculeata	+	+				+	+	
Centropyxis cf. *aculeata*		+						
Centropyxis cassis		+						
Centropyxis constricta		+						
Centropyxis ecornis		+		+		+	+	+
Centropyxis platystoma	+	+						
Centropyxis sp. **a**	+		+					
Centropyxis sp. **b**	+				+			
Centropyxis sp. **c**	+							
Centropyxis sp. **d**	+							
Cyphoderiidae								
Cyphoderia ampulla	+		+		+		+	
Difflugiidae								
Difflugia acuminata		+		+		+		+
Difflugia cf. *amphora*		+				+		
Difflugia ampullula		+				+	+	

Difflugia corona		+				+		
Difflugia distenda		+						
Difflugia gramen	+	+	+	+	+	+	+	+
Difflugia lanceolata		+			+	+		
Difflugia limnetica	+				+			
Difflugia cf. *lithophila*						+		
Difflugia cf. *longicollis*								+
Difflugia cf. *mammilaris*		+						
Difflugia cf. *manicata*		+				+		
Difflugia minutissima		+				+		
Difflugia cf. *oblonga*		+		+		+		+
Difflugia cf. *parva*								+
Difflugia cf. *stoutii*		+						
Difflugia cf. *urceolata*		+						
Difflugia cf. *viscidula*		+						
Difflugia sp. **a**	+	+				+	+	
Difflugia sp. **b**	+						+	
Difflugia sp. **c** [*globulosa*]	+	+		+	+	+		+
Difflugia sp. **d**	+							
Difflugia sp. **e**	+							
Difflugia sp. **f**	+							
Difflugia sp. **g**	+			+	+	+		
Difflugia sp. **h**		+						+
Difflugia sp. **i**								+
Difflugia sp. **j**		+						+
Difflugia sp. **k**						+		
Difflugia sp. **l**						+		
Pontigulasia sp.		+				+		
Zivkovicia sp.	+	+						
Hyalosphaeniidae								
Hyalosphaenia sp.		+						
Euglyphidae								
Euglypha sp.	+	+			+	+		+
Lesquereusiidae								
Lesquereusia spiralis	+	+				+		
Netzelia tuberculata		+	+		+	+		
Nebelidae								
Nebela sp.				+				
Trigonopyxidae								
Cyclopyxis sp.	+							
Trinematidae								
Trinema sp.	+	+						
Foraminifera								
Indet.							+	+
Indet. protists	+		+			+		
Rotifera								
Bdelloidea								

Habrotrochidae								
Habrotrocha sp.		+				+		+
Philodinidae								
Macrotrachela sp.		+						
Philodina alata	+							
Philodina sp.	+							
Rotaria neptunia	+	+				+		
Rotaria sp.						+		
Indet. bdelloid a	+	+		+	+	+		+
Indet. bdelloid b	+	+	+	+	+	+	+	+
Monogononta								
Asplanchnidae								
Asplanchna brightwellii	+	+	+	+	+	+	+	+
Asplanchna priodonta	+	+	+	+	+	+		+
Asplanchna sieboldii	+	+	+	+		+		+
Brachionidae								
Anuraeopsis coelata	+	+			+	+		+
Anuraeopsis fissa	+	+			+	+		
Brachionus angularis	+	+	+	+	+	+	+	+
Brachionus angularis bidens		+		+		+		+
Brachionus cf. *baylyi* n. sp.			+	+				
Brachionus bennini	+	+	+		+			+
Brachionus bidentatus	+					+	+	
Brachionus budapestinensis	+	+			+			
Brachionus calyciflorus	+	+				+	+	+
B. c. amphiceros	+	+	+	+	+	+	+	+
B. cf. *calyciflorus* n. sp.	+	+		+	+	+		+
Brachionus caudatus	+		+					
Brachionus dichotomus	+							
Brachionus diversicornis	+	+		+	+	+	+	+
Brachionus falcatus	+	+						
Brachionus cf. *ibericus*								+
Brachionus cf. *leydigii*						+		
Brachionus lyratus	+	+		+	+	+		+
Brachionus nilsoni	+	+		+	+	+	+	+
Brachionus novaezealandiae								+
Brachionus plicatilis	+		+	+				
Brachionus quadridentatus	+	+				+	+	+
B. q. cluniorbicularis					+		+	
Brachionus rubens	+		+			+	+	
Brachionus cf. *sericus*								
Brachionus urceolaris	+	+		+	+	+	+	
Brachionus sp.	+	+	+			+	+	+
Keratella australis	+	+	+	+	+	+	+	+
Keratella cochlearis	+	+				+		+
Keratella procurva	+	+	+	+	+	+	+	+
Keratella quadrata	+		+		+		+	+

