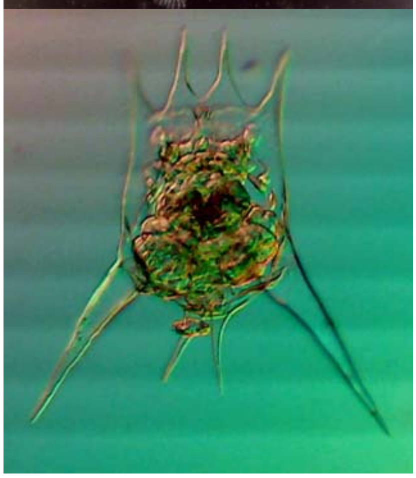
Lower Murray, Lower Lakes & Coorong zooplankton: a review



R.J. Shiel, Ecology & Evolutionary Biology

Report to DEH SA, Mar 19, 2010

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Lower Murray, Lower Lakes & Coorong zooplankton: a review

Prepared for:

Jason Higham, Manager

Ecological Investigations
Coorong, Lower Lakes and Murray Mouth Projects
Department for Environment and Heritage
Level 5, 91-97 Grenfell St
Adelaide 5000, SA
Office: [08] 8463 7594
E: jason.higham@sa.gov.au

by:

Dr Russell J. Shiel

Principal, R.J. Shiel & Associates
Ecological Consultants
3 Hillcrest Ave, Crafers West, SA 5152
(08) 8339 5510, mob, 0403-455396
e-mail russell.shiel@adelaide.edu.au
Contracting through Wetland Research & Management
28 William St, Glen Forrest, WA 6071
(08) 9298 9807
e-mail awstorey@cyllene.uwa.edu.au

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Frontispiece: R. Murray, Scott's Ck, SA. Daphniidae: *Daphniopsis truncata* (halophile) SE S.A.; Centropagidae: *Gladioferens spinosus* (euryhaline) L. Albert; Brachionidae: *Brachionus calyciflorus amphiceros* [halophile) L. Albert.

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Disclaimer

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INTRODUCTION

Zooplankton [from Gk *ζώο* = animal and *πλαγκτόν* = drifting] is a collective term for the assemblage of protists, rotifers, microcrustaceans and juvenile stages of small macroinvertebrates, such as dipteran larvae or mites, floating in the pelagic of the world's oceans. The term is also now in common usage to describe the open-water (planktonic) microfauna of inland waters – lakes, reservoirs, billabongs, and rivers. *Zooplankton* is used more generally here to include taxa which may be littoral in habit, but often are collected in open water when flushed out of submerged vegetation by currents, or are indiscriminately collected from submerged macrophytes when sweep net or cone-net sampling methods are used.

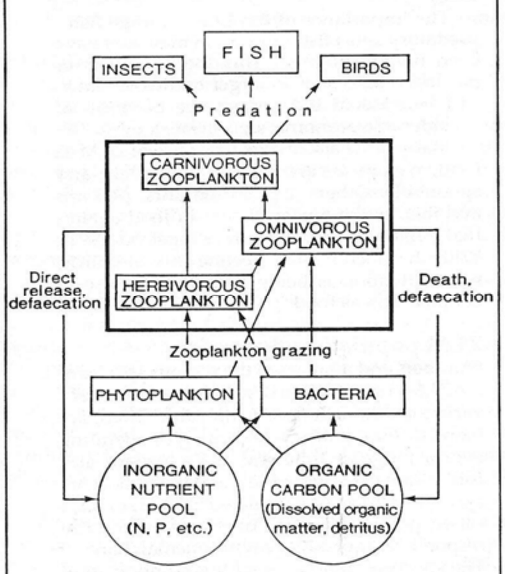


Fig. 1: Zooplankton in aquatic food webs [from Green & Shiel 1992]

Zooplankton in Australian inland waters occupy a range of niches [Fig. 1], such as bacteriovores, herbivores, carnivores, parasites, endosymbionts, which live internally in a relationship from which both organisms derive some benefit, or epizoites. Epizoites live on other animals, e.g. protists and rotifers on cladocerans or copepods, are transported for little energetic expenditure, may derive food particles or obtain some other benefit from the 'host' organism, but (theoretically at least) do it no harm. In fact, a heavy load of epizoites, such as the ciliate *Epistylis* on copepods, may impair the ability of the host to swim and/or feed. A Sth Australian example is the rotifer *Brachionus rubens* on the cladoceran *Moina micrura* (Shiel & Koste (1985)).

The generalized interactions shown in the zooplankton box in the flow diagram above are expanded in Fig 2 [right]. Zooplankton are critical in aquatic foodwebs, providing links between bacteria/phytoplankton and higher order consumers. Rotifers and/or small microcrustaceans are usually first feed for juvenile fish, and because they are generally small (<0.5 mm in freshwaters), sensitive to environmental changes; any deleterious impact such as increasing salinity which affects the zooplankton will have ramifications up food chains, through macroinvertebrates and/or fish to birds.

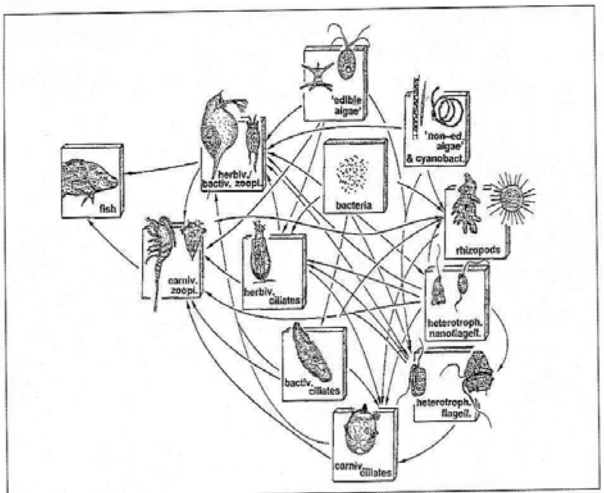


Figure 2 Simplified microfaunal food web from Murray-Darling waters. Except for fish, each compartment may contain scores to hundreds of species on any sampling occasion (from Shiel & Green (1992) *Vict. Nat.* 109)

