Limnology of the Intermittent Pools of Bells Creek, Paroo, arid Australia, with Special Reference to Biodiversity of Invertebrates and Succession

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Timms, B.V. (2001).Limnology of the intermittent pools of Bells Creek, Paroo, arid Australia, with special reference to biodiversity of invertebrates and succession. *Proceedings of the Linnean Society of New South Wales*. **123**, 193-213.

Eight intermittent pools in Bells Creek, 130km nw of Bourke, were studied following filling in April 1998 till drying, up to 9 months later. Their waters were fresh, alkaline and turbid, except for the lower two pools which became hyposaline.The pools contained cummulatively 38 species of zooplankton, 86+ macroinvertebrates, 3 amphibians, but no fish. Momentary species richness was much less in each pool and was related to pool size, persistance, and amount of aquatic vegetation. Community structure changed as the pools matured, but not as markedly as in nearby purely lentic sites due mainly to paucity of large branchipods and persistence of dominant species. These pools are modifications of previously described wetland types.

Manuscript received 22 November 2000, accepted for publication 18 July 2001.

KEYWORDS: arid-zone creeks, environmental conditions, zooplankton, littoral macroinvertebrates, species richness, succession, wetland typology

INTRODUCTION

After significant rainfall, much of the lower and middle catchment of the Paroo River, in far western NSW and south-west Qld is a lakeland (Timms 1998a). Over the last decade, much has been learnt on the limnology of the lakes, riverine waterholes and larger wetlands (Kingsford 1999), but little data are available on the creeks in the Paroo area. Apart from the main braided course of the Paroo River, the middle Paroo catchment has few defined watercourses. One stream is Bells Creek, c. 130 km north-west of Bourke and flowing through Nellyvale, Muella and Bloodwood Stations (Fig. 1). It terminates in moderately sized salt lakes (Timms 1993) and, unusually for small watercourses of the area, has a number of pools along its lower reaches.

This paper documents the limnology of eight of these pools during a wet year (1998). Other aquatic studies in the area have concentrated on waterbirds (Kingsford and Porter 1999; Timms 1997a), saline lakes (Timms 1993, 1998b, 1998c), wetland typology (Timms and Boulton in press) and succession in claypans (Hancock and Timms unpublished data). Of particular interest in the creek pools is invertebrate community structure compared to that in larger lakes and wetlands in the Paroo. In question is the role of size and habitat type in the differentiation of aquatic invertebrates in semidesert wetlands. Also of interest is succession in these pool communities subject to some flow compared to succession in nearby claypans that are shallower, far more turbid and lentic.

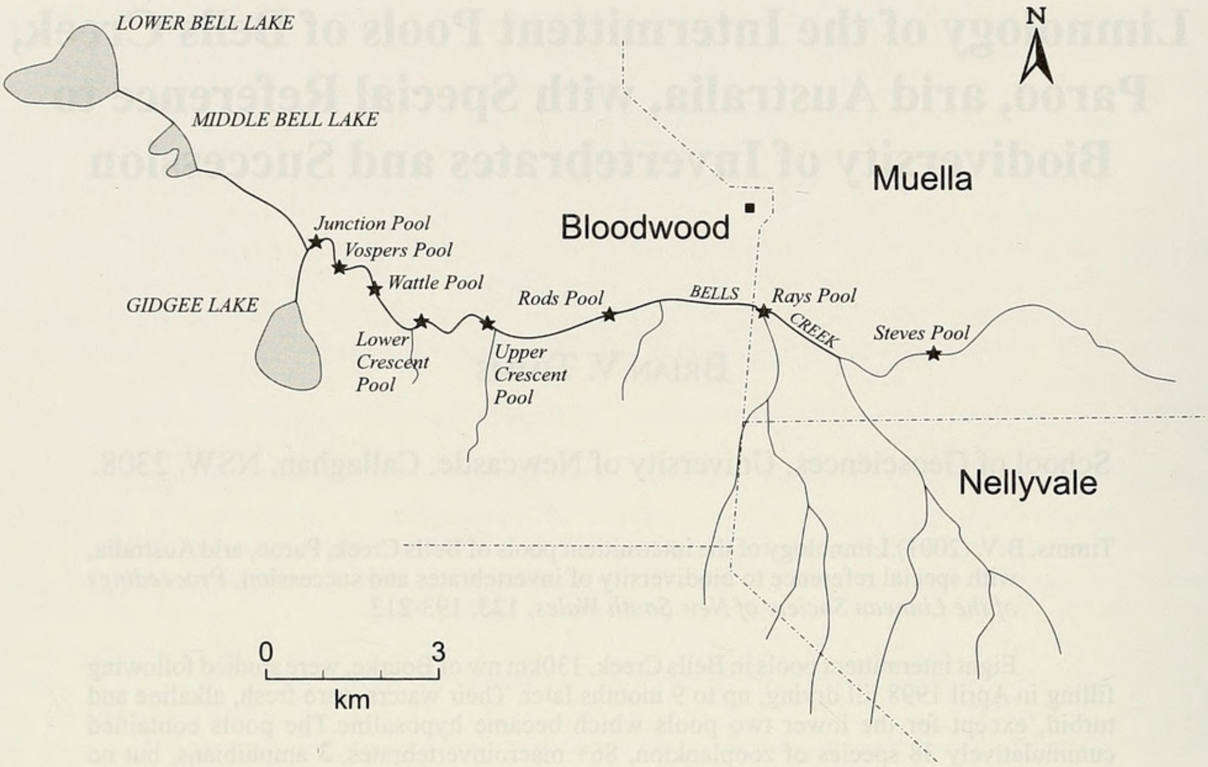


Figure 1. Map of Bells Creek showing property boundaries, the eight pools and the terminal salt lakes.

MATERIALS AND METHODS

Study Area

Bells Creek is 23 km long and flows northwest from slightly elevated stony hills towards Cuttaburra Creek, an interdistributory stream from the Warrego to the Paroo River in far north-western NSW. Bells Ck's path is blocked by quaternary dunes so that it terminates in three salt lakes and a number of pools have developed, largely on bends, in the lower gradient downstream reaches (Fig.1). These pools range in size from 85-500m long and are all less than 1m deep (Table 1). While most contained water for most of 1998, generally they dry for a large portion of each year and perhaps all year during droughts. During 1995 to 2000 their relative persistence was Upper Crescent> Lower Crescent>> Rods> Steves> Vospers> Junction> Wattle>> Rays (all names of local validity only). Observations on Bells Ck during 1998-90 suggest the creek flows after c. 25mm of rain over a day or two. Such flows are slow and may not reach the lower pools. Larger flows generated by rainfall >50-100mm scour the pools and eventually fill the terminal lakes. Annual rainfall for the area averages 310mm per year, while evaporation is c. 2600mm (Bell 1972; Timms 1997a). Rainfall figures for 1998 are from Bloodwood homestead, a few kilometres from the pools.

