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Buntine-Marchagee NDRC

Wetland Invertebrate Sampling 2008

Prepared by

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Frontispiece (top to bottom): W016; W023 (Hodgson North); and Melissa Cundy sampling the invertebrate fauna at W011 (all photos taken by Andrew Storey/WRM, August 2008).

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1 INTRODUCTION

1.1 Background

The Buntine Marchagee Natural Diversity Recovery Catchment (BMNDRC) was selected as a recovery catchment under the State Salinity Strategy. The Strategy describes Recovery Catchments as a key measure for biodiversity conservation under the 1996 Salinity Action Plan (SAP). Recovery Catchments are based on the identification of major, high priority public assets that are at risk from salinity and warrant significant, ongoing investment in their recovery and protection. The operational goal of the BMNDRC project is **"for the next 10 years, maintain the 2007 richness, distribution, abundance and condition of a representative sample of biodiversity assets threatened by salinity within the BMNDRC"** (DEC 2007).

A number of factors contributed to the selection of the Buntine-Marchagee catchment as a NDRC. Firstly, the catchment supports a diverse range of wetland types, and its naturally saline braided channels sustain a significant proportion of the regional invertebrate fauna. In addition, there are a variety of key ecological and social values, including terrestrial vegetation associations, declared rare and priority flora, potential Threatened Ecological Communities (TEC's), threatened and priority fauna, indigenous and non-indigenous cultural values and recreational use. Finally, there is local support for landcare-associated projects within the catchment, and such support is necessary if any rehabilitation or active management is to be successful.

A number of aquatic studies have already been undertaken within the BMNDRC (Storey *et al.* 2004a & b, Lynas *et al*. 2006). To assist in the characterisation and prioritisation of the numerous wetlands throughout the Buntine-Marchagee catchment, and to begin the collection of baseline data to assess the effectiveness of management actions, twenty wetlands were originally chosen for detailed sampling. To maximise the biodiversity recorded, wetlands were selected to provide a geographical spread along the main braided drainage system, with a range of different physical characteristics and types of remnant vegetation communities. The selection also focused on those with the best examples of relatively intact remnant fringing vegetation.

Eight wetlands were sampled in November 2003 by the Department of Conservation and Land Management (CALM) for a range of parameters including aquatic invertebrates, water chemistry, fringing and aquatic vegetation and wetland-scale water dynamics. The November 2003 invertebrate sampling was the first of a number of aquatic invertebrate surveys undertaken in these wetlands. Due to low water levels only eight of the twenty wetlands could be sampled, however, this limited sampling provided:

- a late spring sample to act as a baseline against which comparison can be made;
- establishment of sites for on-going monitoring; and
- a test of field sampling protocols.

BMNDRC wetlands were again sampled in August 2004 and August 2005 by the authors. Following good winter rains, a total of twenty wetlands were sampled on both occasions. This sampling was undertaken to further develop the baseline for comparison with future years, to assess the conservation value of the wetlands, and to assess temporal change against samples collected from the eight wetlands in 2003.

Analysis of the 2004 and 2005 data consistently demonstrated a clear separation of sites into the same general groupings as identified from physico-chemical parameters (viz. fresh/brackish and hypersaline), indicating that water quality was a major influence on invertebrate composition (Storey *et al*. 2004a and b, Lynas *et al*. 2006). Hypersaline wetlands had relatively low biodiversity in terms of species richness when compared against previous studies from southwestern Australia, however, the few fresh/brackish wetlands had relatively high taxa richness (Storey *et al*. 2004a and b, Lynas *et al*. 2006). The fauna of the wetlands, particularly the saline wetlands generally consisted of ubiquitous and cosmopolitan species, commonly found across southern Australia. The exceptions were, a possible new species of non-biting midge (Chironomidae) (?*Cladopelma* sp. nov.), a new species of *Hexarthra* rotifer, *Hexarthra propinqua*, being the first record from Australia of a species previously recorded principally from Europe, the collection of the rotifer *Trichocerca obtusidens* in 2004 which has not formally been recorded from Australia, and two native species of brineshrimp, *Parartemia serventyi* and *Parartemia contracta*, endemic to south-western Australia. Endemic taxa were consistently recorded from the fresher water sites, which also supported the greatest overall species richness (Storey *et al*. 2004a and b, Lynas *et al*. 2006).

Following the August 2005 sampling, the authors developed a means for assigning biodiversity priority to the BMNDRC wetlands for future monitoring. Priority was determined on the basis of both biodiversity and pairwise similarity over time. Wetlands were ranked according to the total number of invertebrate taxa recorded, the total number of vertebrate fauna (fish, frogs and birds), the number of conservation significant fauna (including southwest endemic, locally endemic, species new to science and IUCN Redlisted fauna), and percent pairwise similarity over time. The mean across these individual ranks was calculated, and wetlands ordered according to their mean rank. Based on this ranking, ten wetlands were chosen for ongoing monitoring, with five from each salinity type (i.e. five hypersaline and five fresh/brackish sites). Priority wetlands chosen for future monitoring based on their high biodiversity include, the hypersaline wetlands W002, W061, W004, W001, and W019, and the fresher water sites W011, W072, W020, W010, and W009.

Based on data collected by Storey *et al.* (2004a & b) and Lynas *et al*. (2006), it was considered that the sampling gave a robust data set, which detailed aquatic faunal biodiversity and causal relationships between the fauna and physico-chemical conditions within the BMNDRC. It was considered that additional samples in future years from these and adjacent wetlands, particularly fresh/brackish wetlands, will provide greater insights into their conservation significance, a better understanding of inter-annual variation, and would provide the basis for ongoing monitoring, against which future change, either improvement or deterioration may be assessed.

Sampling to date had consisted of single snap-shots of the catchment at one instance in time each winter, with the actual time of sampling varying depending on rainfall and length of the winter season. The only unknown to date was whether the faunal assemblages within a wetland varied significantly over the hydrocycle (i.e. from first filling at the start of winter until they dried in late spring), and whether within-wetland changes were greater or less than between-wetland differences. It was unknown whether assemblage composition was consistent over the period of inundation, or whether composition changed over time, either predictably or randomly. It was also unknown how salinity levels within a wetland varied over the winter fill period, and if large variations were experienced, whether this influenced assemblage composition, and it was unknown if species of conservation significance appeared and disappeared over the winter period or were always present. Obviously, if large temporal changes occurred naturally, it would be difficult to compare within and across wetlands over time, unless sampling was standardised to the exact same time in the hydrocyle in terms of salinity concentration, length of time since inundation etc. Answering these issues was seen as a final, critical step before ongoing monitoring could commence, otherwise future monitoring may not be able to differentiate natural seasonal cycles in assemblage composition from anthropogenic-influenced changes. Therefore, it was decided to resample the priority suite of wetlands identified by Lynas *et al*. (2006) on at least three occasions over the 2006 winter period, ideally shortly after filling, in mid-winter and as the wetlands receded to measure changes in physico-chemistry and determine relative changes in assemblage composition.

1.2 Study objectives

The overall objective of the study was to sample 10 wetlands (+/- 5) in the BMNDRC on three occasions during winter 2006 to assess successional changes in aquatic invertebrate fauna in each wetland in relation to changing salt concentrations and salt loads.

Where possible, the data were to be analysed to determine:

- Which wetlands have the most biodiversity? How does this ranking vary when different parameters are considered? (eg. permanent versus temporary resident fauna)?
- What is the conservation significance of each taxa, assemblage and wetland?
- What species are common across a number of wetlands? What species are unique to individual (or group of) wetlands
- Which of the 2006 samples seem to have similar suites of invertebrate communities, with a measure of this similarity? Which species (or group of species) define these wetland types?
- What is the similarity / dissimilarity between the parameters measured at each of the wetlands, with a measure of this?
- What are the relationships between biodiversity and physico-chemistry of each wetland?
- What differences and similarities are there from the data available for those sites sampled in 2006 and previous sampling
- Which components (e.g. micro, macro, insects, crustacea) show the least variability, being the component to target for future monitoring. i.e. the greatest ability to detect change?

- What are the minimum wetland monitoring requirements (i.e. timing and parameters) for each wetland to be able to effectively evaluate future management actions?

Sampling for this project was intended to take place over the winter of 2006, however, the northern Wheatbelt Region suffered a drought in winter of 2006 and 2007, with below average rainfall, with many wetlands failing to fill. Therefore, sampling was suspended until sufficient winter rains occurred to allow sampling across the winter months. Following good early rains in May/June 2008, it was decided to proceed with this project over the winter of 2008.

2 METHODS

2.1 Study area

The Buntine-Marchagee Natural Diversity Recovery Catchment (BMNDRC) is located in the Northern Wheatbelt Region, in the vicinity of the towns of Dalwallinu and Coorow, approximately 250 km NNE of Perth. Within the extensively cleared catchment, there are over 1000 wetlands and six broad wetland types. The range of wetland types includes fresh/brackish wetlands, bentonite wetlands, freshwater claypans, gypsum lakes, granite rock pools and saline wetlands and channels.

2.2 Sites and sampling design

A total of 14 wetlands were selected for sampling within the BMNDRC during August (13th – 15th), September (15th – 16th) and October (22nd – 23rd) 2008 (Table 1 and Figure 1). Due to the ephemeral nature of some wetlands, not all wetlands were able to be sampled on all occasions (see Table 1). Wetlands selected for sampling were either those previously determined as 'priority wetlands' by Lynas *et al*. (2006), or additional wetlands sampled at the request of the DEC.

Following the 2005 aquatic surveys, Lynas *et al*. (2006) assigned ten wetlands as priority for future monitoring. Priority wetlands were determined on the basis of both biodiversity and high percent temporal pairwise similarity (i.e. wetlands which showed low inter-annual variability). Wetlands were ranked according to the total number of invertebrate taxa recorded (temporary and permanent taxa), the total number of vertebrate fauna (fish, frogs and birds), the number of conservation significant fauna (including southwest endemic, locally endemic, new species to science, & IUCN Redlisted fauna), and percent temporal pairwise similarity (Lynas *et al.* 2006). Wetlands were then ordered according to their mean overall rank, with five wetlands selected from each broad salinity type (hypersaline and fresher water sites) (Table 2).

Of the ten priority wetlands determined by Lynas *et al.* (2006) seven were selected for sampling during the current study (Table 2). The hypersaline wetland W061 was not included in the current survey as it was considered highly degraded by the BMNDRC project team. The fresher wetlands W020 and W072 were also excluded as W020 has appeared as a result of rising water tables since land clearing (and is also located just outside the BMNDRC), and site W072 consists of freshwater pools on a granite outcrop, and therefore was not considered to be directly threatened by salinity, and so of low risk.

However, an additional seven sites were sampled at the request of the DEC. These included:

- sites W015 and W016 which had previously been sampled and found to have reasonably high priority rank. Although they were not in the top ten of Lynas *et al.* (2006), these wetlands had other values (vegetation and social/cultural values) which made them worthy of monitoring (and possibly worthy of active management).

- site W012 had previously been sampled as part of site W011 (a high priority wetland as determined by Lynas *et al*., (2006)), but was sampled as a separate site in 2008 so that its own biodiversity values could be determined.
- site W013 is a new site located in the vicinity of sites W011 and W012, which was considered to be in good condition and had good riparian vegetation and therefore included to document biodiversity values (see Figure 1)
- site W074 was a newly identified shallow claypan wetland, containing freshwater, which was added to the survey to document biodiversity values of this wetland type not yet represented in the surveys.
- sites W023 and W024 are also additional wetlands, recently discovered by the BMNDRC project team. They appeared in good condition, with fresher water, good riparian vegetation and relatively diverse waterbird populations, and were added to the survey to document biodiversity values of these new wetlands.

Table 1. Sites sampled within the BMNDRC during August, September and October 2008.

			Sampled in 2008			Sampled previously		
Site		**Salinity Category**	**August**	**September**	**October**	**2003**	**2004**	**2005**
W001	Koobabbie/Gypsum lake	Hypersaline	✓	✓	✓			✓
W002	Koobabbie/Gypsum lake	Hypersaline	✓	✓	✓	✓	✓	✓
W004	Dobson's lowland	Hypersaline	✓	✓	✓	✓	✓	✓
W009	Hunts mid-slope	Brackish	✓	✓	✓	✓	✓	✓
W010	Saline playa (SAP site)	Saline	✓	✓	✓	✓	✓	✓
W011	Hunts upslope	Saline	✓	✓	✓	✓	✓	✓
W012	Hunts upslope	Hypersaline	✓	✓	✓			
W013	Hunts upslope	Saline	✓	✓	✓			
W015	Nabappie wetland suite	Saline	✓	✓	✓			✓
W016	Nabappie wetland suite	Saline	✓	✓				✓
W019		Hypersaline	✓	✓	✓	✓	✓	✓
W023	Hodgson's wetland north	Brackish	✓	✓	✓			
W024	Hodgson's wetland south	Fresh	✓	✓	✓			
W074	Claypan	Fresh	✓					

Table 2. Wetlands ranked by 'priority', as determined by Lynas *et al.* (2006) on the basis of both biodiversity and percent temporal pairwise similarity.

Wetland type	Wetland code	Priority rank	Sampled in 2008
Hypersaline	W002	1	✓
	W061	2	
	W001	3	✓
	W004	4	✓
	W019	5	✓
	W070	6	
	W008	7	
	W056	8	
Fresher (brackish & saline)	W011	1	✓
	W020	2	
	W010	3	✓
	W009	4	✓
	W072	5	
	W015	6	✓
	W016	7	✓
	W052	8	

Photographs of the 14 wetlands sampled during 2008 are provided in Appendix 1.

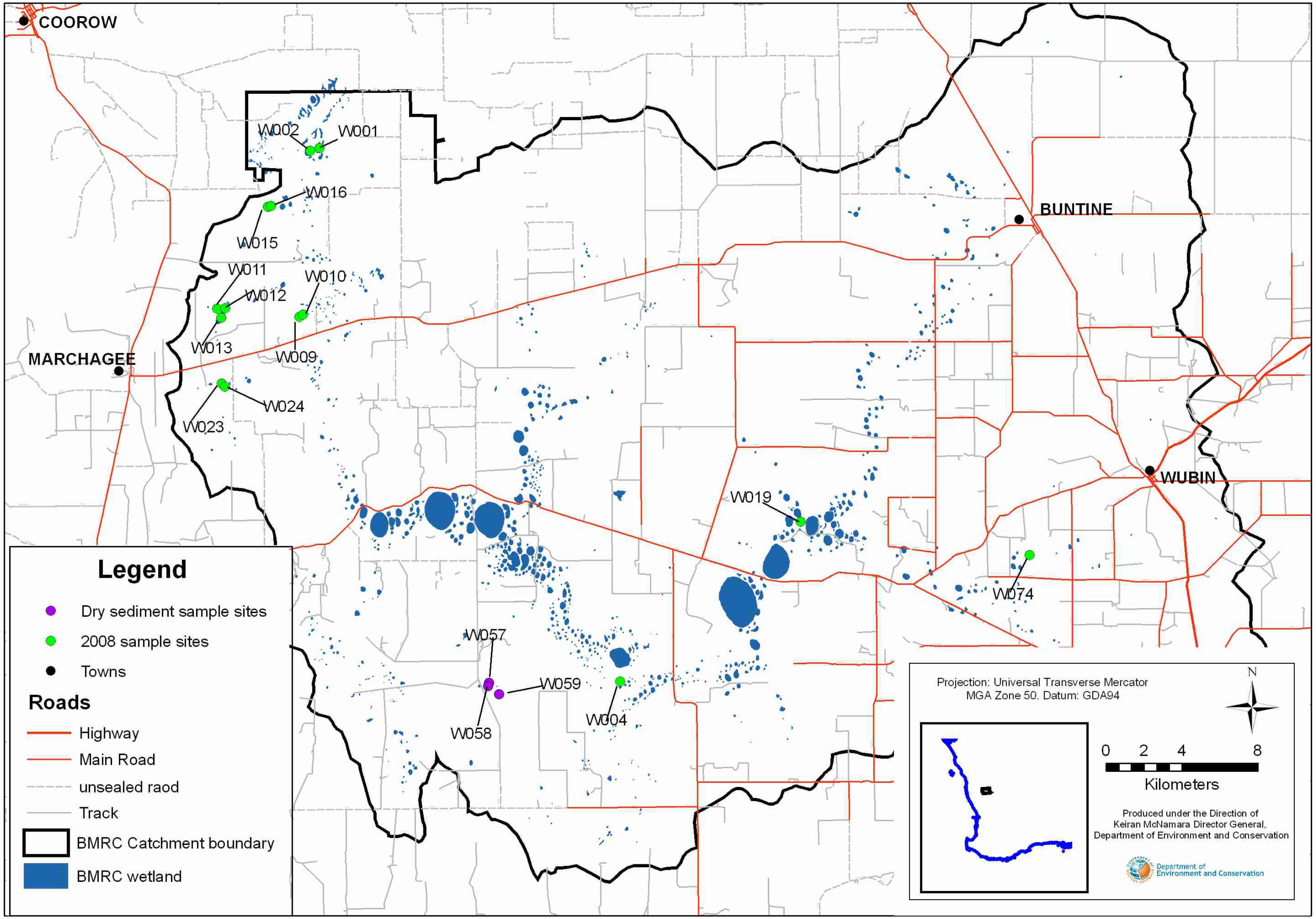


Figure 1. Location of sites within the BMNDRC.