For various historical reasons, the study of zooplankton has been neglected in Australia (see Green & Shiel 1992). In particular, within the Murray-Darling Basin, there has been only a single basin-wide survey of the zooplankton (Shiel 1981), and that only published in part (Shiel *et al.* 1982). There have been more recent localized studies of upper-reach streams (e.g. Nielsen *et al.* 2005) or of environmental flows (e.g. Gigney *et al.* 2006), but no intensive work on zooplankton dynamics in the lower reaches, nor of the effects of extended drought over recent years on the ecology of the zooplankton communities of the Lower Murray, Lower Lakes and Coorong Lagoons. For convenience, these areas are treated separately below.

THE LOWER R. MURRAY

The 1981 PhD project cited above included regular sampling from 21 sites downstream of the Murray-Darling confluence (Fig. 3). For the purposes of this Lower Murray literature review, only those sites below Swan Reach (site #11, Fig. 3) were considered. The published report on lower Murray zooplankton, which was based primarily on weekly sampling at Mannum, is included as an appendix (Shiel *et al.* 1982) and summarized briefly below.

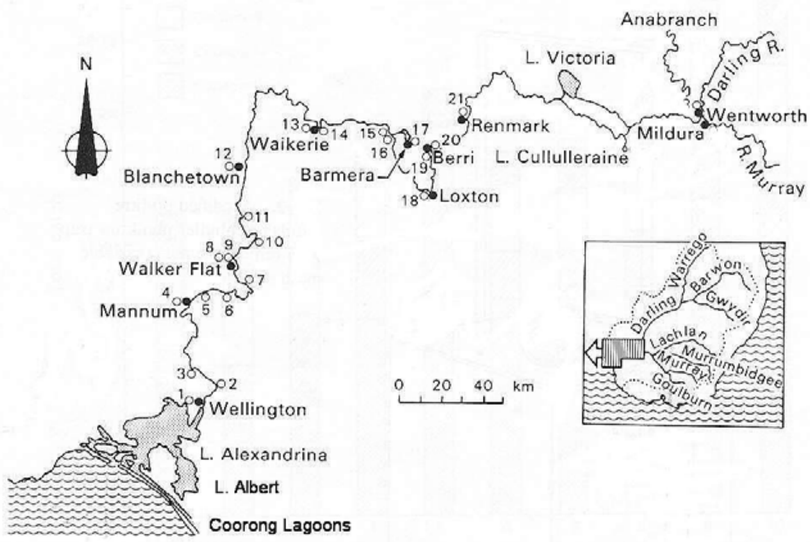


Fig. 3 Map of the River Murray below the Darling confluence. Sampling sites are numbered.

Zooplankton of the lower River Murray over the 1976-79 study were dominated by rotifers and microcrustaceans (Fig. 4). Macro-invertebrate larvae were collected occasionally, e.g. dipteran larvae, mussel glochidia, juvenile water mites. Protists were beyond the scope of the project, and not collected efficiently by the sampling methods used. In total 133 zooplankton taxa were recorded from the lower River, with marked temporal variability in species composition, depending on water source. Darling River flows were dominated by warm stenothermal rotifers, typical of temperate-tropical rivers. This riverine assemblage is

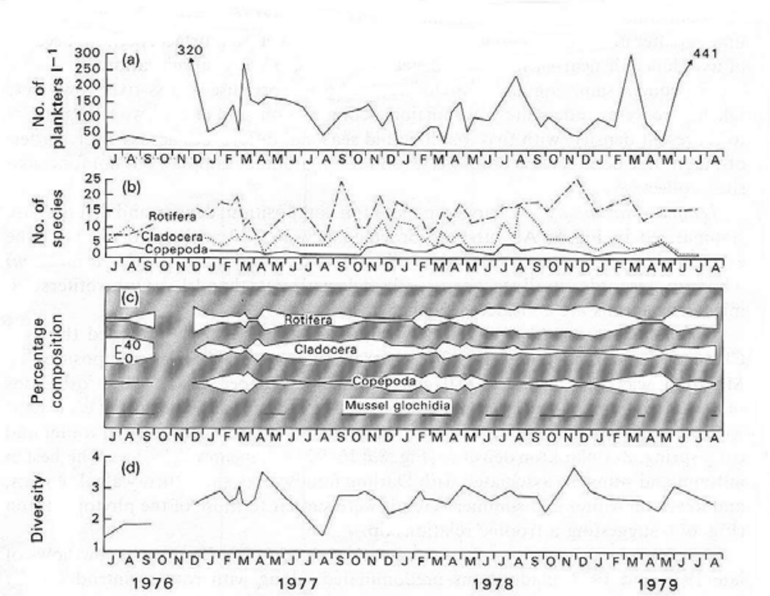
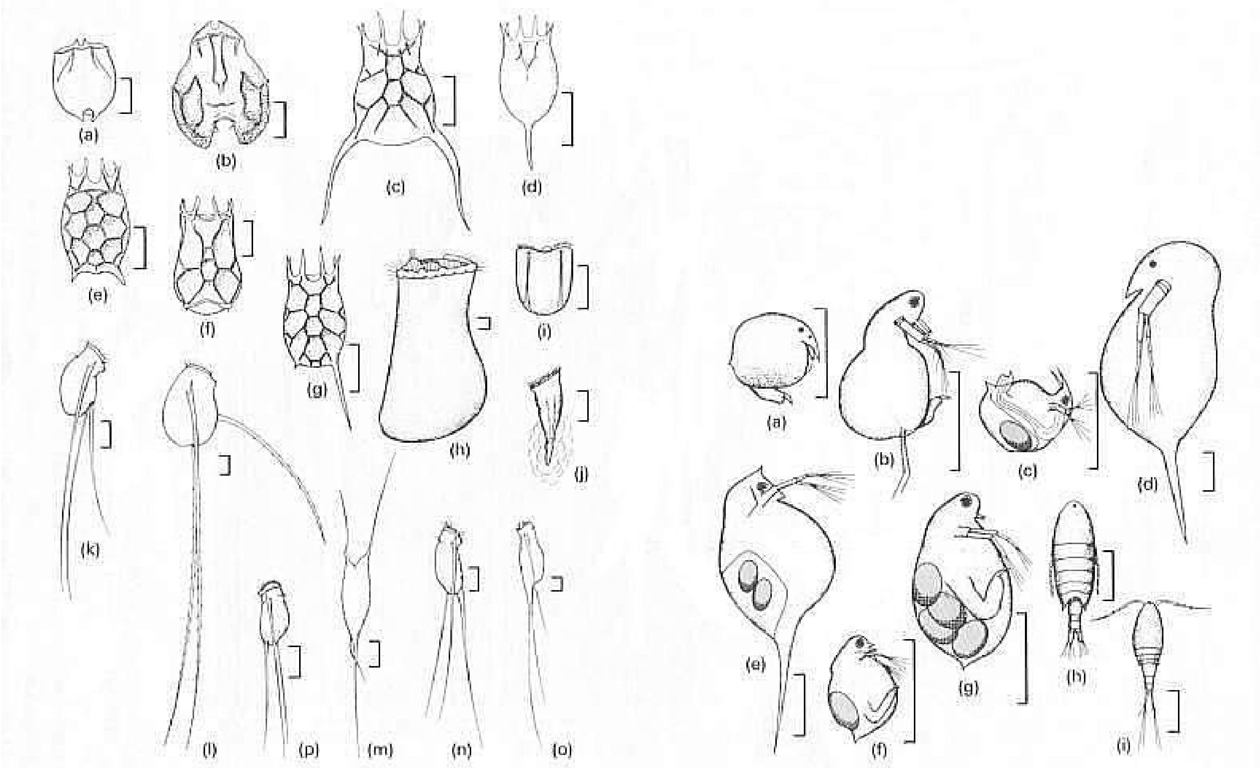