In 1998 the pools (see Fig 1 and Table 1) first filled after 66mm of rain on 20 and 21 April. Rainfall on 21 June, during 5-23 September and on 11 November produced similar or smaller flows to the April event. A large flow occured during July/early August following 172.5 mm of rain 18-27 July, when the creek ran for 18 days and up to 52 cms deep (R. Barden, pers. comm.). Most pools were low before this major flow (Rays Pool had dried). After this flow, levels receded at different rates, Rays Pool dried between September and November, Steves, Rods, Lower Crescent and Wattle Pools dried between November and January the next year, leaving just Upper Crescent, Vospers and Junction Pools persisting through till January from the April filling. The lower two pools (Vospers and Junction) were aided in their persistence by connection to Gidgee Lake, a terminal salt lake.

Table 1 Some physical and chemical features of eight Bells Creek pools.

Pool	Size (m)			Conductivity (µS/cm)		Turbidity (FTU)		pH	
	Length	Width	Depth⁺	mean	range	mean	range	mean	range
Steves	85	5	0.6	75	34-140	143	39-212	7.5	6.7-8.2
Rays*	110	9	0.2	134	101-155	98	38-157	8.2	8.1-8.3
Rods	220	15	0.4	358	106-756	321	28-964	7.5	7.2-8.5
Upper Crescent	410	22	0.9	263	104-932	245	40-444	7.8	7.1-9
Lower Crescent	500	17	0.7	124	80-355	211	49-448	7.5	6.6-8
Wattle	230	8	0.4	471	167-1341	194	64-368	8.1	7.3-8.7
Vospers	350	16	0.6	8962	916-66700	13	0-23	8.5	7.5-9.1
Junction	270	18	0.5	14030	1850-60600	9	3-18	8.5	7.7-8.9

*Dimensions at beginning of study; sandy stream bed shifted during study and pool partially infilled.
⁺Depth when full and overflowing

Sampling

Sampling commenced 28 April following the filling of the pools around 22 April. Subsequent visits were made on 3 & 21 May, 9 & 27 June, 16 July, 6 August, 26 September, 25 November and 21 January.

On each occasion a surface water sample from the deepest area was taken for immediate measurement of temperature, conductivity, pH, and later measurement of turbidity. Instruments used were a mercury thermometer, a HANNA HI 8633 conductivity meter, a HANNA HI 8924 pH meter and a HACH DR/2000 Spectrophotometer method 8237 for turbidity. Depth was read from a graduated staff installed in each pond.

Zooplankton was collected with a net of mesh size 159µm mounted on a pole and with a rectangular aperture 30 x 15 cm. Collections were made for one minute (2-5 minutes if plankton was sparse) in the deepest area of each pond. In the laboratory species were identified and a random sub-sample of 200 individuals counted. The remainder of the sample was scanned for rare species and these added to the count as 0.1. To simplify the data, percentage occurrences were averaged for the 8-10 samples from each pool and summarized into occurrences in the early (28 April, 3 & 21 May), middle (9 & 27 June, 16 July, 6 August) or late stages of filling (26 September, 25 November, 21 January).

Macroinvertebrates were sampled with a rectangular net of aperture 30 x 15 cm and mesh size 1mm. This was swept through the pond for 15 minutes. Animals caught were examined in a white tray and abundance recorded as r = 1 individual in whole collection, x =2-10 individuals, xx = 11-100, xxx = c. 100- c. 1,000, xxxx = c. 1,000 - 10,000, and rarely xxxxx = > c. 10,000. As for zooplankton samples, data were simplified by averaging, this time on a log scale, with the number of 'x's converted to integers. Although this method is approximate, it provides a rapid assessment of relative numbers. The notation used for occurrences in the early, middle and late stages of the filling cycle for zooplankton was also used for macroinvertebrates.

Statistical methods

Similarities in invertebrate community structure among the pools and the average situation for four wetland types (freshwater lakes, hyposaline lakes, claypans, and vegetated pools) at Bloodwood (from Timms and Boulton in press) were compared using a combination of classification and ordination approaches: hierarchial clustering and non-metric multidimensional scaling (NMDS). To ordinate the data, $\log_{10}(x+1)$ transformed data was used and the subroutine MDS in PRIMER, employing 50 random starts to minimise the risk of erroneously accepting solutions trapped in local minima (Clarke and Warwick 1994). Spearman Rank Correlations (Zar 1984) were used to assess the influence of various environmental variables on species richness in the ponds.

RESULTS

Physical and Chemical Features.

Recorded water temperatures ranged from 7.8 to 35.1°C, with the average recorded temperature for each visit ranging from c. 10°C in winter to c. 32°C in summer (Table 2).

Most pools had fresh water (conductivity <400µmS/cm), a slightly alkaline pH and were moderately turbid (200-300 FTU)(Tables 1 and 2). The two saline pools (Vospers and Junction) were different, not only in higher conductivity but their pHs were higher and turbidities lower. In general, the conductivity and pH of pools increased over time whereas turbidity reached a maximum sometime after filling (Table 2). These changes were greatest in Vospers and Junction Pools which commenced as turbid freshwater pools but finished as clear saline pools.

Table 2. Seasonal changes in some parameters.

Date	Water temperatue for all pools in ^{0}C		Predator/ non-predator ratio*		Seasonal changes in Lower Crescent Pool			
	mean	range	mean	SD	Depth in cms	Conductivity in umS/cm	pH	Turbidity in FTU
Apr-28	20.8	17.6 - 22.4	0.81	0.26	77	100	6.6	125
May-03	20.1	15.3 - 22.5	0.66	0.14	73	87	7.8	103
May-21	14.2	7.8- 20.2	0.55	0.11	70	90	7.4	163
Jun-09	13.9	12.2 - 17	0.68	0.18	60	112	7.5	301
Jun-27	11.2	8 - 15.5	0.82	0.27	74	80	7.5	270
Jul-16	10.5	9 - 11.2	0.81	0.22	59	93	7.5	360
Aug-06	16.1	12.7 - 21.4	0.94	0.21	83	83	7.3	448
Sep-26	19.8	14.2 - 24.2	1.02	0.24	86	116	7.5	80
Nov-25	24.1	20.5 - 27.5	1.10	0.35	65	355	8	49
Jan-21	32.3	30 - 35.1	0.93	0.36	dry			

*assignment follows Boulton (1999)