2.3 Environmental characteristics

When sampling at each wetland on each occasion, a number of environmental characteristics were recorded. Water depth was measured either using a graduated pole or the depth gauge established in the wetland. The extent of macrophyte cover was visually appraised, and recorded as percentage cover for each wetland. The presence of a salt crust within wetlands was also recorded, with crust thickness (mm) being reported. Benthic mat thickness (mm), when present, was also recorded.

At each site a number of water quality variables were recorded *in situ* using portable WTW field meters, including pH, electrical conductivity (mS/cm), dissolved oxygen (% and mg/L), redox (mV), and water temperature (°C). Undisturbed water samples were taken for laboratory analyses of turbidity, nutrients (total nitrogen and total phosphorus). Samples collected for nutrients were filtered through 0.45 μm Millipore nitrocellulose filters. All water samples were kept cool in an esky while in the field, and frozen as soon as possible for subsequent transport to the laboratory. All laboratory analyses were conducted by the Natural Resources Chemistry Laboratory, Chemistry Centre, WA (a NATA accredited laboratory). Water quality variables measured are summarised in Table 3.

Table 3. Water quality parameters measured.

Parameter	Units
Dissolved oxygen	%
Dissolved oxygen	mg/L
Water temp	°C
Conductivity	mS/cm
pH	
Redox potential	mV
Depth	m
Colour	TCU
Total nitrogen	mg/L
Total phosphorus	mg/L
Turbidity	NTU
Salt crust	mm
Benthic mat thickness	mm
Macrophyte cover	%

To provide a means of comparison, water quality was assessed against the guidelines for the protection of aquatic ecosystems (ANZECC/ARMCANZ 2000), using data specific to slightly disturbed wetlands from south-west Western Australia. The ANZECC guidelines specify biological, sediment and water quality guidelines for protecting the range of aquatic ecosystems, from freshwater to marine (ANZECC/ARMCANZ 2000). The primary objective of the guidelines is to "maintain and enhance the 'ecological integrity' of freshwater and marine ecosystems, including biological diversity, relative abundance, and ecological processes" (ANZECC/ARMCANZ 2000).

Caution must be taken when applying trigger values to natural systems because the guidelines are generic and somewhat conservative. A recorded value outside the guidelines does not necessarily indicate anthropogenic disturbance. When applying trigger values (TVs), ANZECC/ARMCANZ (2000) state the following:

> *"Trigger values are concentrations that, if exceeded, would indicate a potential environmental problem, and so 'trigger' a management response, e.g. further investigation and subsequent refinement of the guidelines according to local conditions." (Section 2.1.4); and*
>
> *"Exceedances of the trigger values are an 'early warning' mechanism to alert managers of a potential problem. They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity." (Section 7.4.4).*

Hence, TVs should not be used in a 'pass-fail' approach to water quality management. Their main purpose is to inform managers and regulators that changes in water quality are occurring and may need to be investigated. Where natural levels of a parameter exceed the generic trigger value due to naturally elevated levels (i.e. due to natural mineralization in a catchment), ANZECC/ARMCANZ (2000) recommend development of system-specific trigger values to better reflect the natural state of the river or wetland.

2.4 Invertebrate fauna

Aquatic invertebrates were collected from each wetland on each sampling occasion. Microinvertebrate samples were collected by gentle sweeping over an approximate 15 m distance with a 53 µm mesh pond net. Care was taken not to disturb the benthos (bottom sediments). Samples were preserved in 70% ethanol and sent to Dr Russ Shiel of The University of Adelaide for processing. Dr Shiel is a world authority on microfauna, with extensive experience in fauna survey and impact assessment across Australasia, including Western Australia, and the BMNDRC.

Plate 1. Using the 250 µm mesh pond net to selectively collect aquatic macroinvertebrates at W011 (photo by Andrew Storey/WRM, 2008).

Microinvertebrate samples were processed by identifying the first 200-300 individuals encountered in an agitated sample decanted into a 125 mm^2 gridded plastic tray, with the tray then scanned for additional missed taxa also taken to species, and recorded as 'present'. Specimens were identified to the lowest taxon possible, i.e. species or morphotypes. Where specific names could not be assigned, vouchers were established and specimens/images sent to various world experts. These vouchers are held by Dr Shiel at The University of Adelaide, South Australia.

Macroinvertebrate sampling was conducted with a 250 µm mesh FBA pond net to selectively collect the macroinvertebrate fauna. All meso-habitats were sampled, including trailing riparian vegetation, woody debris, open water column (Plate 1), and benthic sediments with the aim of maximising the number of species recorded. Each sample was washed through a 250 µm sieve to remove fine sediment, leaf litter and other debris. Samples were then preserved in 70% ethanol.

In the laboratory, macroinvertebrates were removed from samples by sorting under a low power dissecting microscope. Collected specimens were then identified to the lowest possible level (genus or species level) and enumerated to $\log_{10}$ scale abundance classes (*i.e.* 1 = 1 - 10 individuals, 2 = 11 - 100 individuals, 3 = 101-1000 individuals, 4 = >1000). In-house expertise was used to identify invertebrate taxa using available published keys and through reference to the established voucher collections held by the ARL. External specialist taxonomic expertise was sub-contracted to assist with Chironomidae (non-biting midges) (Dr Don Edward, The University of Western Australia).

2.5 Vertebrate fauna

Water-dependent vertebrate fauna were noted while sampling at each wetland. Opportunistic surveys of adult frogs were conducted in conjunction with aquatic surveys, by comparing any calls heard on the day of sampling with audio files for south-west species. The total number of each species of water-dependent bird (*i.e.* waterfowl, water hen, herons, egrets, cormorants *etc*) was recorded from the vicinity of each wetland. There is a tendency to 'drive' birds along the watercourses when sampling, so every attempt was made to avoid counting birds twice and not to count birds moving from one site into the next. Although fish were not specifically targeted, they were occasionally caught in macroinvertebrate sweep samples. Any fish collected were identified according to Allen *et al.* (2002).

2.6 Bentonite wetlands

As mentioned previously, the BMNDRC supports wetlands of numerous types, including bentonite wetlands. The bentonite wetlands are of special interest because their substrate is uncommon in southwestern WA, making them distinctive, especially with respect to flora. Reflecting their uniqueness, several bentonite wetlands just to the south-west of the BMNDRC have been nominated as Threatened Ecological Communities. To fully document the biodiversity values of the BMNDRC, it was necessary to examine the invertebrate taxa diversity, abundance and composition of these wetlands. However, to-date the wetlands have not held water during any of the sampling rounds conducted by the DEC or the authors.

Wetlands in Australia, particularly ephemeral and seasonally-inundated wetlands tend to support two broad groups of fauna, 'temporary residents' which recolonise a waterbody when it is inundated (i.e. midge larvae, dragonflies, damselflies, mosquitoes, beetles, mayflies etc), and 'permanent residents' which are always present in the wetland, but survive periods when the wetland is dry through resistant life stages (i.e. drought-resistant eggs). By re-hydrating samples of wetland sediment in the laboratory it is possible to trigger the emergence of a proportion of these 'permanent' residents from their resistant stages, and thereby document the fauna of the wetland. Knowledge of the permanent residents provides an integrated measure of the wetland over recent seasons/years.

Therefore, following the 2008 aquatic survey, dry sediment samples were collected in mid-summer from three bentonite wetlands within the BMNDRC (W057, W058 & W059; Figure 1). Drought resistant eggs of permanent resident fauna of ephemeral wetlands tend to settle in the surficial sediments (i.e. top ~ 5 mm – 10 mm), and tend to collect around the waterline where they may be blown by prevailing winds. Therefore, sediment samples for fauna were collected from around the shore of each bentonite wetland. At each wetland, from at least three locations across the bed of the dry lake, the top 2 – 5 mm of sediment was carefully removed with a trowel and placed in a 1 L plastic container, to provide approx 1 kg of dry sediment. Each container was labelled with site location details, and a waterproof label was placed in each container and the lid loosely screwed onto the container to enable aeration. Samples were kept cool and dark and freighted to Dr Russell Shiel (The University of Adelaide) for rehydration.

Permanent resident aquatic fauna was determined by re-hydrating 100 g of dry lake sediments in plastic trays flooded with 400 ml of deionised water in a Controlled Temperature Room under constant light and 20 ^{o}C (see Plate 2). Two 100 g samples were measured from each wetland sample to provide a replicate. Samples were examined daily to every 2 – 3 days for 58 days post rehydration for any emerging fauna, and any animals observed were identified to species level, where possible, and recorded as present. Samples were kept rehydrated, with animals fed on bakers yeast culture, and examined until no new taxa were recorded.

Plate 2. Example of the set-up and rehydration of dry sediments from BMNDRC bentonite wetlands. This photograph was taken ~30 days after rehydration and a green algal film is visible across the surface of the floc. The optic fibre from the side allows observation of inhabitants against the surface floc background (photo by Russ Shiel/Adelaide University, September 2009).

2.7 Data analysis

2.7.1 Univariate analysis

Wetlands were *a priori* classified as either fresh, brackish, saline or hypersaline based on ANZECC/ARMCANZ (2000) classifications. Analysis of variance was used to test for seasonal differences in taxa richness, using wetlands as replicates, to determine if there was a change in diversity which could be related to changes in physico-chemical conditions. The fauna was classified into permanent and temporary residents, and analysed separately to assess distinct changes in either component.

2.7.2 Multivariate analysis

Multivariate analyses were performed using the PRIMER package v 6 (Plymouth Routines in Multivariate Ecological Research; Clarke & Gorley 2006) to investigate differences in aquatic fauna assemblages (permanent invertebrates, temporary invertebrates & total invertebrates) across different *a priori* groupings (i.e. sites, months, years and salinity categories). The relationship between invertebrate assemblages and physico-chemical characteristics was also examined using PRIMER. The PRIMER package, developed for multivariate analysis of marine fauna samples, has been applied extensively to analysis of freshwater invertebrate data. Analyses used included:

1. Examining similarity between fauna assemblages using the Bray-Curtis Similarity Measure (Bray and Curtis 1957). To illustrate change in assemblages over time (both inter-annual, and intra-annual variation), between-year and between-month pairwise similiarities were calculated using Bray-Curtis Similarity Measure. Average similarities were compared in a number of instances, i.e. between years, between months within a year, and between fauna types (permanent, temporary and total invertebrate fauna).
2. Describing pattern amongst the fauna assemblage data using ordination techniques based on Bray-Curtis similarity matrices. Ordination of data was by Multi-Dimensional Scaling (MDS) (Clarke & Warwick 2001). Ordinations were depicted as two-dimensional plots.
3. For any *a priori* groups (*i.e.* sites, months, years & salinity category), Analysis of Similarity (ANOSIM) – effectively an analogue of the univariate ANOVA – was conducted to determine if groups were significantly different from one another. The ANOSIM test statistic reflects the observed differences *between* groups compared with the differences amongst replicates *within* the groups. The test is based upon rank similarities between samples in the underlying Bray-Curtis similarity matrix. The analysis presents the significance of the overall test (Significance level of sample statistic), and significance of each pairwise comparison (Significance level %), with degree of separation between groups (R-statistic), where R-statistic >0.75 = groups well separated, R-statistic >0.5 = groups overlapping but clearly different, and R-statistic >0.25 = groups barely separable. A significance level <5% = significant effect/difference.
4. The SIMPER routine was used to examine which taxa were contributing to the separation of any groups that were found to be different according to the ANOSIM procedure or otherwise found to be separated in cluster or ordination analyses.
5. The relationship between the environmental and biotic data was assessed in two ways:
   - 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), and
   - for visualisation, the numeric value of key environmental data (as determined by BIOENV) were superimposed onto MDS ordinations, as circles of differing sizes – so-called 'bubble plots'.

Water quality data were similarly analysed using MDS to discern patterns, gradients and similarities in water quality amongst the *a priori* groups (i.e. sites, months, years & salinity category). In this case, however, the MDS was based on a Euclidean Distance measure rather than Bray-Curtis. Water quality variables which were not normally distributed were appropriately transformed and all water quality variables standardised prior to analysis.

3 RESULTS AND DISCUSSION

3.1 Environmental data

3.1.1 Raw data

To provide a means of comparison, water quality at each wetland was assessed against the guidelines for the protection of aquatic ecosystems (ANZECC/ARMCANZ 2000). The default trigger values for physical and chemical stressors applicable to south-west Western Australia are provided in Table 4. All environmental data recorded from the BMNDRC wetlands during 2008 are detailed in Tables 5, 6 and 7.

Table 4. ANZECC/ARMCANZ (2000) default physico-chemical trigger values for slightly disturbed Western Australian ecosystems.

Ecosystem Type	*TP*	*TN*	*DO*	*pH*
	mg/L	mg/L	% saturation[b]	
Upland River[a]	0.02	0.45	90 - na	6.5 – 8.0
Lowland River[a]	0.065	1.2	80 - 120	6.5 – 8.0
Lakes & Reservoirs	0.01	0.35	90 – no data	6.5 – 8.0
Wetlands	0.06	1.5	90 - 120	7.0 – 8.5

Na = not applicable
[a] All values during base river flow not storm events
[b] Derived from daytime measurements; may vary diurnally and with depth.

pH

ANZECC/ARMCANZ (2000) guidelines recommend pH in wetlands within south-west WA should be between 7.0 and 8.5. A number of wetlands recorded values outside this range, however, none are likely due to anthropogenic disturbance (i.e. disturbance of acid sulphate soils) or are likely to cause ecological impact. With the exception of W001 and W002, the pH values recorded during the current study were generally circum-neutral to basic, as would be expected for saline wetlands, and ranged from 6.5 (W015 in October) to 9.74 (W011 in September) (Table 5). W001 and W002 are naturally acidic gypsum wetlands and recorded pH values ranging from 3.12 (W001 in October) to 6.21 (W002 in August). Interestingly, pH at W002 showed considerable change over the study period, ranging from 4.74 in October to 6.23 in August (Table 5). The resident fauna in this wetland are likely adapted to the acidic conditions.