Keratella slacki	+	+						
Keratella tropica	+	+	+	+	+	+	+	+
Keratella sp.					+			
Plationus patulus	+	+					+	
Collothecidae								
Collotheca pelagica	+	+	+	+	+	+		+
Collotheca sp.		+				+		+
Conochilidae								
Conochilus dossuarius	+	+				+		+
Conochilus sp.	+				+		+	
Dicranophoridae								
Dicranophorus epicharis	+	+						
Encentrum aquilus		+				+		
Encentrum saundersiae	+					+		
Encentrum sp.	+				+		+	
Epiphanidae								
Microcodides chlaena	+							
Proalides tentaculatus	+	+	+	+	+	+	+	+
Euchlanidae								
Euchlanis sp.		+			+			
Flosculariidae								
Indet. flosculariid		+						+
Gastropodidae					+			
Ascomorpha cf. *ovalis*	+							
Gastropus sp.					+			
Hexarthridae								
Hexarthra brandorffi	+		+	+				+
Hexarthra intermedia	+	+		+	+	+		+
Hexarthra mira	+						+	
Ituridae								
Itura myersi								+
Lecanidae								
Lecane bulla	+	+		+	+	+		+
Lecane closterocerca	+				+			
Lecane curvicornis	+	+						
Lecane hamata	+		+		+			
Lecane ludwigii	+	+			+			
Lecane luna		+				+		
Lecane monostyla						+		
Lecane stenroosi	+							
Lecane thalera					+			
Lecane sp.		+				+	+	+
Lecane (s. str.) sp.							+	
Lecane (*M.*) sp.		+				+		
Lepadellidae								
Colurella adriatica	+		+				+	+
Colurella uncinata bicuspidata			+					
Colurella sp.		+			+			
Lepadella rhomboides		+						

Lepadella sp. a					+		+	
Lepadella sp. b						+		
Lindiidae								
Lindia torulosa		+						
Mytilinidae								
Lophocharis sp.	+				+			
Notommatidae								
Cephalodella forficula		+			+	+		
Cephalodella gibba	+			+	+		+	
Cephalodella megalocephala								+
Cephalodella cf. *tenuiseta*						+		
Cephalodella cf. *ventripes*	+							
Cephalodella sp. **a**	+				+			
Cephalodella sp. **b**	+	+						
Cephalodella sp. **c**							+	+
Eosphora anthadis	+	+			+			
Eosphora najas						+		
Eosphora thoides		+						+
Eothinia elongata						+		
Notommata cerberus	+							
Notommata sp.	+	+				+	+	+
cf. *Taphrocampa* sp.		+		+				
Proalidae								
Proales daphnicola							+	
Proales sp.	+	+	+		+	+		
Synchaetidae								
Polyarthra dolichoptera	+	+	+	+	+	+	+	+
Synchaeta oblonga		+		+		+		
Synchaeta pectinata	+	+	+	+		+		+
Synchaeta triophthalma								+
Synchaeta n. sp.	+	+	+	+	+	+	+	+
Synchaeta sp. a [cf. *cecilia*]	+	+	+		+	+	+	+
Synchaeta sp. b								+
Testudinellidae								
Pompholyx complanata		+			+			+
Testudinella obscura								+
Trichocercidae								
Trichocerca obtusidens							+	
Trichocerca pusilla	+	+	+	+	+	+	+	+
Trichocerca rattus carinata		+		+	+			+
Trichocerca cf. *ruttneri*		+				+		
Trichocerca similis	+	+			+	+		+
Trichocerca similis grandis	+	+	+	+	+	+		+
Trichocerca sp. a	+	+				+		+
Trichocerca sp. b	+	+						+
Trichocerca sp. c	+	+				+		
Trichocerca sp. d	+		+		+			
Trochosphaeriidae								
Filinia australiensis	+	+		+	+	+	+	+