Aquatic plants

During the 1998 filling aquatic plants did not appear till many months after initial filling and were only common during the last third of the filling (summer). Composition varied from pool to pool, with *Marsilea drummondii* common in Steves Pool, *Eleocharis pallens* in Rods Pool, *Nitella subtilissima* in the Crescent pools, and *Glossostigma diandrum* then *Lepilaena bilocularis* in Vospers and Junction Pools. Other species present in some pools included *Callitriche stagnalis, Diplachne muelleri, Marsilea angustifolia, Mimulus repens, Myriophyllum verrucosum, Ottelia ovalifolia*, and *Vallisneria gigantea.*

Zooplankton

Thirty-eight taxa, some identified only to generic level, were caught in the eight pools (Appendix 1). This list does not include rotifers, the larger taxa of which were not common in the net zooplankton. The two largest and most persistent pools, Upper and Lower Crescent, had the most species, while the most intermittent pool, Rays, had by far the least (Fig. 2a). Many species were littoral strays appearing only rarely in collections; they were encountered more regularly in the larger pools which had more aquatic plants. Also some eulimentic species, such as *Calamoecia* spp. and *Ceriodaphnia* spp., and most conchostracans were restricted to the larger pools, further enhancing their species richness (Appendix 1). Momentary species richness varied in the same pattern between the pools as did cumulative species richness (Fig. 2a). Species turnover percentages (calculated by expressing as a percentage the number of different species since the last visit/number of species present) averaged 35% and were highest in the two pools, Vospers and Junction, which changed from fresh to saline during the study (Fig. 2a).

All pools were dominated by *Boeckella triarticulata* throughout most of their existence while *Microcyclops* sp. and/or *Mesocyclops* sp., *Daphnia angulata* and *Moina micrura* were dominant at some stage (Appendix 1). The larger pools also had *Calamoecia* spp important, while the two saline pools had additional species, *Apocyclops dengizicus, Daphnia* n.sp., *Daphniopsis queenslandensis*, and various ostracods dominant during their saline phase (Appendix 1). Large branchipods were unimportant, except in claypan-like Steves Pool, and also to a lesser extent in the next two pools downstream.

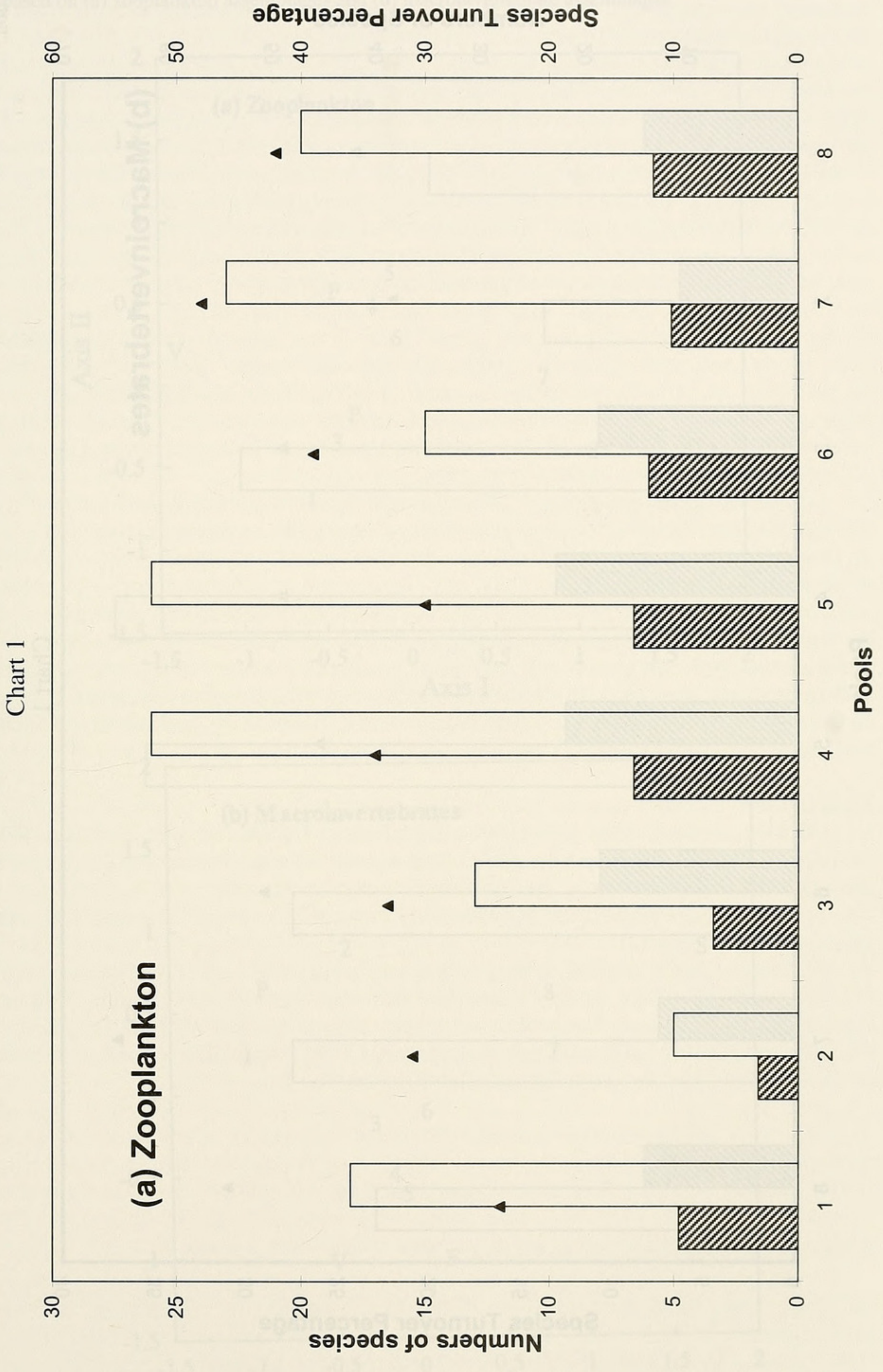
Species composition changed during the life of the pools (Appendix 1). Almost invariably the colonizers were various large branchipods, *B. triarticulata, Microcyclops* sp., *Moina micrura*, and also *Calamoecia lucasi* in the larger pools. Except for *M. micrura* and many large branchipods these persisted into the middle period of the life of the pool and were joined by *Mesocyclops* sp., *Daphnia* spp. and sometimes ostracods. The saline pools started differentiating at this stage with the appearance of *Daphniopsis queenslandensis, Cyprinotus* sp. and other ostracods. The last successional stage varied between the pools, with simplification of species structure to just the core dominants in the smaller pools, the reappearance *of M. micrura* together with *Ceriodaphnia* spp., *Simocephalus* spp., various chydorids and ostracods in the larger pools, and in the two lower pools the appearance of many saline species, particularly ostracods.