Dissolved oxygen

Dissolved oxygen ranged from 26% at W024 in October to 153.4% at W010 at the same time of year (Table 5). DO values outside the ANZECC/ARMCANZ (2000) guidelines were commonly recorded (Tables 4 and 5). Sites which recorded 'high' DO values (>120%) likely go into oxygen stress at night, and may become anoxic as respiration by plants, algae and fauna depletes DO. The 'low' DO levels recorded during the current study are not considered sufficiently low to have an ecological impact. DO concentrations less than ~20% typically represent environmental conditions of 'stress' to resident aquatic fauna, particularly fish with high metabolic demand for oxygen.

Electrical conductivity

As expected, a range of electrical conductivities (Ec) were recorded from Buntine-Marchagee wetlands, from fresh through to hypersaline. The lowest Ec was recorded from

W074 in August (0.7 mScm), and the highest from W019 in October (224 mS/cm). Electrical conductivity is likely to exhibit strong variability over the hydrological cycle dependent on monthly and seasonal rainfall and rate of evapo-concentration. As rainfall decreases and waters recede, electrical conductivity will increase.

Nutrients

Wetlands with elevated nutrient levels may be at an increased level of risk from algal and cyanobacterial blooms (ANZECC/ARMCANZ 2000), which may become more apparent as water levels recede, nutrients are evapo-concentrated, and water temperature increases. Such nuisance blooms can result in adverse impacts to the aquatic ecosystem through toxic effects, reductions in dissolved oxygen and changes in biodiversity (ANZECC/ARMCANZ 2000). Highly eutrophic waters tend to support high abundances of pollution-tolerant species, but few rare taxa, and overall, a less complex community structure. In highly coloured waterbodies (i.e. those with high tannin content), however, this process is likely to be limited by reduced light penetration and therefore reduced primary production.

Nitrogen levels exceeded ANZECC/ARMCANZ (2000) guidelines (1.5 mg/L) from the majority of wetlands sampled (Figure 2 & Table 6). Total nitrogen recorded during the current study ranged from 0.68 mg/L at W019 (August) to 7.7 mg/L at W016 (in September) (Table 6). Generally, nitrogen levels increased within each wetland over the hydrologic cycle, with the greatest levels being recorded in October (Table 6). Elevated nitrogen levels were also recorded from many BMNDRC wetlands in August 2004 and August 2005 (Storey *et al.* 2004b, Lynas *et al.* 2006).

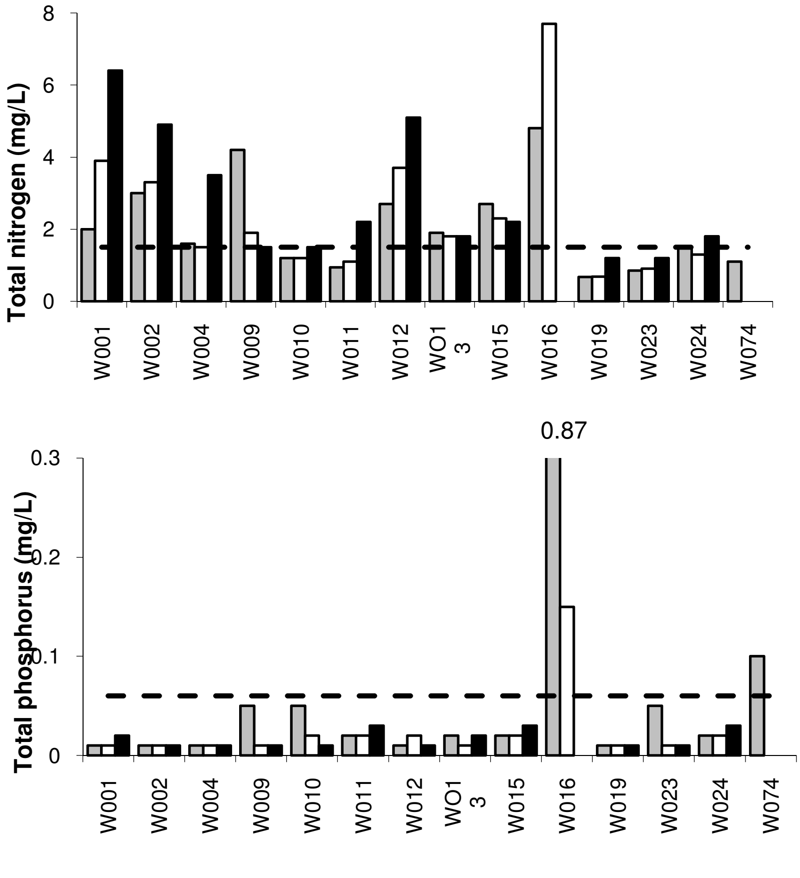


Figure 2. Nutrient levels recorded from Buntine-Marchagee wetlands on each sampling occasion in 2008; total nitrogen (top) and total phosphorus (bottom). The dashed line refers to the ANZECC/ARMCANZ (2000) trigger value/s. Shaded column = August, open column = Sept , and solid column = October.

The guideline for total phosphorus (0.060 mg/l), was exceeded only in two sites, W016 (0.87 mg/l in August and 0.15 mg/L in September) and W074 (0.1 mg/L in August) (Figure 2 & Table 6). Elevated total phosphorus has previously been recorded from W016 (Lynas *et al.* 2006).

Table 5. *In situ* water quality results from BMNDRC wetlands sampled in August, September and October 2008. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

Water quality parameter	*Site*													
AUGUST 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**	**W016**	**W019**	**W023**	**W024**	**W074**
DO (%)	95.3	98.7	97.3	114.9	102.3	112.6	95.3	101.9	99.1	91.4	111.2	81.5	69.8	122.3
DO (mg/L)	9.16	9.49	10.08	11.22	9.35	10.47	9.2	10.57	11.35	9.95	11.9	8.02	7.38	12.48
Water temp	17.6	17	14.9	18.1	20.8	19.1	17.8	14	9.7	11.4	11.6	16.3	13.8	15
Cond mS/cm	49.1	25.5	48.8	2.84	6	5.69	51.2	7.28	8.45	26	>200	4.2	1.57	0.7
pH	3.86	6.21	8.43	8.66	8.36	9.29	8.87	8.66	7.68	8.12	7.58	8.19	7.74	8.65
Redox	169.6	52	-91.1	-104.3	-88.5	-140.4	-115.8	-104.8	-45.3	-71.6	-42.4	-76.7	-52.4	-102.6
Depth (m)	0.18	0.49	0.56	1.15	0.28	0.23	0.85	0.68	0.1	0.15	0.28	1.1	0.26	0.1
SEPTEMBER 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**	**W016**	**W019**	**W023**	**W024**	
DO (%)	93.2	98.6	103.3	124.7	130.3	132	100.2	101.2	126.3	126.4	77.1	74.3	61.3	
DO (mg/L)	9.42	9.57	9.44	11.9	11.96	12.76	9.8	10.07	12.33	12.01	6.39	7.03	5.95	
Water temp	16.1	17.1	20.1	18.7	20	17.1	17.3	15.7	16.9	18.1	25.2	18.8	17.4	
Cond mS/cm	93.3	35.5	72.7	2.69	5.84	5.91	47.1	6.27	6.77	41.9	>200	3.8	1.401	
pH	3.55	5.32	8.26	8.95	8.9	9.74	8.92	8.81	8.1	9.47	7.32	8.15	7.58	
Redox	186.8	85.5	-82.4	-121.2	-119.5	-165.2	-118.5	-111.5	-71.8	-150.4	-28.7	-74.9	-38.8	
Depth (m)	0.12	0.425	0.54	1.03	0.35	0.23	0.88	0.73	0.1	0.08	0.3	1.02	0.3	
OCTOBER 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**		**W019**	**W023**	**W024**	
DO (%)	80.3	93.2	108.1	141.5	153.4	112.1	115.3	96.2	36.7		78.3	108.6	26	
DO (mg/L)	7.23	8.3	8.92	11.76	12.65	9.33	9.62	8.25	3.27		5.8	8.99	2.19	
Water temp	23	21.4	25.7	24.9	25.9	25.7	24.4	23.7	21.8		29.4	26.1	23.1	
Cond mS/cm	202	58.9	114.5	3.11	7.98	8.93	68.1	6.5	4.14		224	4.05	1.419	
pH	3.12	4.74	7.97	9.25	9.15	9.02	8.77	8.61	6.5		7.2	8.28	7.07	
Redox	211.3	113.9	-78.5	-155.7	-149.8	-142	-126.4	-116.9	9.7		-32.6	-97.5	-23.3	
Depth (m)	0.05	0.3	0.45		0.29	0.21	0.8	0.42	0.1		0.19	1	0.3	

Table 6. Water quality results from samples analysed by the Chem. Centre W.A. Shading indicates values outside ANZECC/ARMCANZ (2000) guidelines.

Water quality parameter	*Site*													
AUGUST 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**	**W016**	**W019**	**W023**	**W024**	**W074**
Colour TCU	<1	9	30	16	14	81	39	<1	290	390	11	84	300	140
Tot_N mg/L	2	3	1.6	4.2	1.2	0.94	2.7	1.9	2.7	4.8	0.68	0.85	1.5	1.1
Tot_P mg/L	<0.01	<0.01	<0.01	0.05	0.05	0.02	<0.01	0.02	0.02	0.87	<0.01	0.05	0.02	0.1
Turb NTU	5.6	4.8	3.3	1.3	2.1	2.7	4.8	1.5	1.6	2.2	16	3.4	4.4	420
SEPTEMBER 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**	**W016**	**W019**	**W023**	**W024**	
Colour TCU	5	6	19	18	14	48	30	13	310	210	16	71	340	
Tot_N mg/L	3.9	3.3	1.5	1.9	1.2	1.1	3.7	1.8	2.3	7.7	0.69	0.91	1.3	
Tot_P mg/L	<0.01	<0.01	<0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.15	<0.01	0.01	0.02	
Turb NTU	<0.5	<0.5	1.4	<0.5	<0.5	<0.5	1.4	<0.5	0.6	0.6	11	3	1.4	
OCTOBER 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**		**W019**	**W023**	**W024**	
Colour TCU	8	9	21	21	17	44	22	8	50	16	72	340		
Tot_N mg/L	6.4	4.9	3.5	1.5	1.5	2.2	5.1	1.8	2.2	1.2	1.2	1.8		
Tot_P mg/L	0.02	<0.01	<0.01	0.01	0.01	0.03	0.01	0.02	0.03	<0.01	0.01	0.03		
Turb NTU	21	6.7	9.6	1.6	2.9	18	14	1.6	2.1	22	5.1	12		

Table 7. Environmental characteristics of BMNDRC wetlands, as recorded in 2008.

Water quality parameter	*Site*													
AUGUST 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**	**W016**	**W019**	**W023**	**W024**	**W074**
Crust	0	0	0	0	0	0	0	0	0	0	1.5	0	0	0
Matthick	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macrophytes (%)	0	0	0	5	0	75	0	75	0	75	0	1	0	1
SEPTEMBER 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**	**W016**	**W019**	**W023**	**W024**	
Crust	0	0	0	0	0	0	0	0	0	0	1.5	0	0	
Matthick	0	0	0	0	0	0	0	0	0	0	0	0	0	
Macrophytes (%)	0	90	10	25	25	95	5	80	0	90	0	50	0	
OCTOBER 2008														
	W001	**W002**	**W004**	**W009**	**W010**	**W011**	**W012**	**W013**	**W015**		**W019**	**W023**	**W024**	
Crust	2mm-2cm	0	0	0	0	0	0	0	0		2-3cm	0	0	
Matthick	0	0	0	0	0	0	0	0	0		0	0	0	
Macrophytes (%)	0	95	10	50	50	75	75	75	0		0	95	0	

3.1.2 Patterns in environmental data

MDS ordination analysis of physico-chemical data from 2008 showed a significant difference between sampling events, with October separating from other months, but with no difference between August and September (Figure 3). Though statistically significant, months were not strongly separated in ordination space, as indicated by the R values for the significance tests which were <0.5 (Table 8). As expected, there were also significant differences between wetlands of varying salinity category (Figure 3, Table 8). The strongest separation was between brackish and fresh wetlands, while brackish and saline wetlands were not distinguishable. Factors contributing most to the separation of sites were Ec (and associated thickness of salt crusts), pH, colour, dissolved oxygen content.

There were no significant differences between sites, however this likely reflects inherent variability within each wetland, and that only three samples were taken from each wetland, limiting statistical power.

3.1.3 Comparison with previous years sampling

Physico-chemical data from August surveys in each year (2004, 2005 & 2008) were used to investigate inter-annual variability for sites sampled in all three years. Ordinations on these data revealed significant differences between years and between wetlands of differing salinity category (ANOSIM, Table 9). While there were significant changes between years, changes between 2004 and 2005 were more or less consistent across sites (Figure 4). In 2008, however, wetlands W002, W004, W010 and W016 appeared to have shifted closer together in ordination space indicating increased similarity in physico-chemistry between these wetlands. By contrast, wetland W009 appeared to be shifting away. In all instances, the fact that the R values for the significance tests were mostly <0.5 signifies that although statistically significant, years were not strongly separated. Differences were primarily related to annual variations in rainfall and water depth and associated changes in water pH, colour, dissolved oxygen and temperature.

Table 8. Summary of results from ANOSIM on 2008 physico-chemical data for August, September and October. Significance level p<0.05.

Grouping	*R-statistic*	*p-value*
Month		
Pairwise Tests:		
Aug vs Sep.	0.033	0.178
Aug vs. Oct	0.179	0.002
Sep. vs Oct	0.141	0.009
Global Test	0.117	0.002
Salinity category		
Pairwise Tests:		
Hypersaline vs Brackish	0.286	0.023
Hypersaline vs Saline	0.321	0.0001
Hypersaline vs Fresh	0.506	0.005
Brackish vs Saline	0.208	0.063
Brackish vs Fresh	0.710	0.005
Fresh vs Saline	0.384	0.021
Global Test	0.331	0.0001

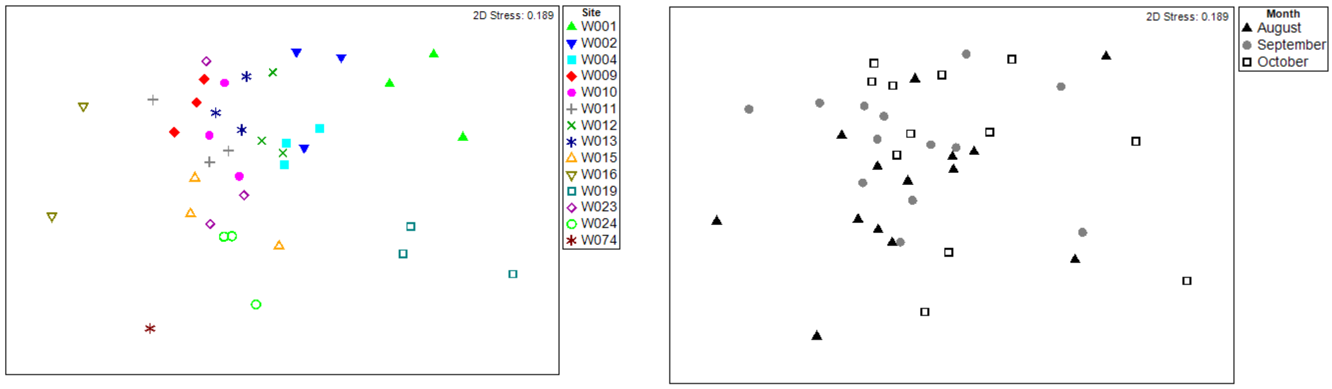


Figure 3. MDS plots of environmental data, with samples coded by site (left) and sampling month (right). MDS is based on normalised and log transformed (where appropriate) data, using the Euclidean Distance Measure. 2D Stress was 0.189.