Filinia brachiata	+	+				+		
Filinia grandis	+	+			+	+	+	+
Filinia longiseta	+	+	+	+	+	+	+	+
Filinia opoliensis	+	+		+	+		+	
Filinia passa	+	+		+	+	+		+
Filinia pejleri	+	+	+	+	+	+	+	+
Filini sp.					+	+	+	
Indet. rotifers	+	+		+	+	+	+	+
Cladocera								
Bosminidae								
Bosmina meridionalis	+	+		+	+	+	+	+
Chydoridae								
Alona cf. *rectangula*	+				+		+	
Alona rigidicaudis	+	+					+	
Alona sp. **a**		+				+		
Alona sp. **b** n. sp.					+	+	+	
Anthalona sp.		+		+			+	+
Chydorus sp.	+	+		+		+		
Pleuroxus inermis	+						+	
Daphnidae								
Ceriodaphnia cornuta	+	+		+	+	+	+	+
Ceriodaphnia sp.	+	+		+	+	+	+	+
Daphnia carinata	+	+		+	+	+	+	+
Daphnia lumholtzii	+	+		+	+	+	+	+
Daphnia projecta		+		+		+		
Daphnia cf. *truncata*				+				
Ilyocryptidae								
Ilyocryptus sp.	+			+	+			
Macrotrichidae								
Macrothrix sp.		+						
Moinidae								
Moina micrura	+	+		+	+	+	+	+
Podonidae								
Podon cf. *polyphemoides*								+
Sididae								
Diaphanosoma unguiculatum		+				+		+
Copepoda								
Calanoida								
Acartiidae								
Acartia sp.								+
Centropagidae								
Boeckella triarticulata	+	+	+	+	+	+	+	+
Calamoecia ampulla	+	+		+	+	+	+	+
Gladioferens pectinatus	+	+		+		+		+
Gladioferens spinosus					+	+	+	
Sulcanidae								

Sulcanus conflictus					+	+		
Calanoid copepodites	+		+		+		+	
Calanoid nauplii	+		+		+		+	
Cyclopoida								
Australocyclops sp.		+					+	
Eucyclops sp						+		
Halicyclops ambiguus		+		+	+	+	+	+
Mesocyclops notius	+	+				+		
Mesocyclops sp.		+		+	+	+		+
cf. *Metacyclops* sp.		+				+		
Microcyclops varicans	+	+			+	+	+	+
Thermocyclops sp.						+		
Cyclopoid copepodites	+		+		+		+	
Cyclopoid nauplii	+				+		+	
Harpacticoida								
Canthocamptidae								
Mesochra parva					+		+	
?*Mesochra* sp.	+			+			+	+
Laophontidae								
Onychocamptus bengalensis					+		+	+
		+		+	+	+	+	+
Harpac nauplii		+			+	+	+	+
Ostracoda								
Australocypris sp.	+							
Cypretta sp.							+	
Limnocythere sp.	+	+		+	+	+		+
Newnhamia cf. *fenestrata*		+						
cf. *Sarscypridopsis* sp.	+							
Indet. juv.	+	+	+		+	+	+	+
Macroinvertebrates								
Cnidaria: indet. medusa								+
Cnidaria: *Cordylophora caspia*		+		+				+
Cnidaria: *Hydra*		+				+		
cf. Polyzoa, resembles *Plumatella*		+			+	+		+
Nematoda		+		+		+	+	+
Turbellaria cf. *Mesostoma*		+			+	+	+	+
Trematoda: cercaria larvae								+
Mollusca: Gastropoda							+	
Mollusca: Bivalvia							+	+
Mollusca: limpet							+	
Kinorhyncha cf. *Echinoderes* sp.				+				
Oligochaeta: Naididae	+	+			+	+	+	+
Polychaete larvae						+	+	+
Tardigrada		+				+		+

Insecta: Diptera	+	+	+		+	+	+	+
Crustacea: Amphipoda: *Austrochiltona*	+	+	+	+	+	+	+	+
Crustacea: Isopoda								+
Crustacea: Decapoda: *Macrobrachium*	+	+		+		+	+	+
Crustacea: Decapoda: crab larvae					+	+		+
Arachnida: oribatid mite	+							+
Arachnida: other mites		+						+
Vertebrates								
Pisces juv.	+	+			+	+	+	+

Appendix 2: Zooplankton sampling sites

Site ID	Site location
GCW-03	Finniss River
GCW-06	Goolwa Barrage
GCW-08	Narnu Hindmarsh Island
GCW-10	Currency Creek – Ballast Stone Winery
ZOO-01	Lake Alexandrina – Point Sturt
ZOO-03	River Murray – Jockwar Road
ZOO-04	Lake Alexandrina – Loveday Bay
ZOO-06	Lake Alexandrina - Tolderol
ZOO-07	Narrung Narrows - jetty
ZOO-08	Lake Albert
ZOO-09	Lake Albert – Meningie jetty boat ramp
C-7	Mundoo Channel
C-10	Coorong – Tauwitcherie Barrage
C-11	Coorong – Mark Point
C-12	Coorong – Long Point