Fig. 4 Temporal variations in zooplankton in the lower Murray, 1976–79. (*a*) Density. (*b*) Number of species of Rotifera, Cladocera and Copepoda. (*c*) Percentage composition. (*d*) Diversity (*H'*).

termed *potamoplankton*.. River Murray flows were dominated by microcrustaceans characteristic of standing waters, and reflecting upstream locks and weirs in which a lacustrine assemblage or *limnoplankton* developed. These and various other sources, e.g., floodplain billabongs, backwaters/slackwaters, irrigation returns, etc contributed to the downstream plankton assemblage, which because of the low declivity of the basin underwent many generations during the long travel time to Lake Alexandrina. Common zooplankton recorded during that study are shown in Fig. 5.



Figs **5** Common planktonic Rotifera (*10*) and Microcrustacea (*11*) in the lower Murray. *10* (*a*) *Brachionus angularis*; (*b*) *B. keikoa*; (*c*) *Keratella australis*; (*d*) *K. cochlearis*; (*e*) *K. procurva*; (*f*) *K. shieli*; (*g*) *K. tropica*; (*h*) *Asplanchna brightwelli*; (*i*) *Pompholyx complanata*; (*j*) *Conochilus dossuarius*; (*k*) *Filinia longiseta*; (*l*) *F. australiensis*; (*m*) *F. opoliensis*; (*n*) *F. pejleri*; (*o*) *F. pejleri grandis*; (*p*) *F. terminalis*. Scalar 50 μm. *11* (*a*) *Chydorus sphaericus*; (*b*) *Moina micrura*; (*c*) *Bosmina meridionalis*; (*d*) *Daphnia carinata*; (*e*) *D. lumholtzi*; (*f*) *Ceriodaphnia cornuta*; (*g*) *C. quadrangula*; (*h*) *Boeckella triarticulata*; (*i*) *Mesocyclops leuckarti*. Scalar 500 μm.

A full list of species and the ranges of water quality in which all taxa were collected are included in the appendix, tabulated as in Tab. 1

Table 1. Frequency of occurrence of rotifers, cladocerans and copepods in the River Murray at Mannum

+ + + + Present in > 50% of samples; + + + 30–49%; + + 10–29%; + < 10%. Known range of water quality for each taxon in Murray waters is given (Shiel 1981)