Ordination of the pool data with averages from habitat types taken from a similar study (Timms and Boulton, in press) suggested the two upper pools had similarities to claypans, three middle pools behaved like freshwater lakes, while the lower two pools had some similarities to hyposaline lakes (Fig. 3a). There was little affinity of the creek pools with vegetated pools despite the appearance of many plants late in their life.

Macroinvertebrates

Approximately 86 taxa were collected from the eight pools (Appendix 2). This list includes large ostracods, the large cladoceran *Simocephalus* and large branchipods accounted for in the zooplankton collections, but is incomplete in that benthic invertebrates, particularly chironomids, were inadequately sampled and some of the taxa probably

Figure 2a. Mean momentary species richness (bars with diagonal stripes) and cumulative species richness (clear bars) of zooplankton in the eight pools. Also shown are species turnover percentage for each pool. Key to pools: 1 = Steves, 2 = Rays, 3 = Rods, 4 = Upper Crescent, 5 =Lower Crescent, 6 = Wattle, 7 = Vospers, and 8 = Junction.



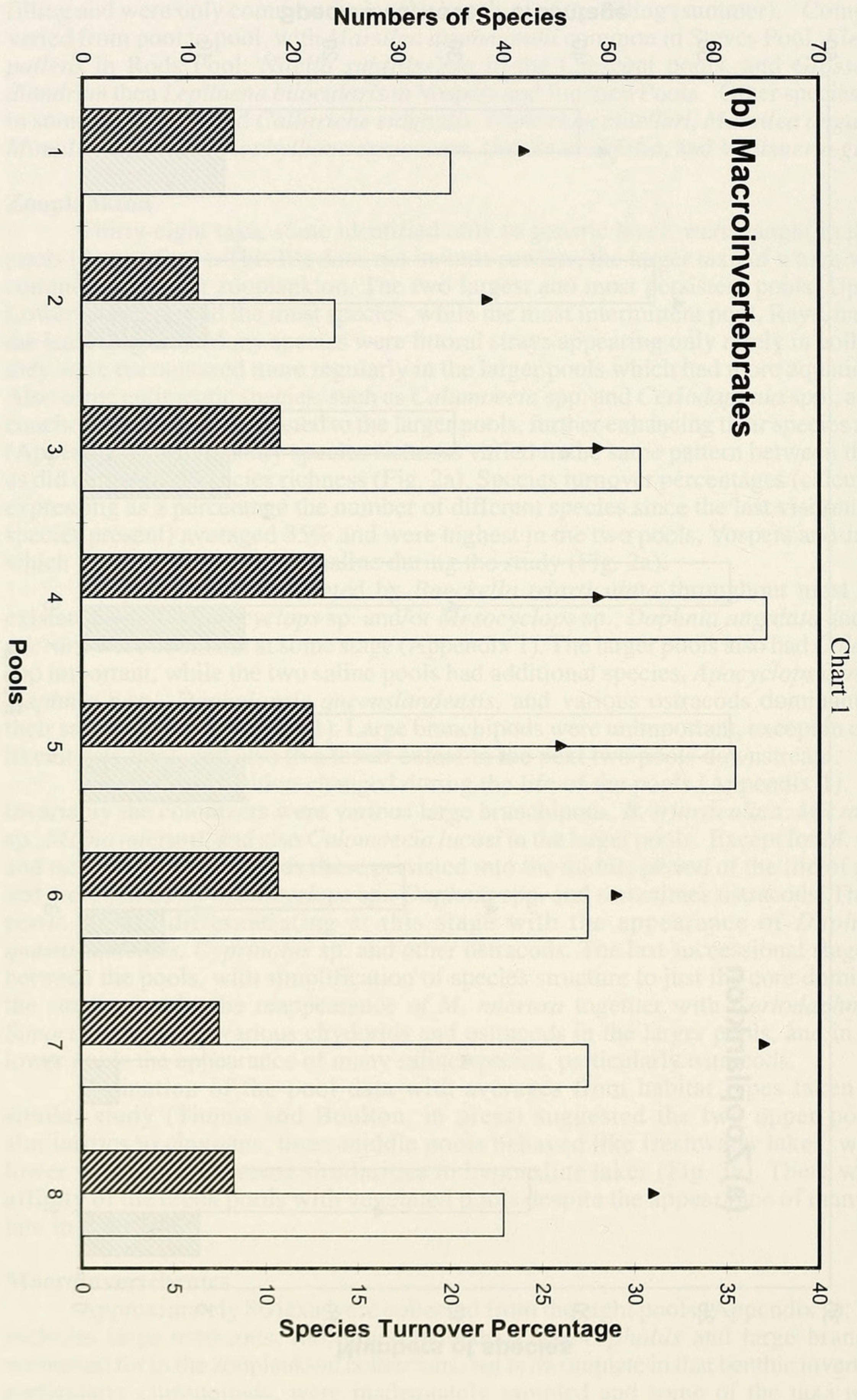
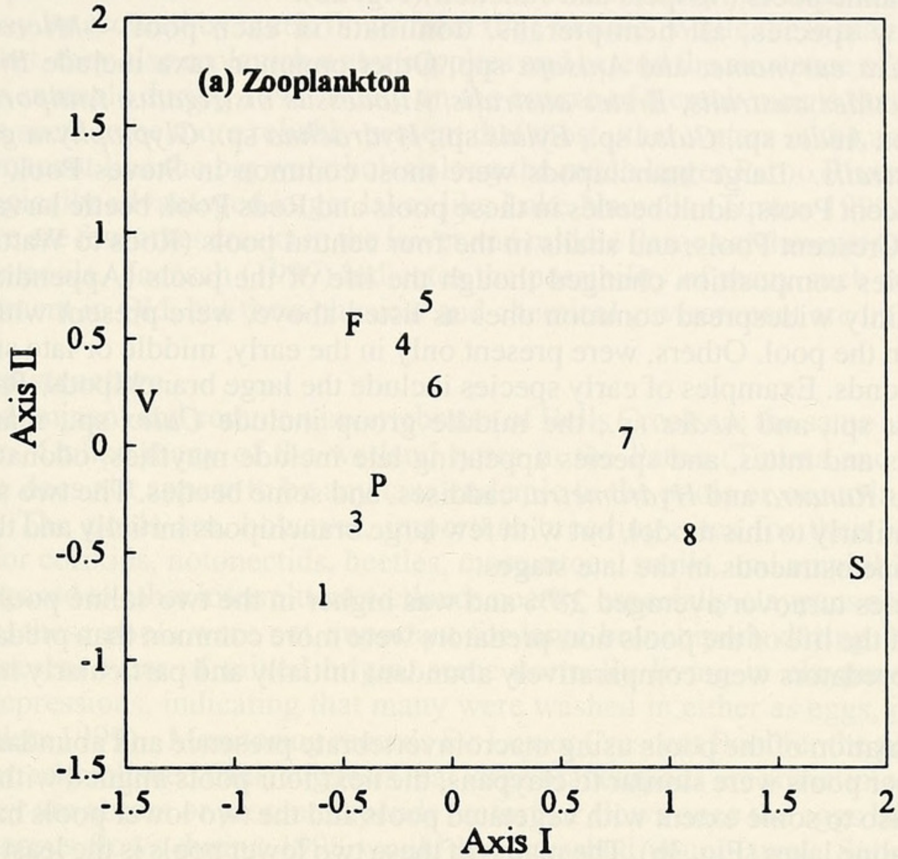
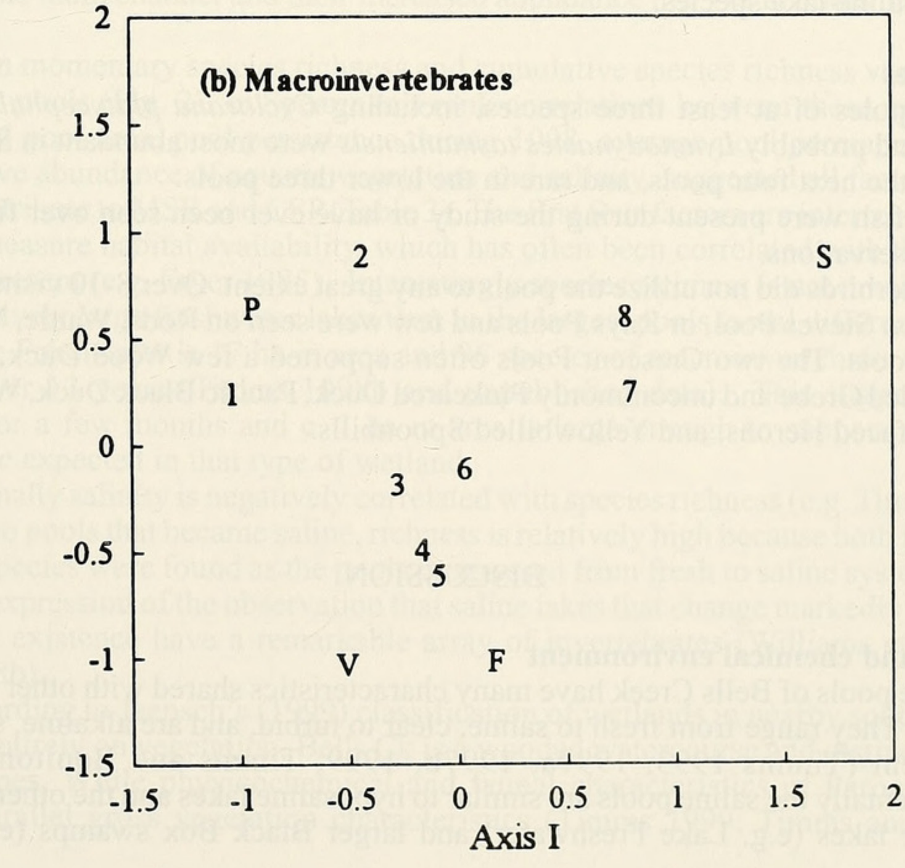