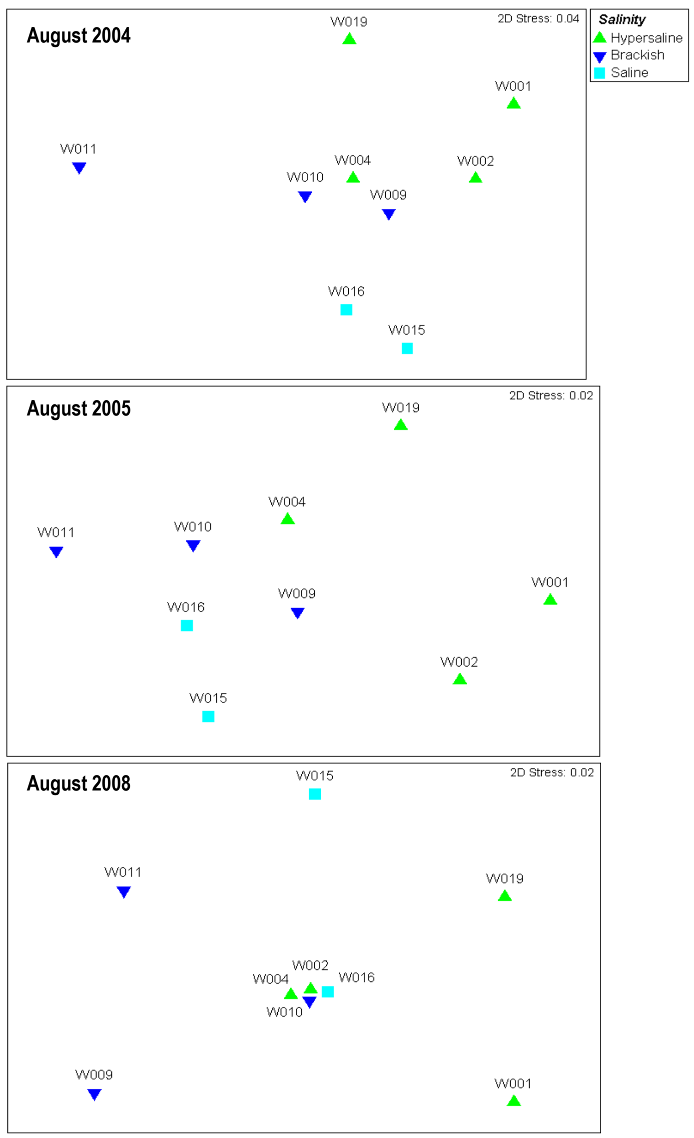


Figure 4. MDS plots of environmental data from August 2004, 2005 and 2008, with samples coded by salinity category. MDS was based on normalised and log transformed (where appropriate) data, using the Euclidean Distance Measure.

Table 9. Summary of results from ANOSIM on 2004, 2005 and 2008 physico-chemical data. Significance level p<0.05

Grouping	*R-statistic*	*p-value*
Year		
Pairwise Tests:		
2004 vs 2005.	0.301	0.004
2004 vs.2008	-0.030	0.626
2005 vs 2008	0.307	0.003
Global Test	0.197	0.003
Salinity category		
Pairwise Tests:		
Hypersaline vs Brackish	0.438	0.002
Hypersaline vs Saline	0.259	0.001
Brackish vs Saline	0.222	0.062
Global Test	0.222	0.0001

NB – the MDS plots are presented as individual years to more easily illustrate patterns and temporal change.

3.2 Invertebrate fauna

3.2.1 Taxonomic composition

A total of 187 invertebrate taxa were recorded from the 39 individual samples collected from 14 wetlands during 2008; 96 taxa were recorded in August, 85 in September, and 84 in October (Appendix 2). This compares with 135 and 150 taxa recorded from 21 BMNDRC wetlands sampled in August 2004 and 2005, respectively.

Ephemeral wetland systems will, at varying times, support both permanent and temporary resident aquatic invertebrate fauna. Some species possess life history strategies which enable them to remain within a system once surface waters have evaporated. Such taxa are referred to as 'permanent residents'. Conversely, other species, including those that possess short maturation times, are thought to endure the dry season as terrestrial adult stages (e.g. dragonflies, caddisflies and some beetles), or in nearby permanent waters. Such species are referred to as 'temporary residents' since they must reinvade each time a seasonal waterbody becomes inundated.

Permanent residents use a number of strategies to survive in ephemeral wetlands. Some species, for example, have drought-resistant spores, eggs or larval stages (e.g. microcrustacea, many species of nematode, and some simulid, chironomid and ephemeropteran species). Most can survive extended periods of drought (Hairston *et al.* 1995). Other species are capable of burrowing into moist sediments of the hyporheic zone, below stones, or into decomposing wood debris (e.g., nemerteans, oligochaetes, some species of chironomids, tabanids, and some mayflies). Many bivalves and gastropods are resistant to desiccation and those species which lack an operculum are able to seal their shells with a mucus plug, known as an epiphragm.

Of the taxa recorded, 74 (39%) were considered to be 'permanent' residents with desiccation-resistant life stages that would allow them to remain within the wetland once surface waters had evaporated. Permanent residents comprised four species of Protist, 18 species of Rotifera, one Platyhelminthes (flat worm), Nematoda (round worm), Oligochaeta (segmented worm), two species of Gastropoda (freshwater snail), two types of Arachnida (water mite), 14 species of Copepoda, 13 species of Cladocera (water fleas), 13 Ostracoda (seed shrimp), and five Anostraca (fairy shrimp) (see Appendix 2). Many micro-crustaceans and branchiopods (Anostraca, Conchostraca and Cladocera) are known to emerge within hours of flooding and develop quickly over a period of about two weeks, before the more predatory colonisers appear (Williams 1984).

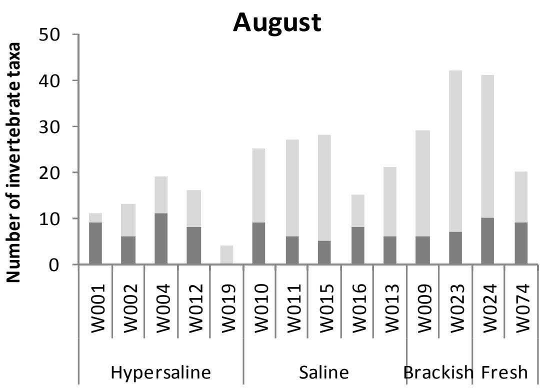
Of the 113 'temporary' fauna, there was one taxa of Cnidaria (freshwater Hydra), one Gastropoda, one Amphipoda (side swimmers), 26 taxa of Chironomidae (non-biting midges), 20 types of other Diptera (larval flies), six taxa of Trichoptera (caddisflies), three Ephemeroptera (mayflies), nine Odonates (damselflies & dragonflies), 26 taxa of Coleoptera (beetles), 19 species of Hemiptera (water bugs), and one Lepidoptera (moth larvae).

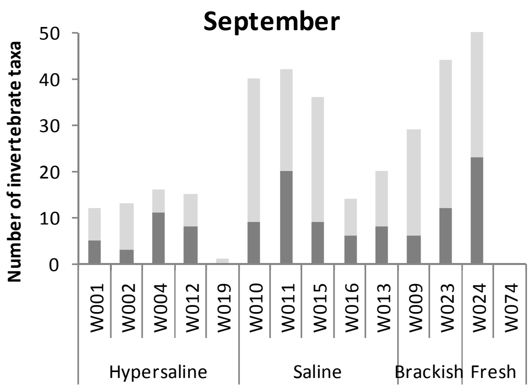
The taxonomic listing includes records of larval and pupal stages for groups such as Diptera and Coleoptera. Current taxonomy in Australia is not sufficiently well developed to allow identification of all members of these groups to species level. In many instances it is likely that these stages are the same species as the larval/adult stages recorded from the same location. However, because this could not be definitively determined, they were treated as separate taxa. Similarly, the taxa listings contain juvenile stages of Copepoda (copepodites and nauplii) which cannot be taken to species level, and are therefore left as unidentified juveniles.

Of the 187 taxa, only two were common and occurred in over 60% of samples (i.e. > 24 samples). These were the chironomid larvae *Procladius paludicola* and amphipod *Austrochiltonia subtenius*. A large number of taxa were recorded infrequently, i.e. 58 taxa were recorded from only one sample.

3.2.2 Taxa richness

Taxa richness varied greatly, both between sites and time of year (Figure 5). In August, the number of taxa recorded ranged from four at the hypersaline W019, to 42 at the brackish site W023. In September, the lowest taxa richness was again recorded from W019 (only one taxa), and the greatest from fresh wetland W024 (60 taxa). Taxa richness ranged from two (hypersaline wetland W001) to 51 (again from brackish wetland W023) in October (see Appendix 2). Generally, a greater number of taxa were recorded from fresh, brackish and saline sites when compared with hypersaline wetlands (Figure 5).





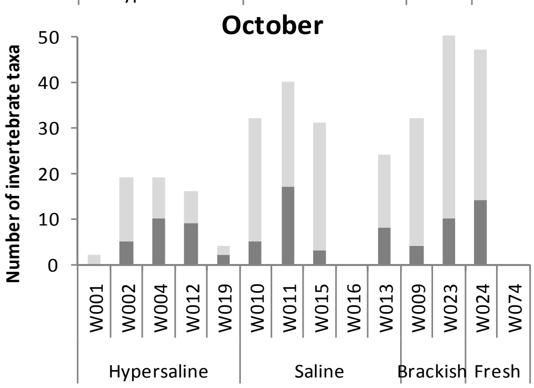


Figure 5. The number of taxa recorded from each wetland sampled within the BMNDRC in August (top left), September (top right) and October (left) 2008. Taxa are divided into permanent and temporary residents. Where no data are shown, the site was dry

Permanent Temporary

There was no significant difference in the mean number of invertebrate taxa per wetland between seasons (One-way ANOVA; df = 38, p = 0.48; Table 10 & Figure 6). However, wetland taxa richness did tend to increase over time in 2008, with the greatest number of invertebrate taxa being recorded in October (mean = 26.42; see Figure 6). It appeared this was due to the colonisation by temporary fauna, which showed a steady increase in taxa richness over 2008 (Figure 6); although this was not significant (Table 10). There was also no significant difference in taxa richness of permanent residents over 2008 (Table 10); however, the number of permanent taxa did increase from August to September as additional fauna began to emerge, and then decreased between September and October, presumably as the species completed their lifecycles (Figure 6).

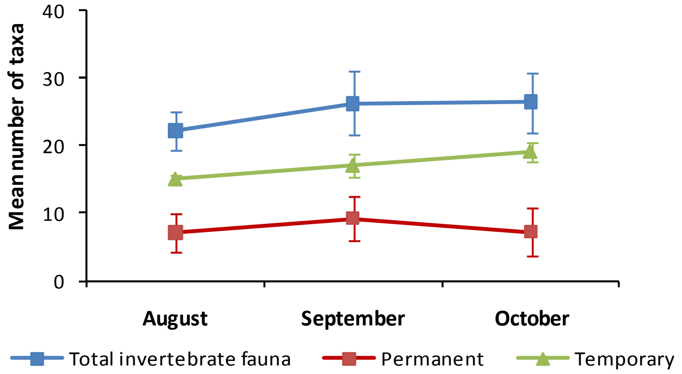


Figure 6. Mean number of taxa (± se) of each fauna type over time (August, September and October 2008).

Table 10. One-way ANOVA results, examining the difference in permanent fauna, temporary fauna and total fauna between seasons (August, September and October 2008).

Fauna type	*Source*	*df*	*Mean square*	*F*	*p-value*
Permanent fauna	Between groups	2	18.04	0.76	0.48
	Within groups	36	23.79		
	Total	38			
Temporary fauna	Between groups	2	54.24	0.40	0.67
	Within groups	36	135.21		
	Total	38			
Total invert fauna	Between groups	2	77.16	0.37	0.69
	Within groups	36	209.84		
	Total	38			

Ranking wetlands based on the diversity of invertebrates showed similar results in each sampling month (Table 11). That is, wetlands W024 and W023 had the highest mean overall ranks during each sampling occasion (Table 11). However, there were differences in the ranking of wetlands based on the different fauna types (Table 11). For example, although W023 had the highest ranking in both the number of total invertebrate fauna and temporary fauna during August, it was ranked eighth based on its permanent fauna richness (Table 11). This likely reflects the fresher, permanent status of this wetland, with permanent fauna adapted to survive in seasonal wetlands. Although the saline wetland W015 was ranked third based on the number of temporary fauna, it was ranked tenth and sixth based on the number of permanent and total number of taxa, respectively (Table 11).

3.2.3 Conservation significance of invertebrates

The majority of invertebrate taxa recorded from the BMNDRC are common, ubiquitous species. Of the 187 taxa recorded during the three sampling occasions in 2008, the majority were indeterminate due to insufficient information/taxonomy (47% of taxa), 22% were cosmopolitan, occurring widely throughout the world, and 19% were Australasian. Species with restricted distributions were recorded in much lower proportions; 6% were endemic to the Australian continent and 4% were restricted to the south-west of Western Australia.

Table 11. Wetlands ranked by: number of total invertebrate fauna (TIFR), permanent fauna (PFR), and temporary fauna (TEMPFR). Wetlands are in order of their mean overall rank (MOR).

Site	*TIFR*	*PFR*	*TEMPFR*	*MOR*
August				
W024	2	2	2	2.00
W023	1	8	1	3.33
W010	6	3	6	5.00
W009	3	9	3	5.00
W004	9	1	9	6.33
W011	5	9	5	6.33
W074	8	3	8	6.33
W015	4	13	3	6.67
W013	7	9	7	7.67
W012	10	6	9	8.33
W016	11	6	11	9.33
W001	13	3	14	10.00
W002	12	9	11	10.67
W019	14	14	13	13.67
Site	***TIFR***	***PFR***	***TEMPFR***	***MOR***
September				
W024	1	1	1	1.00
W023	2	3	2	2.33
W011	3	2	6	3.67
W010	4	5	3	4.00
W015	5	5	4	4.67
W009	6	9	5	6.67
W013	7	7	7	7.00
W004	8	4	12	8.00
W012	9	7	10	8.67
W016	10	9	9	9.33
W002	11	12	8	10.33
W001	12	11	10	11.00
W019	13	13	13	13.00
Site	***TIFR***	***PFR***	***TEMPFR***	***MTR***
October				
W023	1	3	1	1.67
W024	2	2	2	2.00
W011	3	1	6	3.33
W010	4	7	5	5.33
W009	4	9	3	5.33
W015	6	10	3	6.33
W013	7	6	7	6.67
W002	8	7	8	7.67
W004	8	3	9	6.67
W012	10	5	10	8.33
W019	11	11	11	11.00
W001	12	12	11	11.67

Australian endemic species included; the copepods *Mesocyclops brooksi*, and *Metacyclops* cf. *laurentiisae*; the cladocera *Alona rigidicaudis*, *Alona* sp., cf. *Archepleuroxus*, *Daphnia* (s. str.) *carinata* s.l., *Daphnia* (*Daphniopsis*) *truncata*, *Daphnia (Daphniopsis) wardii*, *Daphnia (Daphniopsis)* sp., and *Latonopsis* cf. *brehmi*; and the ostracods *Australocypris* sp. and *Bennelongia* sp. Species recorded from the BMNDRC which are restricted to the south-west of the State included; the Anostraca *Parartemia contracta* and *Parartemia ?longicaudata*; the chironomids *Chironomus occidentalis*, *Dicrotendipes conjunctus* and *Procladius villosimanus*; the dytiscid beetle *Limbodessus inornatus*; and, the octherid Hemiptera *Ochterus occidentalis*. South-west endemics were recorded from W001, W004, W009, W010, W011, W013, W015, W023 and W024. Although south-west endemic species were collected from wetlands of all salinity categories, they were recorded in much lower proportions from hypersaline and saline wetlands than brackish and fresh sites (Figure 7). Introduced species were only recorded from hypersaline and saline wetlands within the BMNDRC (Figure 7). Taxa of conservation significance, including Australian endemics and south-west endemics, were recorded during each sampling occasion (Figure 8).