Species[A]	Abundance	Temperature (°C)	pH	Dissolved oxygen (μg g^{-1})	Conductivity (μS cm^{-1})	Turbidity (NTU)	Habitat[B]	Season[C]
Rotifera								
(1) *Dissotrocha macrostyla* (Ehrenberg) 1838	+	12·0–13·5	7·9–8·4	8·0–10·4	–950	15	L	W
(2) *Rotaria neptunia* (Ehrenberg) 1832	+	12·0–24·0	7·2–8·2	8·4–10·4	850–1000	10–88	L	W
(3) Unidentified bdelloid	+	18·0	8·2	8·6	850	10	L	A/W
(4) *Epiphanes clavulata* (Ehrenberg) 1832	+	13·0–24·0	7·0–8·3	4·5–10·2	31–1000	5–120	L	Sp/Su
(5) *Platyias quadricornis* (Ehrenberg) 1832	+	16·5–27·0	7·6–7·7	7·0–9·0	150–255	27–65	L	Su
(6) *Brachionus angularis* Gosse, 1851	+ + + +	9·0–29·0	7·0–8·7	6·0–12·0	64–1500	75–220	P	*p*
(7) *B. bidentata* Anderson, 1889	+	16·5–23·5	7·9–8·1	6·0–9·0	650–750	67–100	L	Sp
(8) *B. bidentata minor* Koste & Shiel, 1980	+	17·0–22·0	8·2–8·5	9·0–9·7	1000–1475	88	L	Su
(9) *B. budapestinensis* (Daday) 1885	+ +	10·5–29·0	7·5–8·4	8·5–10·0	602–1000	10–65	P	Su/A
(10) *B. calyciflorus** Pallas, 1776	+ +	16·5–29·0	7·5–8·2	8·6–9·0	140–850	10–95	P	A/W
(11) *B. c. gigantea* Koste & Shiel, 1980	+ +	10·0–19·0	7·3–8·5	10·0–10·2	300–1000	9–220	P	*p*
(12) *B. c.* f. *amphiceros* Ehrenberg, 1838	+ +	10·5–25·0	7·1–8·7	6·4–12·0	92–1250	10–65	P	Sp/Su
(13) *B. c.* f. *aneuriformis* Brehm, 1909	+ +	10·0–29·0	7·3–8·5	6·4–10·3	60–1250	9–115	P	Sp/Su
(14) *B. caudatus* f. *austrogenitus* Ahlstrom, 1940	+	23·0	8·0	8·3	602	65	?L	Su
(15) *B. diversicornis* (Daday, 1883)	+ +	15·0–25·0	7·2–8·7	6·4–10·5	500–1000	10–130	P	Su
(16) *B. falcatus* Zacharias, 1898	+	16·5–24·0	7·1–8·7	8·2–9·2	92–1000	8–50	P	Su
(17) *B. keikoa* Koste, 1979	+ + + +	8·5–25·0	7·0–8·7	6·4–12·0	290–1950	20–220	P	*p*
(18) *B. lyratus* Shephard, 1911	+	19·5–29·0	7·5–7·7	9·0–9·4	55–620	37	L	A
(19) *B. novaezealandia* (Morris) 1912	+ +	8·5–21·5	7·8–8·7	8·2–12·0	330–1350	32–250	P	*p*
(20) *B. plicatilis* Muller, 1786	+	14·0	8·0	9·8	875	95	P	Su
(21) *B. quadridentatus* Hermann, 1783	+	15·5–29·0	7·0–7·9	8·4–9·6	120–145	1–10	L/P	W/Su
(22) *B. urceolaris** (Muller) 1773	+	13·0–17·0	7·0–8·1	8·4–10·2	365–380	120–135	P	Sp/Su
(23) *B. u. bennini* (Leissling) 1924	+ +	14·0–24·0	7·6–8·5	8·0–9·8	290–1250	23–120	P/L	A/Sp
(24) *B. u. nilsoni* (Ahlstrom) 1940	+	13·6–17·0	7·6–8·1	8·3–10·2	275–380	–120	P/L	Sp
(25) *Keratella australis* (Berzins) 1963	+ + + +	2·0–29·0	6·7–8·7	6·4–12·0	22–1350	2–275	P	*p*
(26) *K. cochlearis* (Gosse) 1851	+ + +	8·0–25·0	7·0–8·4	6·1–11·3	8–835	1–135	P	W/Sp
(27) *K. procurva** (Thorpe) 1891	+ + +	2·0–27·0	6·2–8·5	6·4–12·0	2–1250	1–135	L	*p*
(28) *K. p. robusta* Koste & Shiel, 1980	+ +	10·5–25·0	7·4–8·7	6·4–10·8	270–1000	15–115	L	*p*

A hiatus followed this initial study; the author researched billabongs and reservoirs upstream of the Murray-Darling confluence 1988-2001, and not until 2003 was there an opportunity to resample the lower Murray. A 3rd-yr Freshwater Ecology camp (Univ. of Adelaide) was held at Scott's Ck, during which students took quantitative and qualitative plankton samples from the Murray. The Ecology camp was held again at Illawonga, near Swan Reach, in 2008, 2009 and 2010, where further series of zooplankton tows and trap samples were collected. Some samples collected during the course of a PhD project related to fish feeding (Katherine Cheshire, SARDI, unpublished PhD thesis & pers. comm.) during 2006-7 from Lock 1 at Blanchetown also were examined. The 2006-8 samples are significant in that the assemblages represent the plankton of drought years, providing a contrast to the assemblages of the late-70's which represent high flow, or at least 'higher' flow years.

An example from the 2009 volumetric samples is given in Table 2.