Figure 2b. Mean momentary species richness (bars with diagonal stripes) and cumulative species richness (clear bars) of littoral macroinvertebrates in the eight pools. Also shown are species turnover percentage for each pool. Key to pools: 1 = Steves, 2 = Rays, 3 = Rods, 4 = Upper Crescent, 5 =Lower Crescent, 6 = Wattle, 7 = Vospers, and 8 = Junction.

Figure 3. Ordination diagrams of the pools (numbers as in Figure 2) and averages for four wetland types (F = freshwater lakes, S = hyposaline lakes, P = claypans, and V = vegetated pools) from Timms and Boulton (in press) based on (a) zooplankton assemblages and (b) macroinvertebrate assemblages.





represent more than one species. Fifteen species are considered rare as only one or two individuals were found throughout the study. MSR and CSR varied by up to 3x between the larger more persistent pools (Upper and Lower Crescent) and the smaller (Steves and Rays) and saline pools (Vospers and Junction)(Fig. 2b).

A few species, all hemipterans, dominate in each pool —*Micronecta* sp., *Agraptocorixa eurynome*, and *Anisops* spp. Other common taxa include *Branchinella* spp., *Triplectides australis, Eretes australis, Allodessus bistrigatus, Antiporus gilberti, Berosus* spp., *Aedes* sp., *Culex* sp., *Eylais* sp., *Hydrachna* sp., *Glyptophysa gibbosa* and *Gabbia australis*. Large branchipods were most common in Steves Pool, Upper and Lower Crescent Pools, adult beetles in these pools and Rods Pool, beetle larvae in Upper and Lower Crescent Pools, and snails in the four central pools (Rods to Wattle).

Species composition changed though the life of the pools (Appendix 2). Some species, mainly widespread common ones as listed above, were present whilever there was water in the pool. Others, were present only in the early, middle or late stages in the life of the ponds. Examples of early species include the large branchipods, *Berosus* spp., *Chironomus* sp., and *Aedes* sp., the middle group include *Culex* sp., many beetles, chironomids and mites, and species appearing late include mayflies, odonates, various bugs such as *Ranatra* and *Hydrometra*, caddises, and some beetles. The two saline pools behaved similarly to this model, but with few large branchipods initially and the presence of large saline ostracods in the late stages.

Species turnover averaged 28% and was higher in the two saline pools (Fig. 2b). For much of the life of the pools non-predators were more common than predators (Table 2), though predators were comparatively abundant initially and particularly in the drying phases.

Ordination of the pools using macroinvertebrate presence and abundance showed the two upper pools were similar to claypans, the next four pools aligned with freshwater pools and also to some extent with vegetated pools and the two lower pools had affinities with hyposaline lakes (Fig. 3b). The match of these two lower pools is the least convincing perhaps because early in their existence they were dominated by freshwater species rather than hyposaline lake species.

Vertebrates

Tadpoles of at least three species, including *Cyclorana platycephala*, *Notoden bennettii* and probably *Lymnodynastes tasmaniensis* were most abundant in Steves Pool, present in the next four pools, and rare in the lower three pools.