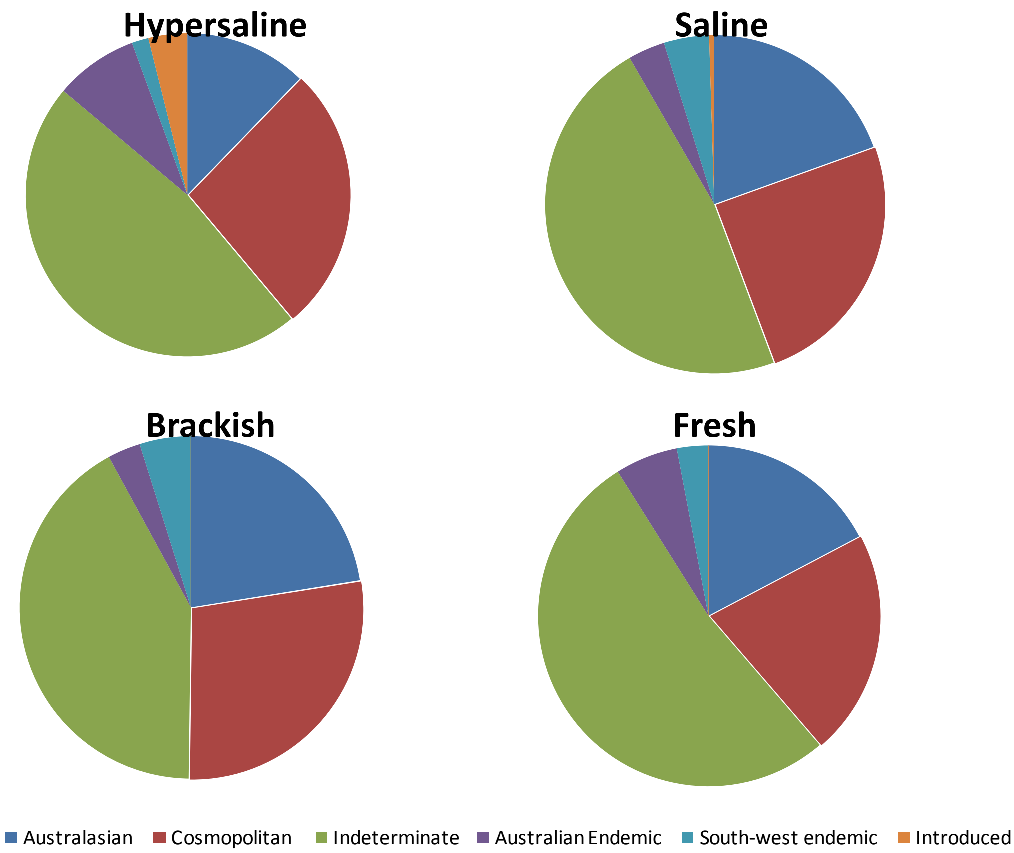


Figure 7. Proportion of invertebrate taxa from each conservation category recorded from BMNDRC in August, September and October of 2008, showing plots for hypersaline wetlands (top left), saline (top right), brackish (bottom left), and fresh wetlands (bottom right).

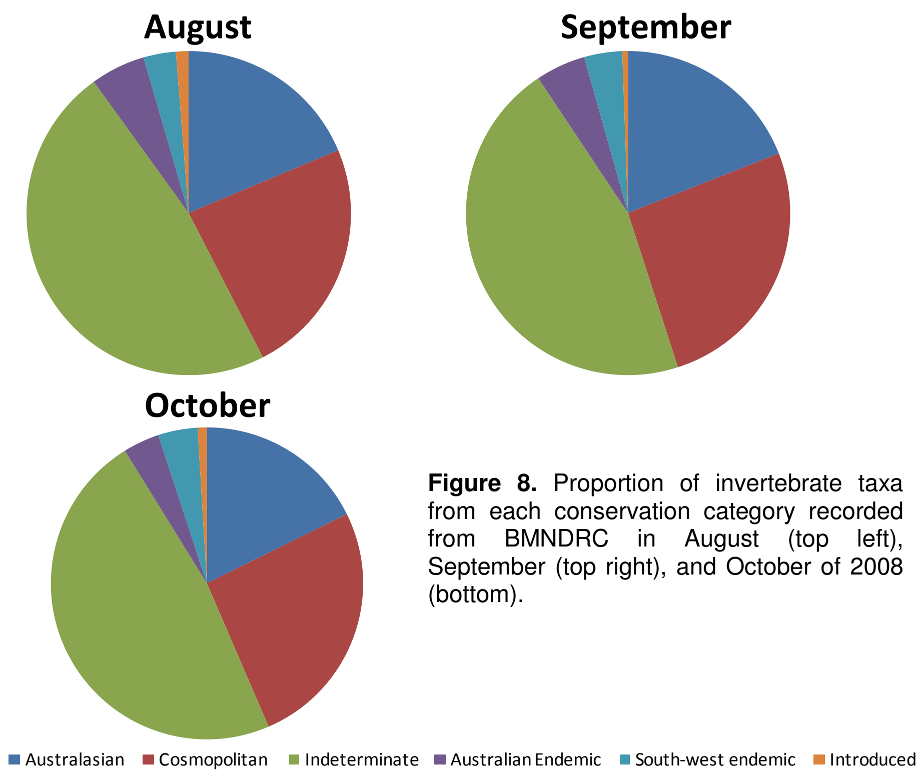


Figure 8. Proportion of invertebrate taxa from each conservation category recorded from BMNDRC in August (top left), September (top right), and October of 2008 (bottom).

3.2.4 Intra-annual variation in assemblage structure

The MDS ordination of invertebrate assemblages for all samples recorded in August, September and October 2008 was 'compressed' by the overbearing influence of outlier wetland W019 (Figure 9). This site was hypersaline and recorded very few taxa (4 in August, 1 in September, and 4 in October). There was zero similarity in the invertebrate assemblages of this site over the year, i.e. there were no common species recorded in August, September or October. Therefore, W019 was removed from the analysis, so that patterns amongst remaining wetlands could be detected over the hydro-cycle.

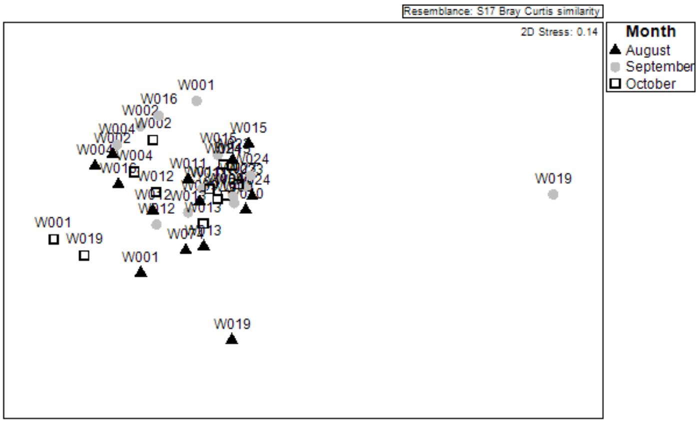


Figure 9. MDS ordination (including site W019) using log10 abundance data collected from BMNDRC wetlands in August, September and October 2008. The ordination is based on the Bray-Curtis Similarity Measure. 2-D Stress was 0.14.

With W019 excluded from the analysis, some patterns became evident in the ordination (Figure 10). Although there was no significant difference in the invertebrate assemblages between seasons, there was a significant difference between salinity category (Table 12 & Figure 10). Post-hoc comparisons showed that the greatest differences in assemblage structure was between hypersaline wetlands and all other salinity types, including saline, brackish and fresh (R>0.4 and p<0.01 in all cases; Table 12). There was no significant difference between brackish and fresh wetlands, nor were there differences between fresh and saline wetlands (Table 12 & Figure 10).

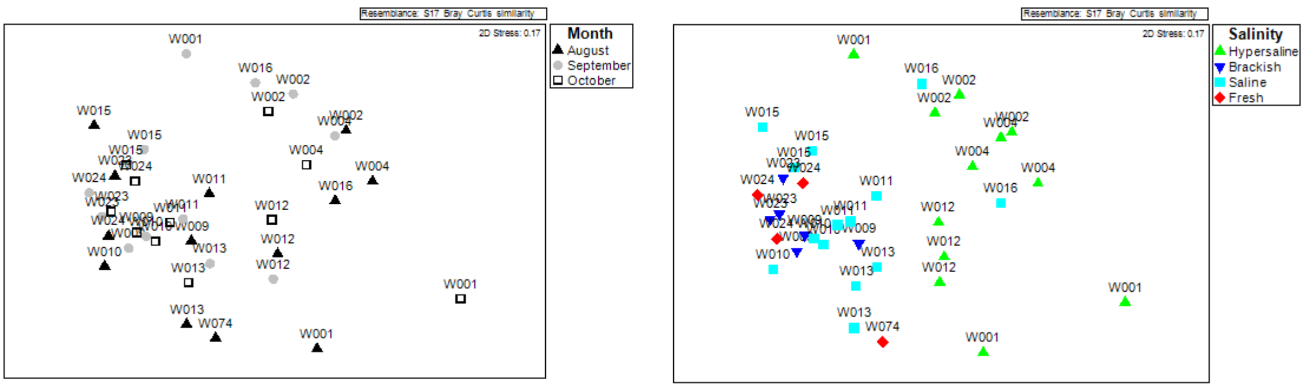


Figure 10. MDS ordination using log10 abundance data collected from BMNDRC wetlands in August, September and October 2008, with wetland W019 removed from analysis. Samples are coded by month (left) and salinity type (right). The ordination is based on the Bray-Curtis Similarity Measure. 2-D Stress was 0.17.

SIMPER analysis was used to determine which species were typical of a group by providing a list of taxa which were found consistently within most samples from a particular group. Average similarity between hypersaline and brackish wetlands was low (14.6%). Many taxa contributed to the differences in invertebrate assemblage structure between hypersaline and brackish wetlands. For example, taxa which were absent from hypersaline wetlands, but which were recorded from brackish wetlands included; the chironomids (non-biting midge larvae) *Dicrotendipes conjunctus*, *Tanytarsus fuscithorax*, *Procladius villosimanus*, *Paramerina levidensis*, *Corynoneura* sp. V49, Orthocladiinae spp. V46, *Ablabesmyia notabilis* and *Kiefferulus intertinctus*; the copepod *Boeckella triarticulata* s.l.; the odonates (dragonflies and damselflies) *Austrolestes annulosus*, *Austrolestes analis*, *Hemianax papuensis*, *Orthetrum caledonicum*, and *Adversaeschna brevistyla*; the Trichoptera (caddisflies) *Triplectides australicus*, *Oecetis* sp., and *Notalina spira*; the Hemiptera (true aquatic bugs) *Agraptocorixa* sp. (F), *Agraptocorixa eurynome*, *Micronecta* sp., *Paraplea brunni*, and *Anisops thienemanni*; and the Ephemeroptera (mayfly larvae) *Tasmanocoenis tillyardi*. The average similarity between hypersaline and fresh wetlands was even lower (12.9%).

Table 12. Summary of results from ANOSIM on 2008 log10 invertebrate abundance data for August, September and October. Significance level p<0.05.

Grouping	*R-statistic*	*p-value*
Month		
Pairwise Tests:		
Aug vs Sep.	-0.029	0.681
Aug vs. Oct	-0.014	0.535
Sep. vs Oct	-0.026	0.644
Global Test	-0.021	0.684
Salinity category		
Pairwise Tests:		
Hypersaline vs Brackish	0.497	0.0003
Hypersaline vs Saline	0.414	0.0002
Hypersaline vs Fresh	0.438	0.006
Brackish vs Saline	-0.011	0.47
Brackish vs Fresh	0.052	0.319
Fresh vs Saline	0.146	0.192
Global Test	0.299	0.0001

The aforementioned species are generally known to be sensitive to salt and/or pollution. Odonata, for example, are considered to be relatively sensitive to salinity (Shirgur and Kelwalramani 1973, Arthington and Watson 1982, Hart *et al.* 1991), and none were recorded from hypersaline wetlands within the BMNDRC. In addition, odonates occur amongst trailing riparian vegetation and macrophytes so their absence from hypersaline wetlands which are primarily characterised by high sediment cover and low vegetative cover is not surprising. Some tolerance to salt was observed, however, with *A. annulosus*, *A. analis*, *A. brevistyla* and *H. papuensis* all being recorded from saline wetlands. *Orthetrum caledonicum* was restricted to brackish and fresh wetlands.

Trichoptera, such as *Notalina spira* and *Triplectides australicus*, generally are found in a variety of aquatic habitats, but are highly sensitive to pollution and intolerant of high salinity. They were not recorded from hypersaline BMNDRC wetlands.

The chironomid *Tanytarsus fuscithorax* was restricted to fresh and brackish wetlands of the BMNDRC. This is a freshwater species and has been used as an indicator for salt (Dr Don Edward, UWA, pers comm.). Its congener, *T. barbitarsus* however, is a known halophile, and is a common salt-lake species in Western Australia (Hart *et al.* 1991, Pinder *et al.* 2004). As expected, it was not recorded from fresh wetlands of the BMNDRC.

3.2.5 Intra-annual variation – permanent vs temporary fauna

Permanent fauna showed the highest variability in assemblage structure over 2008 (i.e. between months of August, September and October). That is, permanent fauna recorded the lowest average Bray-Curtis Similarity (36.9%) of all fauna types (Table 13). Temporary fauna had the highest average percent similarity between months (44.1% similarity), showing the least variability over time (Table 13).

·cent Similarity (%) in log10
between months (August,
·ermanent fauna, temporary

Salinity type	*Wetland*	*Permanent fauna*	*Temporary fauna*	*Total fauna*
Hypersaline	**W001**	12.50	11.11	11.36
	W002	31.42	33.06	32.91
	W004	57.04	44.87	51.39
Brackish	**W009**	67.41	48.95	52.55
Saline	**W010**	51.18	56.82	55.70
	W011	36.38	53.05	47.44
Hypersaline	**W012**	59.48	58.14	58.96
Saline	**W013**	70.79	49.10	56.16
	W015	15.60	49.83	44.81
	W016	18.75	43.24	31.88
Hypersaline	**W019**	0.00	0.00	0.00
Brackish	**W023**	31.19	69.96	61.89
Fresh	**W024**	28.77	54.83	48.13
	W074	NA[1]	NA[1]	NA[1]
	Average	36.96	44.07	42.55

3.2.6 Inter-annual variation in assemblage structure

The MDS ordination of all common sites sampled in August 2004, 2005 and 2008 showed invertebrate assemblages from samples of differing salinity type were separate in ordination space (Figure 11). However, invertebrate assemblages did not appear to be separate between years (Figure 11). This was supported by ANOSIM, whereby salinity types were significantly different (Global $R = 0.29$, $p = 0.001$), but years were not significantly different (Global $R = -0.02$, $p = 0.63$). Post-hoc analysis by salinity type showed that invertebrate assemblages were most different between hypersaline and brackish wetlands, i.e. the R-value was greater (Table 14). This indicates that water quality has a greater influence on the fauna than inter-annual variation.