R. Murray plankton traps, 2	Gp1	Gp2	Gp5	Gp2	Gp1
	22.iv.09	22.iv.09	20.iv.09	21.iv.09	22.iv.09
Site/Depth	1m	1m	2m	2m	4m
Zooplankton					
Ciliophora					
Halteria sp.	5	2	9		
Stenosemella lacustris		12		4	
indet ciliates	10	6	4	1	4
Heliozoa					
indet. heliozoan (amoeba)		9	2	1	3
Rhizopoda					
Arcella sp.					1
Centropyxis sp.					1
Cucurbitella sp.		1			
Cyphoderia sp.		2		2	6
Difflugia acuminata		2			1
Difflugia gramen			1		5
Difflugia cf. *lanceolata*				1	
Difflugia limnetica		1			1
Difflugia oblonga					1
Difflugia sp.	1			1	1
Lesquereusia spiralis				1	
indet. protists					1
Bdelloida					
Philodinidae: *Philodina sp.*					1
indet. bdelloid		1	1		
Monogononta					
Asplanchnidae					
Asplanchna brightwellii		2			
Asplanchna priodonta	1	2	1	1	
Brachionidae					
Anuraeopsis coelata	7	32	46	14	3
Anuraeopsis fissa			1		
Brachionus angularis	12	12	7	15	3
Brachionus budapestinensis			2	1	
Brachionus diversicornis			1	1	
Brachionus falcatus		1			
Brachionus cf. *rubens*			3		
Brachionus urceolaris					1
Keratella tropica	38	77	46	82	21
Collothecidae					
Collotheca pelagica	1	1	1		
Collotheca sp.			2		1
Conochilidae					
Conochilus sp.	4	2	5		1
Epiphanidae					
Proalides tentaculatus	2	2	12	2	
Dicranophoridae					
Encentrum saundersiae		2			
Hexarthridae					
Hexarthra sp.			1	1	
Notommatidae					
Cephalodella sp.			1	1	
Notommata sp.			1	2	
Proales sp.				1	
Synchaetidae					
Polyarthra dolichoptera	53	39	61	52	4
Synchaeta pectinata		14	1	2	2
Synchaeta sp.	4	9	5	6	1
Trichocercidae					
Trichocerca pusilla	12	24	52	5	5
Trichocerca similis		1	2	3	
Trichocerca sp.		2	1	1	
Trichotriidae					
Trichotria sp.					
Trochosphaeridae					
Filinia longiseta	7	3	2	8	2
Filinia opoliensis		2			
Filinia passa	1	2	4	4	
indet rotifer	3				
Copepoda					
Cyclopoida					
copepodites					2
nauplii	3	1			
Calanoida					
nauplii	1	3	2	1	
Cladocera					
Bosminidae					
Bosmina meridionalis		1	1	1	
N in 1 ml	**165**	**270**	**278**	**215**	**72**
from (ml^{-1})	51	28	51	28	57
trap volume (l^{-1})	8	8	8	8	8
Est. N in volume	8,415	7,560	14,173	6,020	4,104
Density l^{-1}	**1,051**	**945**	**1,772**	**753**	**513**
comment					hit botton

Table 2: Zooplankton species and densities l^{-1} in the R. Murray at Illawonga (Swan Reach). Collection date Apr. 20 '09.

Consistent with the 2003 Scott's Ck series, the SARDI 2006-7 series, and the 2008 Swan Reach series, the composition of the R. Murray zooplankton in 2009 was rotifer dominated. Notably absent from plankton tows were larger cladocerans and copepods, only a few of which (juveniles, small) were recorded. A few cladocerans and copepods were dissected from the gut contents of small fish collected concurrently (see below). Again in 2010 (Apr. 12-14), the riverine plankton at Illawonga was rotifer-dominated. Only two species were numerically abundant: a small species of *Synchaeta* and *Keratella tropica.*

In both 2009 and 2010 the microcrustacean assemblage shown on the right side of Fig. 5, relatively abundant in the late 1970's, was missing. Zooplankton densities in 2009-10 were comparable or higher, 200-2,000 ind l^{-1}, to densities recorded in the 1976-79 study, although biomass would be expected to be lower given the predominantly rotifer assemblage. Rotifers have significantly smaller biomass than even the smallest microcrustaceans. For example, the *Synchaeta* dominant in Apr. 2009/2010, all <0.2 mm, may have a dry weight of 0.27 µg (Dumont *et al.* 1975). In contrast, a 2 mm *Daphnia* may have a dry weight of 26-34 µg, and a 2 mm copepod a dry weight of 67 µg. For a juvenile fish, the dietary equivalent in *Synchaeta* of one copepod would be 248 individuals, or of one *Daphnia* would be 96-126 individual *Synchaeta*. The implications for the fish of the change in zooplankton community structure are increased search time, higher energetic expenditure per unit food captured, lower nutritive value per unit food. Notably, juvenile fish collected during the Swan Reach camps were all in poor condition, with gut contents containing terrestrial fractions, 'drop-ins' in the form of insect fragments, with little evidence of planktivory.

Circumstantial evidence suggests that the change in composition during the drought years is not related to water-quality, since all of the rotifer taxa recorded in 2003-2010 (only 2009 shown in Table 2) were present in the 1976-79 study, in similar ranges of water quality, at comparable densities (biomass proviso noted above). Fish predation is implicated in structuring the remaining zooplankton community during low flows. Fish sampling undertaken at the same time by the same students (B. Gillanders, Univ. of Adelaide, pers. comm.) revealed benthic microcrustaceans (harpacticoid copepods, chydorid cladocerans) in the gut contents of juvenile fish, and high densities of fish in the reaches sampled. Notably, all of the zooplankton listed in Table 2 are smaller than 0.4 mm, most are smaller than 200 µm. It is likely that anything larger than this in the plankton during low- or no-flow conditions prevailing at the time had been 'picked off' by visual predators.

It is apparent that the zooplankton assemblage transiting the lower Murray to Lake Alexandrina after protracted drought has changed in both composition and biomass from the late 1976-79 study; the absence of the larger microcrustaceans represents reduced biodiversity and reduced biomass for planktivorous macroinvertebrates and fish. This is significant when comparing the composition of the Lower Lakes' zooplankton over the same time period.

* * *

The Lower Lakes: Alexandrina and Albert

The zooplankton of the Lower Lakes is less studied than that of the R. Murray or headwater impoundments. A single study of L. Alexandrina zooplankton coincided over three years with the lower Murray zooplankton project cited above. Geddes (1984) reported the composition of L. Alexandrina zooplankton (1975-78) as microcrustacean dominated, not surprisingly virtually all were the same species recorded from upstream reservoirs and the mainstem river (cf. microcrustacean component of Fig. 5 with Fig. 6).

Only 28 species *in toto* were recorded from the zooplankton of L. Alexandrina, considerably lower species diversity compared to the lower Murray study, or from headwater R. Murray reservoirs. This is in part a function of sampling method - 158 µm-mesh, which misses many rotifers, vs 53 or 37 µm-mesh used by Shiel (1981), and in part a function of high turbidity in L. Alexandrina, which depresses algal productivity, with flow-on effects up the food chain.