No fish were present during the study or have ever been seen over five years of general observations.

Waterbirds did not utilize the pools to any great extent. Over 8-10 visits none were ever seen on Steves Pool, or Rays Pools and few were seen on Rods, Wattle, Vospers and Junction Pools. The two Crescent Pools often supported a few Wood Duck, Grey Teal, Hoaryheaded Grebe and uncommonly Pinkeared Duck, Pacific Black Duck, Whitenecked and Whitefaced Herons, and Yellowbilled Spoonbills.

DISCUSSION

Physical and chemical environment

The pools of Bells Creek have many characteristics shared with other wetlands in the Paroo. They range from fresh to saline, clear to turbid, and are alkaline, shallow and intermittent (Timms 1993, 1997a, 1997b, 1999; Timms and Boulton in press). Environmentally the saline pools are similar to hyposaline lakes and the others to smaller freshwater lakes (e.g. Lake Freshwater) and larger Black Box swamps (e.g. Tredega

Swamp, both nearby)(Timms 1997a). Certainly all pools are very different physically and chemically from claypans, vegetated depressions, riverine waterholes, and the more turbid lakes.

The pools are also different from other wetlands (except riverine waterholes) in that they may be scoured by creek flows from time to time. While these may wash some organisms out, they also replenish water supplies and extend the existence of the pools as they did for example during 1998. Being on the course of a creek means that at least the larger pools seem to be more reliably present that most other waters in the area, but they are not permanent like the big waterholes along the much larger Paroo River or some of the hydrologically advantaged larger lakes like Lake Numalla (Timms 1999).

There are few other creeks in the lower and middle Paroo catchment (within NSW) with similar pools. Jaensch (1999) indicates the possibility of many such creeks in the upper catchment in Qld, but their physical and chemical environment are unknown.

Community structure

The dominant and common invertebrates of Bells Creek are the same as elsewhere in the Paroo. Unlike many of the wetland types in the Paroo (Timms and Boulton in press), there does not appear to be any taxa endemic to the pools or occurring in greater abundance. The pools are, however, important breeding sites for their inhabitants, especially for corixids, notonectids, beetles, mosquitoes, snails, and amphibians.

Compared to other intermittent wetlands nearby, especially claypans and vegetated depressions, these pools were not important for large branchipods during 1998. Those that were present were of mixed origin, some normally living in claypans, others in vegetated depressions, indicating that many were washed in either as eggs, juveniles or adults (Sanders 1999). Monitoring records for Lower Crescent Pool for the period 1988-2000 (author, unpublished data) suggests that large branchipods are sometimes abundant. Whether they are absent or present depends on further flows once the eggs have hatched — the numerous flows during 1998 would have washed young away. Supporting this intrepretation is the greater abundance of large barnchipods in Steves Pool which is not located on the main channel and their increased abundance in 1998 in pools immediately below it.

Mean momentary species richness and cumulative species richness varies widely between the pools (Fig. 2). In Spearman's rank correlations between these measures of richness and pool area, pool persistence during 1998, average pool permanency 1995-2000, relative abundance of aquatic vegetation and salinity, suggested all factors, except salinity, contribute to MSR and CSR(Table 3). The first four factors are interrelated (Table 3) and all measure habitat availability, which has often been correlated with the number of species present (e.g. Fryer 1985). Interestingly species richness is not much higher in nearby relatively large freshwater lakes than in the largest pools (areal differences of 10-100x). Lake Freshwater is 17 ha in area and 96 species of macroinvertebrate have been recorded over 13 years (Timms 1998b and unpublished data). This suggests a pool persisting for a few months and c. 1 ha in area is large enough to support most local species to be expected in that type of wetland.

Normally salinity is negatively correlated with species richness (e.g. Timms 1993), but in the two pools that became saline, richness is relatively high because both freshwater and saline species were found as the pools progressed from fresh to saline systems. This is a further expression of the observation that saline lakes that change markedly in salinity during their existence have a remarkable array of invertebrates (Williams et al. 1990; Timms 1998b).

According to Jaensch's (1999) classification of wetlands in nearby south-western Qld based entirely on vegetation, Bells Ck is a wooded watercourse and distinctive from 19 other types. While physicochemical and faunal characteristics of Paroo wetlands typically parallel gross vegetation characteristics (Timms 1999; Timms and Boulton

Table 3. Spearman correlation matrix for the relationships between species richness (momentay and cumulative) and pool size, persistence in 1998, average permanency, vegetation and salinity.

	Cumulative S R	Momentary S R	Area of Pool	Persistence	Permanency	Vegetation	Salinity
Cumulative SR	1.000						
Momentary SR	0.731	1.000					
Area of Pool	0.898	0.619	1.000				
Persistence	0.778	0.476	0.905	1.000			
Permanency	0.778	0.690	0.643	0.571	1.000		
Vegetation	0.970	0.786	0.833	0.667	0.810	1.000	
Salinity	0.072	0.071	0.262	0.467	0.333	0.000	1.000

in press), correlations apparently break down at the microscale in creeks. In a comparsion of macroinvertebrate presence and abundance with other wetlands in the Paroo, Bells Ck pools do not represent an extra type of wetland, but modifications of distinctive existing types (Timms and Boulton in press). Ordinations (Fig.3) of both the zooplankton and littoral invertebrate components suggest many of the pools (Upper and Lower Crescent, Wattle and possibly Rods) are similar to freshwater lakes of the area. Steves Pool has some affinities with claypans, while the position (claypan-like or freshwater lake-like) of Rods and Rays Pools varies with the group analysed. The two pools that become saline as they age (Vospers and Junction) have some likeness to hyposaline lakes. In conclusion, while the gross environment of Bells Creek is distinctive and homogeneous according to Jaensch's (1999) classification, the individual pools are somewhat heterogeneous and not distinctive.

Succession

Species composition changed markedly over time in the pools as conditions changed. Because of the persistence of many of the dominant species during the life of the relative long existence of the pools, succession is not as distinct as in the nearby claypans (Hancock and Timms unpublished data) or vegetated depressions (author unpublished data). Nevertheless, except for the initial appearance of predators as in other Paroo intermittent waters (Timms 1997a; Hancock and Timms unpublished data), there is a change from dominance by filter/collecting feeding groups to dominance by predators, as in claypans and temporary waters in general (e.g. Lake *et al.*1989). Succession is also not as distinct as in claypans because filter feeding large branchipods are not as important in the pools as in the pans. On the other hand the development of aquatic vegetation during the existence of the pools, means many species associated with vegetation (e.g. cladocerans, ostracods, beetles) appear later in the succession.