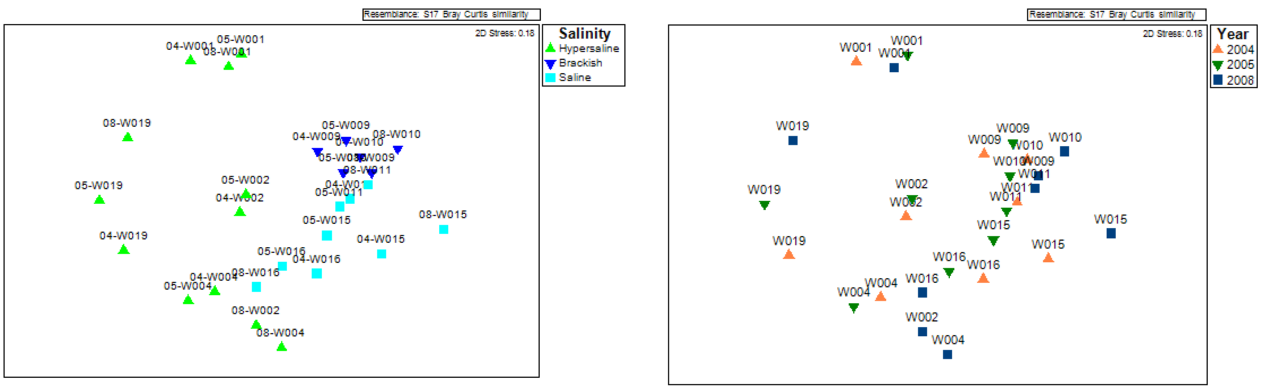


Figure 11. MDS ordination of BMNDRC invertebrate data from common sites sampled in August 2004, 2005 and 2008 using log_{10} abundance data. Samples are coded by salinity category (left) and year (right). MDS is based on the Bray-Curtis Similarity Measure. Stress was 0.18.

[1] W074 was only sampled in August. It was dry in September and October of 2008.

Table 14. Summary of results from ANOSIM on log10 invertebrate abundance data for 2004, 2005 and 2008. Significance level p<0.05.

Grouping		*R-statistic*	*p-value*
Year			
Pairwise Tests:			
	2004 vs 2005	-0.07	0.836
	2004 vs 2008	0.014	0.373
	2005 vs 2008	0.022	0.558
Global Test		-0.023	0.631
Salinity category			
Pairwise Tests:			
	Hypersaline vs Brackish	0.411	0.0009
	Hypersaline vs Saline	0.304	0.002
	Brackish vs Saline	0.216	0.045
Global Test		0.294	0.001

SIMPER analysis was used to determine which species were typical of a group by providing a list of taxa which were found consistently within most samples from a particular group. Average similarity between hypersaline and saline wetlands was 14.5%. Contributing to this low similarity was the presence/absence of some species, and differences in abundances of invertebrates between the two salinity types. For example, species found in greater abundances from saline wetlands included the amphipod *Austrochiltonia subtenuis*, the chironomids *Procladius paludicola* and pupae, the dytiscid beetle *Necterosoma* sp. larvae, the cyclopoid copepod *Apocyclops dengizicus*, and ostracod *Diacypris* sp. A number of species were recorded from the saline wetlands, but not hypersaline wetlands, including the chironomids *Tanytarsus semibarbitarsis*, *Tanytarsus fuscithorax*, *Chironomus aff. altermans*, and ?*Cladopelma* sp., the odonates *Hemicordulia tau*, *Diplacodes haematodes*, and *Austrolestes annulosus*, and the corixid hemipteran *Micronecta robusta*. Average similarity between brackish and saline wetlands was slightly higher, at 26.9%. The least similarity in invertebrate assemblages was between hypersaline and brackish wetlands (11.3%). Species which were recorded from the brackish BMNDRC wetlands, but not the hypersaline wetlands, were the rotifer *Cephalodella gibba,* ostracod *Sarscypridopsis aculeata*, chironomids *Polypedilum nubifer*, *Tanytarsus fuscithorax*, *Dicrotendipes conjunctus*, *Procladius villosimanus* and *Chironomus occidentalis*, the diptera larvae Dolichopodiae spp. and Psychodidae spp., the hemiptera *Agraptocorixa eurynome*, *Micronecta robusta*, *Anisops thienemanni* and *Anisops* juveniles, the Coleoptera *Laccobius clarus*, *Allodessus bistrigatus*, *Rhantus* larvae and *Sternopriscus* larvae, the trichopteran *Triplectides australicus*, and water mites (Hydracarina spp.).

The relationships between patterns in invertebrate fauna and environmental variables were investigated using the BIOENV procedure. Other than electrical conductivity, the environmental variables found to have the greatest influence on the separation of samples between salinity types were water temperature, pH, salt crust thickness, and percent macrophyte cover (Figure 12). The correlation of these variables with the invertebrate ordination was significant (BIOENV; Rho = 0.64, p=0.001). As would be expected, salt crust thickness was higher in hypersaline wetlands, and percent macrophyte cover was greater in brackish and saline wetlands (Figure 12).

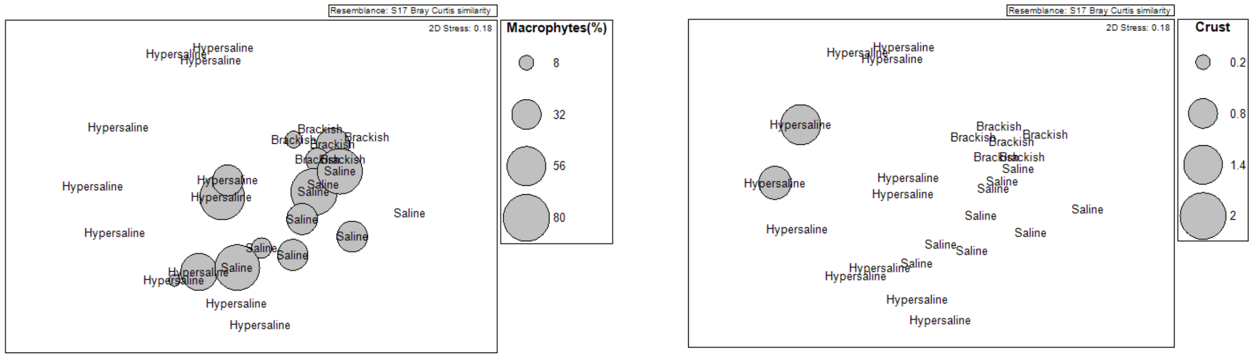
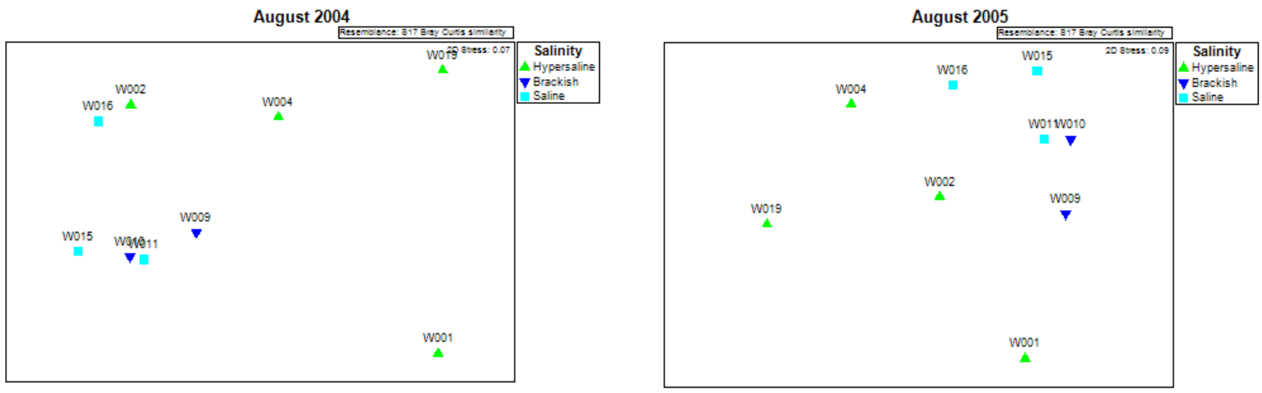


Figure 12. Bubble plots showing the influence of percent macrophyte cover (left) and salt crust thickness (right) on the MDS ordination.

Separation of invertebrate assemblages by salinity type was greatest in August of 2004 and 2005, than in August 2008 (Figure 13).



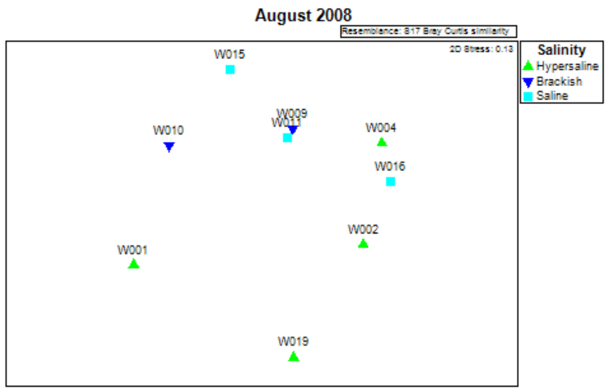


Figure 13. MDS ordinations of BMNDRC invertebrate assemblages, using log10 abundance data, and showing years on separate plots.

Generally, inter-annual similarity was marginally less than intra-annual similarity, i.e. average similarity between months in 2008 (August, September & October) was 42.6%, and average similarity between years (2004, 2005 & 2008) was 40.20% (Table 15). This suggests that invertebrate assemblages of BMNDRC were slightly more variable between years than between months within the same year.

Table 15. Average intra-annual (Aug, Sep, Oct) and inter-annual (2004, 2005, 2008) Bray-Curtis Percent Similarity.

Wetland	*Average intra-annual % similarity*	*Average inter-annual % similarity*
W001	11.36	45.98
W002	32.91	30.36
W004	51.39	36.98
W009	52.55	42.00
W010	55.70	52.88
W011	47.44	42.75
W012	58.96	NA[2]
W013	56.16	NA2
W015	44.81	46.16
W016	31.88	37.46
W019	0.00	27.22
W023	61.89	NA[2]
W024	48.13	NA[2]
W074	NA[3]	NA[2]
Average	**42.55**	**40.20**

As reported previously, there is a strong relationship between taxa richness and salinity (Figure 14), with diversity declining as salinity increases. Therefore, to maintain aquatic diversity, it is necessary to maintain low salinity (fresh/brackish) wetlands. However, because the saline/hypersaline wetlands also support distinct assemblages, overall biodiversity will be maintained by providing wetlands covering the range of salinity conditions.

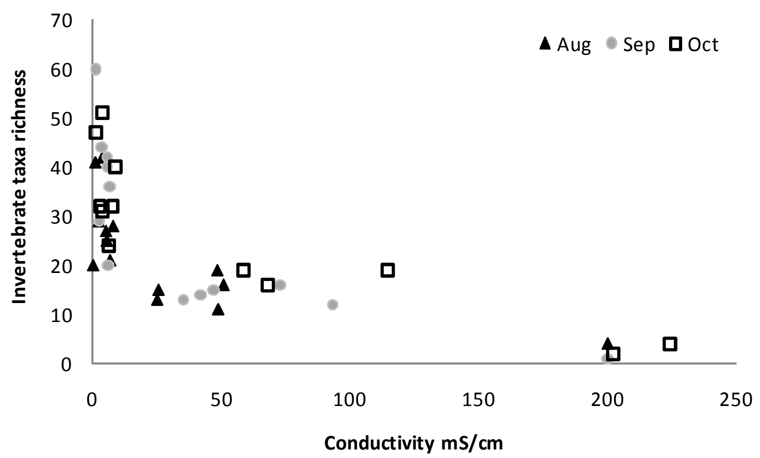


Figure 14. Correlation between taxa richness and conductivity for each month.

[2] not sampled previous to 2008.
[3] only sampled in August; dry in September & October.

3.3 Vertebrate fauna

A number of vertebrate fauna were recorded from wetlands within the BMNDRC, including frogs, fish and birds (Appendix 3). These are briefly discussed below.

3.3.1 Fish

The Swan River goby *Pseudogobius olorum* was again recorded from the catchment. Only one individual was recorded during the surveys; an apparently gravid female from wetland W023. However, additional specimens were subsequently sampled from W023 by Melissa Cundy. The Swan River goby was previously collected from W009 during 2004/05. Prior to this, no fish had been reported for wetlands within the BMNDRC. This species is common and widely distributed in coastal areas of southern Australia from the Murchison River in the north to Esperance in the southeast, occurring in estuaries, rivers, and both freshwater and hypersaline lakes (Morgan *et al.* 1998). The life cycle is typically completed in less than a year, with spawning during spring and autumn, and to a limited extent summer.

3.3.2 Frogs

A total of four frog species were identified by their mating call, three of which had been recorded in previous sampling years. As in previous years, all species were recorded from the fresher water and brackish sites. Species present included bleating frog (*Crinia pseudinsignifiera*), banjo frog (*Limnodynastes dorsalis*), motorbike frog (*Litoria moorei*) and slender tree frog (*Litoria adelaidensis*; Plate 3) (Appendix 3). The slender tree frog was not recorded during 2004/05, but was likely present and not recorded due to the opportunistic nature of the frog surveys.

All species are common and widespread throughout the southern half of the state (Davis 2003).

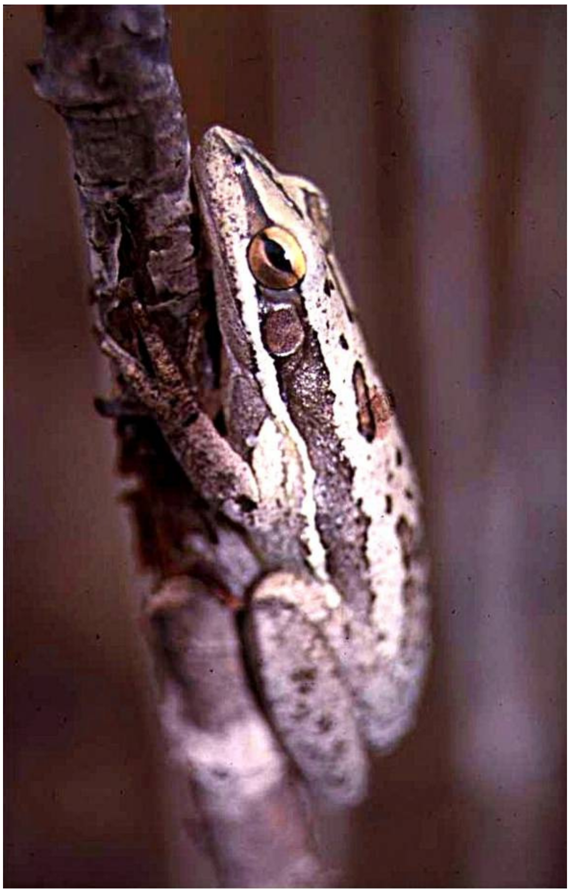


Plate 3. The slender tree frog, *Litoria adelaidensis* (Rob Davis 2001).

3.3.3 Waterbirds

A total of 17 waterbird species were recorded during 2008 (Appendix 3). All are common throughout Western Australia. Species present in 2004/05, but not recorded during 2008 included the blue-billed duck, red-kneed dotterel and bush hen. The blue-billed duck *Oxyura australis*, is currently listed as 'Near Threatened' on the IUCN Redlist of Threatened Species (2008). This duck was observed beside the road causeway in site W020 during 2004 surveys. This may have been a vagrant as the species has not been sighted since (but W020 was not sampled in 2008).

Breeding was observed for 6 of the 17 species recorded in 2008. These are listed in Table 16.

Table 16. Waterbirds observed breeding during August to October surveys in 2008.