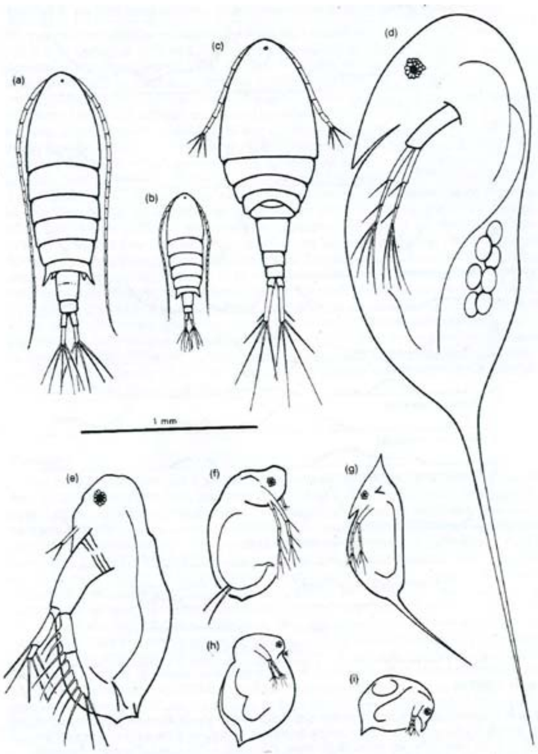


Fig. 6. Major zooplankton species in Lake Alexandrina, showing relative sizes and shapes. (*a*) *Boeckella triarticulata*. (*b*) *Calamoecia ampulla*. (*c*) *Cyclops australis*. (*d*) *Daphnia carinata*. (*e*) *Diaphanosoma unguiculatum*. (*f*) *Moina micrura*. (*g*) *Daphnia lumholtzi*. (*h*) *Ceriodaphnia quadrangula*. (*i*) *Bosmina meridionalis*.

Fig 6 shows the microcrustacean species dominants from L. Alexandrina (from Geddes 1984). All were recorded from upstream sites. Of the 15 rotifer species recorded from L. Alexandrina, generally during high flows from the Murray, some were identifiable as either R. Murray or Darling R. species, their distribution confined to one or other catchment, but persisting in the mixed assemblage below the confluence.

In contrast, similar to the recent plankton tows from the lower R. Murray noted above,samples collected from Lake Alexandrina in Jan. 2009 (M.C. Geddes, pers. comm.) were rotifer-dominated. Most abundant was the freshwater rotifer, *Keratella australis*, with several other Murray-Darling basin rotifers in small numbers. Dominant copepods were freshwater centropagids, *Boeckella triarticulata* and *Calamoecia ampulla*, also dominant in the 1984 study. Cladocerans were not well represented relative to the earlier study; this is likely a reflection of fish or macroinvertebrate predation, as suggested for the lower Murray zooplankton compositional changes noted above. Only a few alonine chydorids and juvenile *Moina micrura* were encountered, with all being <0.5 mm in size (Fig. 7).

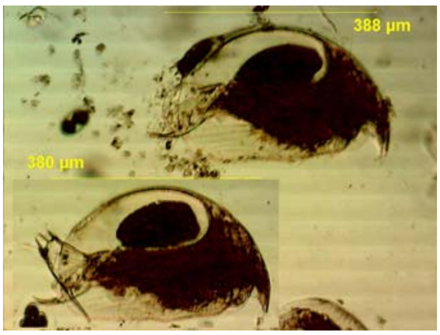


Fig. 7: Cladocera: Chydoridae: *Alona rectangula* cf. *novaezealandiae*. Two parthenogenetic females, L. Alexandrina 21.i.09. *Keratella australis* lorica lower left. [Coll. M.C. Geddes, Univ. of Adelaide, with permission.]

Relative proportions of the components of the zooplankton of L. Alexandrina (6 mS cm^{-1}) at the time of sampling, closer to the barrages at Currency Creek (24 mS cm^{-1}) and L. Albert (10 mS cm^{-1}) are listed in Table 3.

Taxon	**L. Alexandrina**	**Currency Creek**	**L. Albert**
Rotifera			
Asplanchna sieboldii	2		124
Brachionus calyciflorus amphiceros			22
Brachionus cf. *urceolaris*	1		
Brachionus plicatilis		12	
Filinia longiseta	10	1	
F. pejleri	2		
Keratella australis	62		
Keratella tropica	3		
Synchaeta **a** [lg]		12	
Synchaeta **b** [sm]		183	
Copepoda			
Boeckella triarticulata	14		*
Calamoecia ampulla	31		
Gladioferens pectinatus			138
Calanoid copepodites	32	3	28
Nauplii	39	13	2
Cladocera			
Alona cf. *rect. novaezealandiae*	3		
Moina micrura	5		
Macroinvertebrates			
Amphipoda			1
Gerriidae	*		
Vertebrates			
Naupliar fish			*

Table 3: Qualitative composition of zooplankton in three Coorong/Lower Lakes sites across a conductivity range 21 Jan. '09. [Min. count 200 ind., * = present in sample, not in first 200 ind. encountered.

Clear evidence of the spatial differences in plankton assemblages on the same day are provided by a plankton tow from the Currency Ck inlet, north of Goolwa, and closer to the barrages. It contained almost a pure rotifer culture, dominated by two undescribed species of *Synchaeta.* [Fig. 8 left]. Synchaetids are one of the few families of Rotifera recorded in estuarine or marine coastal waters worldwide. Also noted were a few *Brachionus plicatilis* [Fig. 8 right], an inland water brachionid common in salt lakes worldwide, capable of osmoregulating in saline or hypersaline waters. Only a single individual of the L. Alexandrina freshwater rotifer assemblage was recorded, a *Filinia longiseta*, which was likely dead on collection, drift from the lake proper.