Succession in the pools is also masked by seasonal changes and the effect of flows through them. Compared with the semipermanent lakes in the vicinity, the appearance of *Daphnia* spp in the plankton in the middle (winter-spring) stages would be expected, as would the presence of *Moina micrura and Ceriodaphnia cornuta* in warmer months. Similarly among littoral macroinvertebartes, at least some beetles and mites are summer visitors to the area. The effect of flows is harder to determine, but the appearance of some species (e.g. *Culex* sp. and *Berosus* spp.) thought to be colonizers in the middle stages of the existence of the pools would be associated with the large flow in late July and the rejuveniation of the pools. The flows are probably also important in promoting similarity among the pools, despite their differing appearance due to varying development of aquatic vegetation. The first flow is also probably responsible for the low large branchipod numbers as hatchlings would be washed away (see above).

The decline in species richness towards the final stages observed in claypans (Hancock and Timms unpublished data), was not as evident in the creek pools, because of the appearance of many species (e.g. odonates, *Ranatra dispar*) with longer development times in the pools. Also many species were associated with the development of vegetation in the pools in the middle and late stages, a feature absent in the claypans.

Species turnover was greater in the zooplankton (35.6% ± 6.0) than among the macroinvertebrates (28.1% ± 4.4), and the final assemblage contained fewer species than earlier assemblages compared to macroinvertebrates, due largely to the shorter life cycles of zooplankters. These relationships were only partially seen in the claypan successions, because of truncation by early dryness (Hancock and Timms unpublished data).

The two pools (Vospers and Junction) that became hyposaline as they matured, had higher mean species turnovers (45% for zooplankton and 34% for macroinvertebrates) than the other pools because of the demise of strictly freshwater species and the appearance of species tolerant to salinity. Not surprisingly initial and final assemblages, except for a few widespread tolerant species, were quite different in these pools (Appendices 1 and 2). As such they are typical of many lakes in the Paroo which are wide ranging in salinity (Timms 1998b).

ACKNOWLEDGEMENTS

I am greatful to Ron and Sue Barden, former landowners of Bloodwood Station and Ray and Wilga Bremner owners of Muella Station for permission to study and stay on their properties. I am also indebted to Steve Campbell, former manager of Muella Station for assistance, to numerous field assistants, to Andrew Boulton for the ordinations and to Marty Hancock for computing assistance and comments on the manuscript.

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Appendix 1. Crustacean zooplankton in the eight pools: mean percentage abundance and broad seasonal changes.

Species	Average abundance[1]	stage of succession[2]	presence at[3] 1	2	3	4	5	6	7	8
Branchinella spp.	xx	e	x	x	x	x	x	x	x	x
Limnadia sp.	x	e	x		x	x	x	x	x	
Eocyzicus n.sp.	x	e	x					x		x
Limnadopsis spp.	r	e				x				
Caenestheria sp.	x	em	x	x		x	x	x	x	
Caenestheriella n.sp.	x	e	x			x	x			
Triops australiensis Spencer and Hall	x	e	x			x	x			
copepod nauplii	x	e	x		x	x	x	x	x	x
copepod copepodites x	x	e	x			x	x	x	x	x
Boeckella triarticulata Thomson	xxxx	eml	x	x	x	x	x	x	x	x
Calamoecia canberra Bayly	xx	m				x	x			
Calamoecia lucasi Brady	xxx	eml				x	x	x	x	
Microcyclops sp.	xx	e	x		x	x	x	x	x	x
Mesocyclops sp.	xx	ml	x	x	x	x	x	x	x	x
Apocyclops dengizicus (Lepeschkin)	xx	l				x				x
Schizopera sp.	r	l								x
Latonopsis brehmi Petkovski	x	l	x		x					
Daphnia angulata Hebert	xxx	ml	x	x	x	x	x	x	x	x
Daphnia longicephala Hebert	x	m				x			x	
Daphnia projecta Hebert	x	m				x	x			
Daphnia n.sp.	x	l								x
Daphniopsis queenslandensis Sergeev	x	m							x	x
Ceriodaphnia cornuta Sars	x	l				x	x	x		
Ceriodaphnia near *dubia* Richard	x	l				x	x			
Simocephalus victoriensis Dumont	x	ml	x		x	x	x	x	x	x

Species	Average abundance[1]	stage of succession[2]	presence at[3] 1	2	3	4	5	6	7	8
Pleuroxus sp.	r	l				x	x	x		
Bennelongia sp.	r	l	x		x	x	x			
Cypretta sp.	r	l					x			
Cyprinotus sp.	xx	em							x	x
Diacypris spp.	xx	l				x				x
Heterocypris sp.	xx	l				x				x
Reticypris sp.	xx	ml							x	x
Mytilocypris splendida (Chapman)	x	l							x	x
Trigonocypris globulosa De Deckker	xx	ml							x	x
ostracod sp. a	x	m			x	x	x			
ostracod sp. b	x	l				x	x		x	
ostracod sp. c	x	l				x	x			

[1] code: r = <0.1%, x = 0.2 - 1%, xx = 1.1 - 10%, xxx = 10.1 - 25%, xxxx = >25.1%.

[2] code: e = early (April, May) in the life of the pools, middle (June - August), late (September - January).

[3] code to pools: 1= Steves, 2 = Rays, 3 = Rods, 4 = Upper Crescent, 5 = Lower Crescent, 6 = Wattle 7 = Vospers, 8 =Junction.

Appendix 2. Macroinvertebrates in the eight pools: mean log abundance and broad seasonal changes.

Species	Average abundance[1]	Stage of succession[2]	presence in[3]							
			1	2	3	4	5	6	7	8
unidentified triclad platyhelminth	r	m				x	x	x		
unidentified glossiphonid leech	x	ml			x	x	x			
unidentified richardsonid leech	r	m	x		x	x				
Branchinella spp.	xx	e	x	x	x	x	x	x	x	x
Caenestheria lutraria (Brady)	x	eml	x		x				x	
Caenestheriella spp.	xx	eml	x	x		x	x	x	x	
Limnadia sp.	x	e			x	x	x			
Eocyzicus n.sp.	x	em						x	x	x
Limnodopsis birchii (Baird)	x	e				x	x			
Limnodopsis parvispinus Henry	x	em	x	x	x	x	x		x	x
Lynceus sp.	r	e	x							
Triops australiensis Spencer and Hall	x	em	x		x	x	x	x		
Simocephalus spp.	x	ml				x	x	x	x	x
near *Eucypris* sp.	x	l				x	x			
Mytilocypris splendida (Chapman)	x	l							x	x
Trigonocypris globulosa De Deckker	xx	l						x	x	x
Cloeon sp.	x	ml		x	x	x	x	x		
Tasmanocoenis tillyardi (Lestage)	r	l				x	x			
Austrolestes annulosus (Selys)	x	l				x	x	x	x	x
Austrolestes aridus (Tillyard)	r	ml			x	x	x			
Xanthoagrion erythroneurum (Selys)	x	l			x	x	x	x	x	x
unidentified anisopteran odonate	r	l			x	x		x	x	
Diplacodes sp.	r	l							x	
Hemianax papuensis (Burmeister)	r	l			x		x			
Hemicordulia tau (Selys)	r	l			x		x			
Micronecta spp.	xxxx	eml	x	x	x	x	x	x	x	x