Wetland	Month	Species	Nest / Chicks
W002	Oct 2008	Australian Shelduck	1 breeding pair with 1 chick
W009	Sep 2008	Australasian grebe	Empty nest
	Oct 2008	Pacific black duck	1 breeding pair with 7 chicks
W013	Oct 2008	Australian Shelduck	1 breeding pair with 6 chicks
W016	Sep 2008	Black-winged stilt	1 nest with 2 chicks
W024	Sep 2008	Black swan	1 nest with 3 eggs

3.4 Bentonite wetlands

A list of the specimens which have emerged from bentonite sediments after 41 days is provided in Appendix 4. Although the flooded samples were depauperate, there was a high diversity of protists. Various morphotypes of green, white and transparent ciliate protists emerged, but the taxonomy and identification of these specimens was beyond the scope of this study.

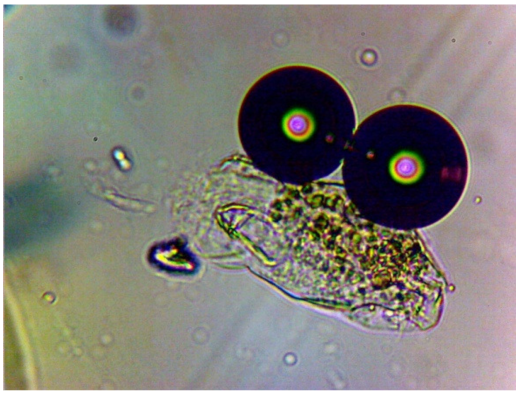


Plate 4. The Rotifer, *Cephalodella catellina* which emerged from W058 ten days after flooding wetland sediment.

The first fauna to emerge were ciliates and flagellates (at days 3-4), with increasing diversity of these fauna by days 5-6. By day 7, a nematode had emerged in W057, and a rotifer in W058. All three wetlands (W057, W058 and W059) had additional ciliate species emerging by day 7-10. Rotifers of the species *Cephalodella catellina* were evident in W058 after ten days (Plate 4). This rotifer was the only species which appeared from the BMNDRC bentonite wetlands; it reached high densities in W058, a few individuals emerged in W059 after 34 days of flooding, and none appeared in W057.

There was no appearance of microcrustaceans (copepods, cladocera or ostracods). However, this was also found to be the case after 41 days of flooding sediment samples collected from Lake Ned, near Forrestania, approximately 80 kms east of Hyden (450 km SE from Perth) (WRM 2008). Microcrustaceans began emerging from Lake Ned sediments 50 days after flooding (WRM 2008). Flooding of the bentonite sediments will continue, with any additional taxa reported to DEC Geraldton in an Inter-office memo.

4 CONCLUSIONS

4.1 Water quality

Analysis of physico-chemical data indicated significant changes between late winter/early spring and mid/late spring. The primary sources of this variation were electrical conductivity, pH, and dissolved oxygen content, however, Total Nitrogen also showed an increase, likely reflecting evapoconcentration of the waterbody.

Generally, Nitrogen levels were elevated across all wetlands, exceeding the recommended trigger value on most occasions. Elevated levels place the wetlands at increased risk of eutrophication and algal blooms, which can lead to reduced biodiversity.

Phosphorus levels were not as elevated, exceeding the recommended trigger value at only two wetlands on three occasions. Given the high nitrogen levels in all wetlands, but the absence of obvious algal blooms, it seems likely that phosphorus is the limiting nutrient, preventing excessive algal growth. If phosphorus levels were to increase, this may well result in algal blooms in many wetlands, particularly towards the end of spring as the wetlands recede and temperature increase. The source of nutrients in the BMNDRC wetlands is unknown, but likely reflects past and current agricultural practices.

In the adjacent Yarra Yarra catchment, WRM (2008) sampled 24 wetlands and drains on one occasion and noted that nutrient levels at most sites were high and well above ANZECC/ARMCANZ guidelines for the protection of aquatic ecosystems. The range for TN was 0.61 - 36 mg/L, and for TP was 0.005 - 0.75 mg/L. Extensive algal blooms were observed in some wetlands during sampling of the Yarra Yarra lakes. WRM (2008) noted that the high nutrient concentrations were not unexpected given the past land management practices and unrestricted access of livestock to the wetlands and natural drainage lines.

In comparison, in the Muir-Unicup catchment, WRM (2005) sampled 27 wetlands in spring, summer and autumn of 1996/97 and again in 2003/04. Total N showed significantly higher concentrations in autumn compared with spring, likely reflecting an evapoconcentration effect, however, total P showed no changes either between-years or seasons. Total N exceeded the ANZECC/ARMCANZ (2000) trigger value in most wetlands on most occasions. Some of the elevated levels may have been due to agricultural practices, however, the high elevated N in wetlands that were well buffered by remnant vegetation was attributed to the breakdown of the organic layer derived from the dense *Baumea articulate* reedbeds. In comparison, the total P levels were very low in nearly all the wetlands, with only a couple of values above the trigger value.

4.2 Invertebrate fauna

4.2.1 Taxonomic composition and taxa richness

A total of 187 invertebrate taxa were recorded from the 39 individual samples collected from 14 wetlands during 2008; 96 taxa were recorded in August, 85 in September, and 84 in October. This compares with 135 and 150 taxa recorded from 21 BMNDRC wetlands sampled in August 2004 and 2005, respectively. Of the 187 taxa, 39% were considered to be 'permanent' residents with desiccation-resistant life stages that would allow them to remain within the wetland once surface waters had evaporated. The remainder were 'temporary fauna', which do not have such resistant life stages and must reinvade each time a seasonal waterbody becomes inundated.

The number of taxa collected[4] varied greatly, both between sites and time of year. Over 2008, taxa richness ranged from one at the hypersaline wetland W019 (in September) to 60 taxa at the fresh wetland W024 (also in September). Generally, a greater number of taxa were recorded from fresh, brackish and saline sites when compared with hypersaline wetlands. This is expected given the well established link between salinity and invertebrate fauna composition. Salinity can affect aquatic invertebrate communities in a number of ways. Elevated salinity in freshwater systems can have a direct impact on fauna through effects on osmoregulatory physiology as the maintenance of constant solute body concentration is impaired (Bayly 1972, Kefford *et al.* 2003). Indirect effects are typically due to alterations in habitat; the loss of aquatic and fringing vegetation around wetlands (Froend 1987) represents a decrease in habitat diversity, a change in food web structure and an increase in predation/competition pressure for invertebrates. There is a general acceptance that when conductivity is less than 1500 µS/cm, freshwater ecosystems experience little ecological stress (Hart *et al.* 1991, Horrigan *et al.* 2005).

Although wetland taxa richness did tend to increase over time during 2008, with the greatest mean number of invertebrate fauna being recorded in October, these differences were not statistically significant. It appeared that the generally higher number of taxa recorded in October was due to the progressive colonisation of wetlands by temporary fauna, which showed a steady increase in taxa richness over 2008. There was also no significant difference in permanent taxa richness over 2008; however, the number of permanent taxa did increase from August to September as additional fauna began to emerge, and then decreased between September and October. This is not entirely unexpected given the cyclic nature of permanent fauna, as they emerge quickly and are then under pressure to complete their life cycle before predatory colonisers appear. Following flooding, the abundance of permanent fauna generally increases rapidly due to the activation of resting stages and diapausing juveniles (Morton and Bayly 1977, Boulton and Lloyd 1992). Those species which survive to take advantage of the environment are those best adapted to the physical and chemical environment (King *et al.* 1996). For example, those permanent fauna which are not tolerant of high salinities will not survive long enough to go through their life cycle in certain wetlands of the BMNDRC. In a study on the influence of seasonality and flooding duration in an experimental billabong, Nielson *et al.* (2002) found that the densities of rotifer populations changed in cyclic patterns that were unrelated to the hydrology of the billabongs. Permanent flooding was found to have only a minor effect on the structure of the zooplankton community. Nielson *et al.* (2002) suggested that increases in macrophyte cover may have influenced the zooplankton community by increasing habitat. This would allow planktonic rotifers to coexist with competitors whilst obtaining refuge from predators. Wiggins *et al*. (1982) suggest that emergence of animals from resting eggs is dependent not only on the availability of water

[4] Taxa richness

but also on receiving the right cues in the right sequence. As the emergent permanent fauna move through the hydrological cycle, they become influence by biotic factors of competition and predation as more permanent fauna emerge and temporary fauna colonise the waterbody.

When wetlands were ranked according to the diversity of invertebrates they support, wetlands W024 and W023 had the highest mean overall ranks during each sampling occasion. This likely reflects the condition of these wetlands, whereby they contain fresh/brackish water, and have a diversity of aquatic habitats not present at saline or hypersaline wetlands, such as trees/shrubs seasonally inundated around the shoreline, large woody debris in the water, emergent macrophytes (Typha), submerged aquatic macrophytes, tannin-stained water, and organic detritus.

However, there were differences in the ranking of wetlands based on the different fauna types. For example, although W023 had the highest ranking in both the number of total invertebrate fauna and temporary fauna during August, it was ranked eighth based on its permanent fauna richness. Although the saline wetland W015 was ranked third based on the number of temporary fauna, it was ranked tenth and sixth based on the number of permanent and total number of taxa, respectively. These differences reflect the preference of temporary fauna for permanently-inundated wetlands, and vice versa the preference/dependence of permanent fauna on seasonal wetlands.

4.2.2 Conservation significance of invertebrates

While the majority of invertebrate taxa recorded from the BMNDRC are common, ubiquitous species with cosmopolitan or Australasian distributions, species with restricted distributions were recorded from the BMNDRC wetlands, with 6% of the total invertebrate fauna being endemic to the Australian continent and 4% being restricted to the south-west of Western Australia.

Wetlands W001, W004, W009, W010, W011, W013, W015, W023 and W024 supported south-west endemics, with lower proportions of endemic taxa from hypersaline and saline wetlands than brackish and fresh sites. Australian endemics and south-west endemics, were recorded during each sampling occasion during 2008. Introduced species were only recorded from hypersaline and saline wetlands within the BMNDRC.

4.2.3 Intra-annual variation in fauna

Analysis showed that intra-annual (i.e. between month) variation in assemblage composition was less than the difference in assemblage composition between salinity categories, indicating that effects of salinity are greater than any seasonal successional changes in the fauna. Aside from the overbearing effects of salinity on the fauna, analyses indicated that the permanent residents (i.e. those with drought-resistant stages adapted to living in seasonal wetlands) were more variable over the winter/spring than the temporary fauna, with a slight increase in the diversity of the temporary fauna over time. It seems likely that the increase in the diversity of temporary fauna over time reflects progressive colonisation of the wetlands by these taxa, most likely as a result of aerial adults progressively finding these wetlands and establishing populations. Conversely, variability in the permanent fauna over the winter/spring likely reflects successional changes in the fauna, with some taxa hatching early and completing their lifecycle (before permanent and temporary resident predators get established), with other species emerging later, and lasting longer into the spring. It is known that some permanent residents will emerge early in the season, when the wetland is at its freshest, whilst others will emerge later in the season as the wetland starts to evapoconcentrate, and concentrations of various parameters, including salinity, increase. With respect to ongoing monitoring, the data indicate that although there are small changes in faunal assemblages over the winter, so long as sampling is conducted when water levels are reasonably high (i.e. not within the first few weeks/month of filling, and not towards the end of the season as the wetland recedes, sampling will collect a reasonably diverse fauna that is comparable to previous winter sampling events. However, ideally, sampling should be planned for August, as there are now three years (2004, 2005 and 2008) of monitoring data collected in August.

4.2.4 Inter-annual variation in fauna

As with analysis of intra-annual variation in patterns of invertebrate assemblage composition, analysis of inter-annual variation showed that salinity was a far greater influence on between-site differences in assemblage composition than between year differences.

When comparing variation between years and between months in 2008, analysis showed that between year differences in assemblage composition were marginally greater than between month differences within the 2008 data. This suggests that invertebrate assemblages of BMNDRC were slightly more variable between years than between months within the same year.

4.3 Vertebrate fauna

Of particular note in 2008 was the discovery of another population of the Swan River Goby in the catchment. Previously taken on one occasion from one wetland (W009), the goby was taken on at least three occasions (during this study and during additional visits by M. Cundy, DEC). The fish were in wetland W023, which added to the biodiversity value of this newly sampled, freshwater wetland.

Other wetland-dependent fauna included four species of frog and 17 species of waterbird, six of which were breeding. Although all the frog and waterbird species are considered ‘common’ in the south-west, their presence adds to the biodiversity values of the wetlands and catchment as a whole. However, these species tended to be present at the fresh and brackish water sites, and deterioration in water quality may adversely affect these species, and therefore biodiversity values of the catchment.

4.4 Bentonite wetlands

The emergence of microinvertebrates from sediments from the bentonite lakes was considered poor when compared to incubation of sediments from other seasonal wetlands in the south-west of the State. They contained a more diverse fauna than a mine-impacted lake in the southwest, but were depauperate when compared with more natural wetlands adjacent to the mine-impacted lake. It is most likely the poor emergence reflects a depauperate egg bank, which may reflect the absence of substantial inundation in recent years. The large numbers of *Cephalodella catellina* emerging from the sediments indicated that this species was coping with the 'last-wetted' condition of the site(s) very well, and there were a lot of *C. catellina* eggs visible in the sediment samples.

Viability of the egg-bank and/or provision of inappropriate cues for emergence (20 ^{o}C in a Constant Temperature room with constant light) are also possible reasons for poor emergence. However, given the natural variation in climatic conditions experienced by south-west microinvertebrates, greater response would have been expected to what would be considered 'average' conditions if viable eggs were present.

Similarly, the resting eggs and ephippia of microinvertebrates in southern Australian wetlands are generally considered to have a naturally high viability as they have evolved under, and are adapted to long periods of ephemerality. Given that resting eggs have been hatched from cores from the Great Lakes, dated at 300-350 years, I seems unlikely there is an egg bank in the sediments that is not viable. A possible explanation is the absence of eggs, reflecting the very ephemeral nature of the wetlands, which seldom hold water.

In the absence of substantial emergence, the sediments will be kept flooded and the rehydration experiment continued for another 30 – 40 days. Past rehydration trials of southwest wetland sediments observed emergence up to 60 days post-flooding. Therefore, more animals may yet appear from the bentonite wetland sediments. Any additional fauna records will be submitted to DEC Geraldton as an Inter-office Memo.

5 RECOMMENDATIONS

- Wetlands W023 and W024, which were sampled for the first time in 2008, supported the highest biodiversity values of any wetlands so far sampled in the catchment. These wetlands should be re-sampled in 2010 and again in 2011 to characterise inter-annual variation in water quality and aquatic fauna, and to provide as comprehensive a species list as possible.

- The claypan site W074, although not especially diverse, did support several taxa not represented in other wetlands, and therefore increased to the biodiversity values of the catchment. Similarly, this wetland should be re-sampled in 2010 and again in 2011 to characterise inter-annual variation in water quality and aquatic fauna, and to provide as comprehensive a species list as possible for freshwater 'clay-pan-type' wetlands, which are poorly represented in the catchment.

- The operational goal of the BMNDRC project is "for the next 10 years, maintain the 2007 richness, distribution, abundance and condition of a representative sample of biodiversity assets threatened by salinity within the BMNDRC". To determine whether this goal is being met, it is necessary to conduct on-going monitoring of the biodiversity values of the selected representative suite of wetlands. A single sampling event after 10 years (i.e. in 2017) will show if the project was successful (or not), but does not allow adaptive management to achieve the goal. Similarly, sampling in 2017 will not provide early feedback on the success of any on-ground management activities. Therefore, it is recommended that regular, but low frequency monitoring of water quality and aquatic fauna is conducted, ideally every third year, and at a minimum every fifth year.

- Sampling from 2008 indicated there is a small change in biodiversity over the hydrocycle, with a slight increase in temporary fauna, and successional changes in the permanent fauna from mid winter into spring, however, monthly changes were small, suggesting time of sampling each winter is not critical for determining biodiversity values. However, based on the existence of the current database, with data collected from wetlands in August each year (i.e. 2004, 2005 and 2008), it is recommended that any future monitoring is also conducted in the month of August.