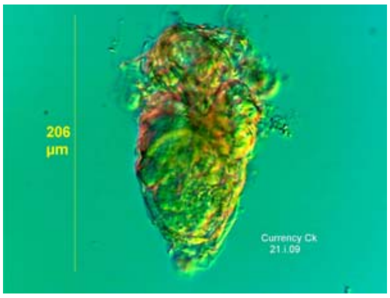
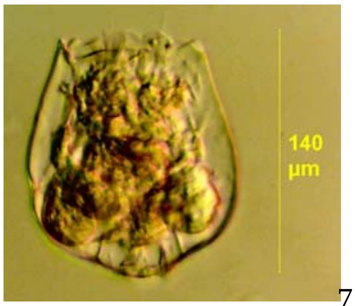


Fig. 8 (left) *Synchaeta* sp. a and (right) *Brachionus plicatilis,* Currency Ck, 21.i.09 [Coll. M.C. Geddes, University of Adelaide, with permission.]



Notably, in the course of clearing trophi (species-specific teeth) to identify the species of *Synchaeta,* gut contents of the larger species '**a**' were found to contain trophi of the smaller species '**b**' (Fig. 9), which is the first record of estuarine rotifer trophic interactions, and carnivory by *Synchaeta*, for the continent!

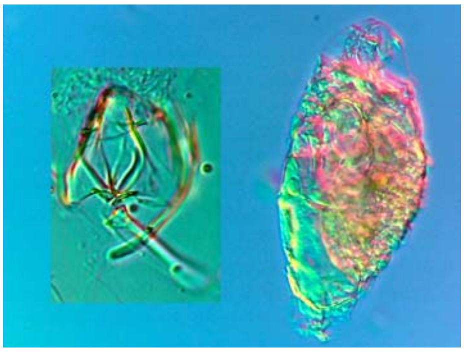
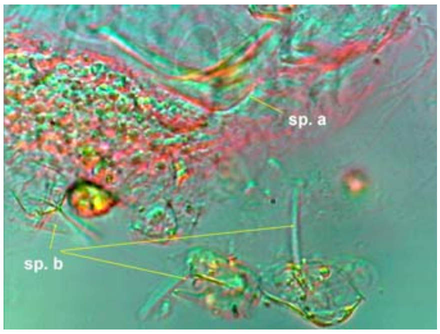


Fig. 9: *Synchaeta* sp. 'a' with eroded trophi (inset left) and gut contents (right). Five trophi of the smaller species 'b' were visible in otherwise amorphous gut contents.



As shown in Table 3, L. Albert on the same day had a markedly different zooplankton community to that in L. Alexandrina, likely a reflection of the higher salinity (10 mS cm^{-1}). Numerically dominant in L. Albert was the halotolerant calanoid copepod *Gladioferens pectinatus,* an estuarine species, the ecology of which was detailed from the Brisbane River by Bayly (1965). A few *Boeckella triarticulata* were noted, possibly hanging on at the higher concentration at the time. An amphipod, also halotolerant, was noted, as were several larval fish, species not determined, but possibly gobies.

Only two rotifer species were present in Lake Albert, albeit in large numbers (Table 3) – the euryhaline brachionid *Brachionus calyciflorus amphiceros* and it's main predator, *Asplanchna sieboldii* (Asplanchnidae). This association is notable in that the prey develops caudal spines as a defence against predation by the *Asplancha* (Fig. 10). Examination of the gut contents of several *A. sieboldii,* by erosion of tissues in sodium hypochlorite to expose the resistant teeth (trophi), demonstrated trophi of the prey in the gut (Fig. 11).

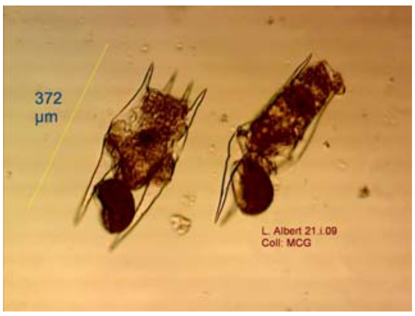


Fig. 10: *Brachionus calyciflorus,* L. Albert 21.i.09

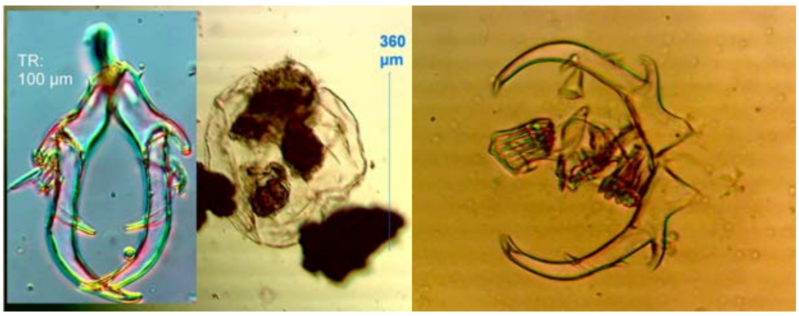


Fig. 11: *Asplanchna sieboldii* – left, trophi; centre, contracted female; right, trophi of 2nd ind.with 2 sets of prey trophi in gut contents.

The absence of other rotifers suggests that less tolerant species which may have survived in Lake Albert at lower ambient concentrations no longer do. However, it is likely that propagules in the L. Albert sediment contain all of the species which *did* occur there. There is good evidence that sedimentary propagules can recolonize a wetland very quickly after re-watering (Tan & Shiel 1993). The survival time of this egg-bank without rewetting is not known, although some copepod diapause (resting) eggs recovered from Great Lakes (USA) cores dated at >300 years were still viable (Hairston 1996).

Further zooplankton samples also were collected from L. Albert in Sept. 2009 while sampling L. Alexandrina at the Narrung barrage. The conductivity at the sampling point, east of the barrage, was about 10 mS cm^{-1}, while L. Alexandrina, west of the Narrung barrage, was 6 mS cm^{-1}, comparable to the conductivities recorded in Jan. 2009 by Mike Geddes (University of Adelaide). These samples have only been cursorily examined and await full treatment. Suffice to note here, they contained a copepod-dominated 'estuarine' assemblage of *Gladioferens* (Calanoida), *Halicyclops* (Cyclopoida) and *Mesochra* (Harpacticoida). The rotifers present in the Jan. samples were not recorded, reflecting spatial and/or temporal heterogeneity in L. Albert zooplankton community composition.