Species	Average abundance[1]	Stage of succession[2]	presence in[3] 1	2	3	4	5	6	7	8
Agraptocorixaeurynome Kirkaldy	xxx	eml	x	x	x	x	x	x	x	x
Agraptoco rixa hirtifrons Hale	x	ml			x	x	x			
Agraptocorixaparvipunctata Hale	x	ml	x		x	x	x	x	x	x
Anisops ?calcaratus Hale	xxx	eml	x	x	x	x	x	x	x	x
Anisops gratus Hale	xx	eml	x	x	x	x	x	x	x	x
Anisops stahi Kirkaldy	xx	eml	x	x	x	x	x	x		x
Anisops thienemanni Lundbald	xx	eml	x	x	x	x	x	x	x	x
Ranatra dispar Montandon	r	l	x			x	x			
Hydrometra sp.	r	l					x			
unidentified velid hemiptera	x	l	x		x	x	x			
unidentified microvelid hemipteran	x	l	x		x	x	x			
Oecetis sp.	x	l		x	x	x		x	x	x
Notolina sp.	r	l	x			x			x	
Triplectides ?australicus Banks	x	ml	x		x	x	x	x	x	x
Haliplus sp.	x	l	x		x	x	x	x		x
Allodessus bistrigatus (Clark)	xx	eml	x	x	x	x	x	x	x	x
Antiporous gilberti Clark	xx	eml	x	x	x	x	x	x	x	x
Cybister tripunctatus Olivier	r	l					x			
Eretes australis (Erichson)	xx	eml	x	x	x	x	x	x	x	
Hyphydrus elegans (Montrouzier)	r	l			x		x		x	
Laccophilus religatus Sharp	r	em			x	x				
Megaporus howitti Clark	r	ml	x			x	x	x	x	
Rhantus suturalis MacLeay	r	m	x			x				
Sternopriscus multimaculatus (Clark)	r	e						x	x	x
dytiscid larvae *Antiporus* sp.	xx	eml	x		x		x	x	x	x
dytiscid larvae Bidessini group	r	e					x			
dytiscid larvae *Cybister* sp.	r	ml				x				

Species	Average abundance[1]	Stage of succession[2]	presence in[3] 1	2	3	4	5	6	7	8
dytiscid larvae *Eretes* sp.	x	l	x			x	x	x		
dytiscid larvae *Hyphydrus* sp.	r	l							x	x
dytiscid larvae *Megaporus* sp.	r	m				x				
dytiscid larvae *Rhantus* sp.	r	l				x				
dytiscid larvae *Platynectes* sp.	r	l				x	x			
dytiscid larvae unidentified genus	r	l	x	x	x					
Agraphydrus sp.	r	e		x						
Berosus spp.	xxx	em	x	x	x	x	x	x	x	x
Enochrus eyrensis (Blackburn)	x	ml	x	x	x	x	x			
Enochrus maculiceps MacLeay	r	m	x							
Helochares clypeatus (Blackburn)	r	m	x	x						
Helocares tristis MacLeay	x	l					x			
Hydrophilus brevispina Fairmaire	r	l			x		x			
Paracymus pygmaeus (MacLeay)	r	l			x					
Sternolopus immarginatus d'Orchymont	r	l	x		x					
hydrophilid larvae *Berosus* spp.	x	eml		x	x		x	x	x	x
hydrophilid larvae *Hydrophilus* sp.	r	ml			x		x			
hydrophilid larvae unknown sp. a	r	ml	x			x	x			
hydrophilid larvae unknown sp. b	r	l				x				
Hydrochus australis Motschulsky	x	ml	x		x	x	x		x	
Spercheus platycephalus MacLeay	r	l			x					
spercheid larvae *Sprecheus* sp.	r	l			x	x	x			
Dineutes australis (Fabricus)	r	l			x	x				
unidentified curculionid beetle	r	e			x	x	x	x		
scirtid larvae unidentified species	r	e				x	x			
Ablabesmyia notabilis Skuse	r	e				x	x		x	
Coelopynia pruinosa Freeman	r	em			x	x	x			

Species	Average abundance[1]	Stage of succession[2]	presence in[3] 1	2	3	4	5	6	7	8
Chironomus sp.a	r	em				x				x
Chironomus sp. b	r	e				x				
Cyrotpchironomus griseidorsum Keiffer	r	m				x	x			
Dicrotendipes sp.	r	l	x							
Paratanytarsus sp.	r	e							x	x
Polypedilum nubifer Skuse	x	ml				x	x	x	x	x
unidentified ceratopogonid larvae	r	e						x	x	x
Aedes sp.	xx	e		x	x	x	x	x	x	x
Culex sp.	xx	m	x	x		x	x	x	x	x
Anopheles sp.a	r	ml			x	x	x			
Anopheles sp. b	r	m				x	x			x
unidentified culicid larvae	r	e				x	x			
unidentified stratiomyid larvae	r	l						x	x	
unidentified tabanid larvae	r	e			x	x	x		x	x
unidentified pyralid larvae	r	l			x	x		x	x	x
Arrenurus spp.	x	ml				x	x	x	x	
Diplodontus spp.	x	eml			x	x	x	x	x	x
Eylais spp.	xx	eml	x		x	x	x	x	x	x
Hydrachna spp.	r	ml				x			x	
Limnesia spp.	r	l			x	x	x	x		
Gabbia australis Tryon	xxx	eml			x	x	x	x	x	
Glyptophysa gibbosa (Gould)	xxx	eml	x	x	x	x	x	x	x	x
Isidorella newcombi Adams & Angas	x	eml	x		x	x	x			

1 code: r = <0.05, x = 0.06 - 0.2, xx = 0.21 - 1, xxx = 1.1 - 2.5, xxxx = >2.51 log mean abundance
2 code: e = early (April, May) in the life of the pools, middle (June - August), late (September - January).
3 code to pools: 1= Steves, 2 = Rays, 3 = Rods, 4 = Upper Crescent, 5 = Lower Crescent, 6 = Wattle
7 = Vospers, 8 =Junction.