Table 3 demonstrates the inverse relationship between zooplankton species diversity and salinity. Not only are more sensitive species lost as the salinity increases; there are also compositional changes - the same *genera* may be represented, but *species* replacements occur as tolerance levels are reached or exceeded. It is likely that the 6 mS cm^{-1} recorded in L. Alexandrina on the sampling date is approaching the tolerance level of 'freshwater' microfauna. Notably, all the species recorded are eurytolerant, extending into slightly 'brackish' water.

Loss of species diversity with salinization in southern Australia was demonstrated unequivocally from >200 wetlands in the wheatbelt of W.A. by Pinder *et al.* (2005) (Fig. 12). Note that this relationship is for inland waters, and will be different for estuarine-marine diversity.

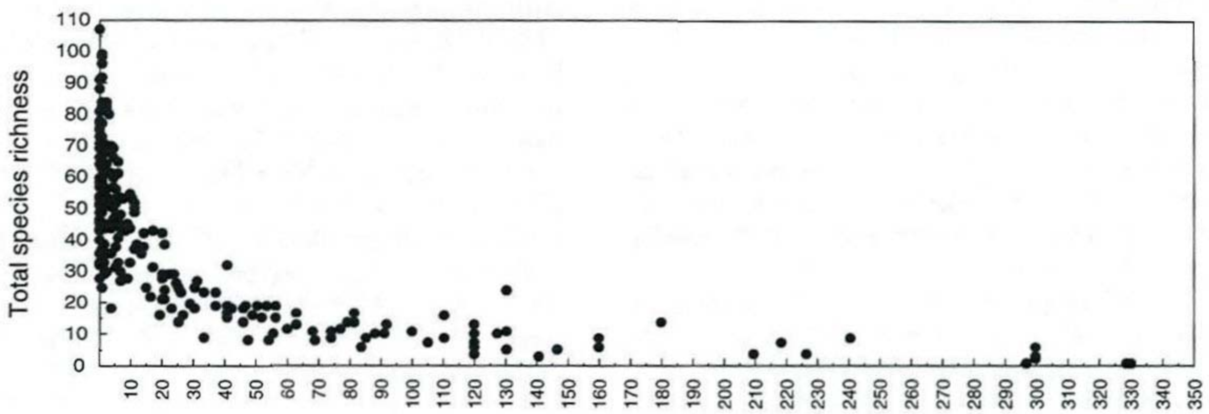


Fig. 12: Species richness vs salinity [TDS, grams L^{-1}] in 230 wheatbelt wetlands (from Pinder *et. al* .2005).

It is evident that decreased flows into L. Alexandrina, and the resulting salinization, have been a significant driver of observed changes in the zooplankton community. Food web interactions also are likely to have influenced compositional changes, but the extent of these is unstudied.

In summary, lower River Murray zooplankton discharging into Lake Alexandrina persist in the plankton community until their tolerances are exceeded, or they are eaten. There has been a significant change in the zooplankton of L. Alexandrina following extended drought conditions and reduced inflows from the R. Murray. Residual plankters appear to be widely tolerant species. On present evidence, it is unlikely that the true freshwater species of the R. Murray persist at the current 6 mg l^{-1} in L. Alexandrina. Only the euryhaline species survive, with replacement by more tolerant estuarine or halophile inland-water species which can cope in the opposite direction, i.e. into 'freshish' water. Closer to the barrages, and the influence of estuarine conditions, even the eurytolerant freshwater species are lost, replaced by euryhaline taxa. Species diversity is reduced, although biomass may not be. Species which tolerate higher salinities may reach high densities in the absence of competition. Relative biomass data for the Lower Lakes plankton assemblage is lacking.

The Coorong Lagoons

There had been no previous study of the zooplankton of the Murray Mouth or Coorong Estuary before the managed barrage release of Sept-Oct 2003 reported by Geddes (2005). The freshwater zooplankton of Lake Alexandrina (rotifers, the calanoids *Boeckella triarticulata/Calamoecia ampulla*) flushed into the Murray Mouth by the barrage releases was replaced by an estuarine assemblage in samples taken from the North Lagoon – large numbers of several undescribed species of the halophile rotifer *Synchaeta,* the copepods *Gladioferens*, *Halicyclops*, and *Mesochra.*

Further sampling along the North Lagoon during periods of no outflow (2004-2005) collected an estuarine zooplankton assemblage, including *Synchaeta*, *Gladioferens, Halicyclops* & *Mesochra*, and meroplankton including crab larve, barnacle nauplii, polychaete larvae and gastropod larvae at sites east of the Murray Mouth (Geddes *et al.* in MS).

Zooplankton also were collected during a trophic ecology study reported by Geddes & Francis (2008) after a protracted period of no flow. Plankton tows taken in 2007 and 2008 from the North Lagoon 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.

No zooplankton were collected from the hypersaline South Lagoon during the 2003-2008 sampling. Benthic ostracods (?*Diacypris*) were collected on occasions. Samples contained primarily brine shrimp (*Parartemia*), which will be reported elsewhere (M.C. Geddes, pers. comm.)

Collections from lakes around the Coorong Lagoons, e.g. De Deckker & Geddes (1980), ongoing PhD projects (e.g. by Abigail Goodman, Univ. of Adelaide pers. comm.) are not detailed here. A diverse fresh- to halophile zooplankton assemblage occurs in the numerous lakes of the southeast of S.A. which act as refugia and potential sources of inocula to the Lower Lakes and Coorong.

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Appendix:

.pdf copy of Shiel *et al.* [1982] which contains ecological ranges of lower Murray zooplankton.