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APPENDICES

Appendix 1. Site photographs

W001


W002


W004


W009

W010

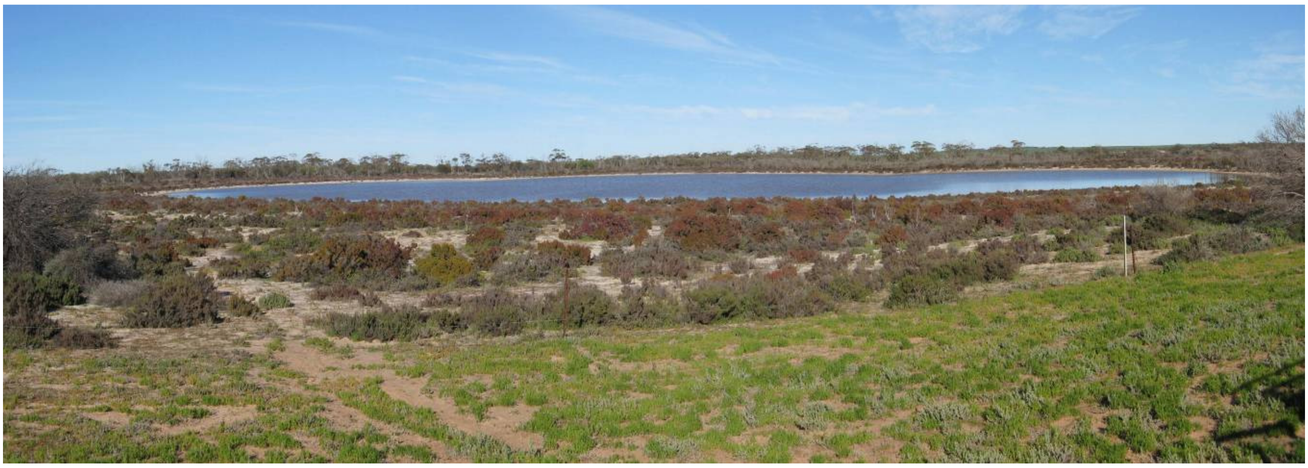
W011

W012

W015

W016

W019



W023

W024

W074

Appendix 2. Abundance of invertebrates from each site sampled. Values are $\log_{10}$ abundance classes where 1 = 1 individual, 2 = 2-10 individuals, 3 = 10 – 100, and so on.

Table A2-1. August 2008.

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
ROTIFERA																
Bdelloidea																
Monogononta		*Brachionus plicatilis s.l.*	0	0	4	0	0	0	3	3	0	2	0	0	0	0
	Hexarthridae	*Hexarthra cf. brandorffi*	4	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hexarthra fennica	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Notommatidae	*Cephalodella sp.*	0	0	0	0	2	0	0	0	0	0	0	0	0	0
NEMATODA		Nematoda spp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ANNELIDA	**OLIGOCHAETA**	Oligochaeta spp.	0	0	0	0	1	0	0	1	0	0	0	0	0	0
MOLLUSCA																
GASTROPODA	**Pomatiopsidae**	*Coxiella (Coxiella) sp*	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Ancylidae	*Ferrissia petterdi*	0	0	0	0	0	0	0	0	0	0	0	0	0	2
ARTHROPODA																
ARACHNIDA																
ACARIFORMES		Hydracarina spp.	0	0	0	2	1	0	0	0	0	0	0	1	1	3
ORIBATIDA		Oribatida spp	0	0	0	0	0	0	0	2	1	0	0	0	0	3
CRUSTACEA																
COPEPODA																
Cyclopoida	**Cyclopidae**	*Apocyclops dengizicus*	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		Metacyclops arnaudi	0	1	0	0	0	0	0	0	0	0	0	0	0	0
		Metacyclops cf. laurentiisae	0	0	2	0	0	0	0	0	0	0	0	0	0	0
		Metacyclops sp. a	0	3	0	0	0	0	0	0	0	0	0	0	0	0
		copepodites	0	4	3	0	0	0	0	0	0	3	0	3	1	0
		nauplii	0	3	3	0	0	0	0	0	0	4	0	3	0	0
Calanoida	**Centropagidae**	*Boeckella triarticulata s.l.*	0	0	0	4	2	3	0	3	0	0	0	0	4	3
		Calamoecia clitellata	0	0	0	0	0	0	3	0	0	0	0	0	0	0

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
		Calamoecia trilobata	2	0	0	0	0	0	0	0	0	0	0	0	0	0
		Calamoecia sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	2
		calanoid copepodites	2	0	0	3	2	0	3	0	0	0	0	0	4	3
		calanoid nauplii	3	0	0	3	4	1	3	3	0	1	0	0	3	3
Harpacticoida		*indet. sp./juv.*	0	0	0	1	0	0	0	0	0	0	0	0	1	0
CLADOCERA	**Chydoridae**	*Alona rigidicaudis*	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Alona cf. verrucosa	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Alona sp. [n. sp.?]	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Daphnidae	*Daphnia (s. str.) carinata s.l.*	0	0	0	2	3	4	0	0	1	0	0	4	0	3
		Daphnia (Daphniopsis) wardii	0	0	0	0	0	3	3	0	0	0	0	0	0	0
		Daphnia (Daphniopsis) sp.	0	2	3	0	0	0	0	0	0	3	0	0	0	0
		Simocephalus elizabethae	0	0	0	0	0	0	0	0	0	0	0	1	0	0
OSTRACODA	**Ostracoda**	*Australocypris sp.*	0	0	2	0	0	0	0	0	3	0	0	0	0	2
		Cypretta sp.	0	0	0	0	0	0	0	0	1	0	0	1	0	0
		Diacypris sp. b	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Limnocythere sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Mytilocypris sp.	0	0	0	0	0	2	0	0	0	0	0	0	0	0
		Platycypris sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Reticypris sp.	2	1	0	0	0	3	3	0	0	0	0	0	0	0
		cf. Sarscypridopsis sp.	0	0	0	0	2	0	0	0	0	0	0	2	0	0
		larger kidney bean	1	0	0	0	0	0	0	0	0	0	0	0	0	0
		indet. juvenile	0	0	0	0	1	0	3	0	0	2	0	0	1	0
ANOSTRACA	**Artemiidae**	*Artemia nr parthogenetica*	0	0	0	0	0	0	2	0	0	1	0	0	0	0
		Artemia franciscana	2	0	2	0	0	0	0	0	0	0	0	0	0	0
	Parartemidae	*Parartemia contracta*	2	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parartemia ?longicaudata	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Thamnocephalidae	*Branchinella affinis*	0	0	0	0	0	0	0	0	0	0	0	0	0	4
AMPHIPODA	**Ceinidae**	*Austrochiltonia subtenius*	0	1	0	3	0	3	2	3	4	2	0	3	4	0
INSECTA																
DIPTERA		Unknown diptera (P)	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
	Athericidae	Athericidae spp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Chironomidae	Chironomid spp. (P)	0	0	0	2	2	2	0	0	0	0	0	1	0	0
		Tanytarsus sp. (P)	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Procladius paludicola (P)	0	0	0	0	0	0	0	0	3	0	0	0	0	0
	Chironominae	*Chironomus aff. altermans*	0	0	0	0	3	0	0	0	2	0	0	3	2	0
		Parachironomus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Tanytarsus sp.	0	0	0	3	0	0	0	0	0	0	0	0	0	0
		Tanytarsus fuscithorax	0	0	0	0	3	0	0	0	3	0	0	3	4	0
		Tanytarsus semibarbitarsus	0	0	0	4	0	4	0	0	0	4	0	0	0	0
		Tanytarsus barbitarsus	0	4	4	4	0	3	3	0	0	3	0	0	0	0
		Dicrotendipes conjunctus	0	0	0	3	3	2	0	0	0	0	0	3	1	0
		Polypedilum nubifer	0	0	0	4	4	0	0	0	0	0	0	3	1	0
		Polypedilum (Pentapedilum) leei	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Cladopelma curtivalva	0	0	0	0	0	4	2	0	0	0	0	2	0	0
		Larsia ?albiceps	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		Kiefferulus intertinctus	0	0	0	0	0	0	0	0	2	0	0	2	0	0
	Tanypodinae	*Procladius villosimanus*	0	0	0	0	0	0	0	0	0	0	0	3	0	0
		Procladius paludicola	0	3	0	2	0	4	2	0	3	0	0	2	2	1
		Ablabesmyia notabilis	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		Paramerina levidensis	0	0	0	0	0	0	0	0	0	0	0	3	0	0
	Orthocladiinae	*Orthocladiinae spp. V46*	0	0	0	0	3	0	0	0	0	0	0	3	2	0
		Paralimnophyes sp. V42	0	0	0	0	0	0	0	0	0	0	0	2	2	0
		Corynoneura sp. V49	0	0	0	0	0	0	0	0	0	0	0	3	1	0
	Culicidae	*Culicinae spp. (L)*	0	0	3	0	2	0	0	0	2	0	0	0	0	0
		Culicinae spp. (P)	0	0	2	0	0	0	1	0	1	0	0	0	1	0
		Culex sp.	0	0	0	0	0	0	0	0	0	1	0	1	0	1
	Ceratopogonidae	Ceratopogonid spp. (P)	0	0	0	0	0	2	0	3	0	0	1	0	0	0
		Ceratopogoniinae spp.	2	0	0	0	0	0	3	4	0	2	0	2	0	2
		Dasyheleinae spp.	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	Dolichopodidae	Dolichopodiae spp.	0	0	0	2	3	0	0	1	1	0	0	0	0	0
	Ephydridae	Ephydridae spp.	0	0	2	2	4	0	0	0	1	2	0	0	0	0
		Ephydridae spp. (P)	0	0	0	0	2	0	0	3	0	0	0	0	0	0
	Muscidae	Muscidae spp.	0	0	2	2	0	0	0	0	0	0	0	0	0	0
		Muscidae spp. (P)	1	1	0	0	0	1	0	2	0	0	2	0	0	0
	Psychodidae	Psychodidae spp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Sciomyzidae	?Sciomyzidae spp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Simuliidae	Simuliidae spp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Stratiomyidae	Stratiomyidae spp.	0	0	0	2	0	0	0	0	0	0	0	0	0	0

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
	Tabanidae	Tabanidae spp.	0	0	0	2	0	0	0	0	2	0	2	1	2	0
	Tipulidae	Tipulidae spp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0
TRICHOPTERA	**Leptoceridae**	*Triplectides australicus*	0	0	0	2	0	0	0	0	0	0	0	2	2	0
		Notalina spira	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Oecetis sp.	0	0	0	0	0	0	0	0	0	0	0	2	0	0
EPHEMEROPTERA	**Caenidae**	*Tasmanocoenis tillyardi*	0	0	0	0	0	0	0	0	0	0	0	2	0	0
	Baetidae	Baetidae spp. (imm)	0	0	0	0	0	0	0	0	0	0	0	2	2	0
ODONATA																
ANISOPTERA	**Libellulidae**	*Orthetrum caledonicum*	0	0	0	0	0	0	0	0	0	0	0	1	0	0
		Diplacodes haematodes	0	0	0	0	0	3	0	0	2	0	0	2	2	0
		Austrothemis nigrescens	0	0	0	0	0	0	0	0	0	0	0	2	0	0
	Aeshnidae	*Hemianax papuensis*	0	0	0	0	0	0	0	0	2	0	0	2	3	0
		Adversaeschna brevistyla	0	0	0	2	0	2	0	0	0	0	0	0	0	0
ZYGOPTERA	**Lestidae**	*Austrolestes annulosus*	0	0	0	3	0	3	0	0	0	0	0	0	3	0
		Austrolestes analis	0	0	0	0	0	0	0	0	3	0	0	3	0	0
COLEOPTERA	**Dytiscidae**	*Necterosoma penicillatum*	0	0	1	0	2	2	0	2	0	0	0	0	1	0
		Necterosoma sp. (L)	0	0	2	1	0	3	0	0	0	0	0	2	0	3
		Sternopriscus mulimaculatus	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Sternopriscus sp. (F)	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Allodessus bistrigatus	0	0	0	0	0	0	0	3	0	0	0	0	2	0
		Rhantus sp (L)	0	0	0	0	3	0	0	0	0	0	0	0	0	0
		Onychohydrus sp (L)	0	0	0	0	0	0	0	0	0	0	0	2	0	0
		Dytiscidae spp. (L imm.)	0	1	0	0	0	2	0	0	0	0	0	0	0	0
		Limbodessus shuckardii	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Hydrophilidae	*Berosus discolor*	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Berosus sp. (L)	0	0	0	0	0	2	0	0	0	0	0	0	0	0
		Berosus macumbensis	0	0	0	0	0	0	0	0	0	1	0	0	2	1
		Helochares sp. (L)	0	0	0	0	0	0	0	0	1	0	0	0	0	0
		Limnoxenus sp (L)	0	0	0	0	0	0	0	0	1	0	0	0	1	0
	Limnichidae	*Limnichidae spp*	0	0	0	0	0	0	0	0	0	0	0	0	3	0
HEMIPTERA	**Corixidae**	*Corixidae juv.*	0	0	0	0	3	2	0	1	0	0	0	2	3	0
		Micronecta spA (lined)	0	0	0	4	3	2	0	2	0	0	0	1	0	1
		Micronecta sp. (imm)	0	0	0	3	0	0	0	0	0	0	0	0	0	0

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
		Agraptocorixa eurynome	0	0	0	2	0	0	0	0	0	0	0	0	0	0
		Agraptocorixa sp. (F)	0	0	0	1	0	1	0	0	0	0	0	0	2	1
	Notonectidae	*Anisops thienemanni*	0	0	0	0	2	0	0	0	1	0	0	0	1	0
		Anisops sp. (imm & F)	0	0	0	0	3	2	0	0	2	0	0	4	2	1
		Notonecta sp.	0	0	0	2	0	2	2	4	0	0	0	0	3	0
	Gelastocoridae	*Nerthra sp. (imm)*	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Ochteridae	*Ochterus occidentalis*	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Velidae	Velidae spp. (damaged)	0	1	0	0	0	0	0	0	0	0	1	0	0	0
		Microvelia peramoena	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Pleidae	*Paraplea brunni*	0	0	0	0	0	0	0	0	0	0	0	2	0	0
LEPIDOPTERA	**Pyralidae**	Nymphulinae spp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0
		Taxa richness	**11**	**13**	**19**	**29**	**25**	**27**	**16**	**21**	**28**	**15**	**4**	**42**	**41**	**20**

Table A2-2. September 2008.

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024
PROTISTA															
Rhizopoda	**Arcellidae**	*Arcella sp.*	0	0	0	0	0	0	0	0	0	0	0	0	2
	Lesquereusidae	*Netzelia tuberculata*	0	0	0	0	0	0	0	0	0	0	0	0	1
ROTIFERA															
Bdelloidea		*indet. bdelloid*	0	0	0	0	0	0	0	0	0	0	0	0	1
Monogononta	**Brachionidae**	*Brachionus cf. ibericus*	0	0	1	0	0	0	0	0	0	0	0	0	0
		Brachionus plicatilis s.l.	0	0	0	0	0	2	3	3	0	0	0	0	0
	Euchlanidae	*Euchlanis sp.*	0	0	0	0	0	0	0	0	0	0	0	0	1
	Hexarthridae	*Hexarthra fennica*	0	0	0	0	0	0	0	3	0	0	0	0	0
	Lecanidae	*Lecane bulla*	0	0	0	0	0	0	0	0	0	0	0	0	2
		Lecane a	0	0	0	0	0	1	0	0	0	0	0	0	0
		Lecane b	0	0	0	0	0	2	0	0	0	0	0	1	0
		Lecane hamata	0	0	0	0	0	0	0	0	0	0	0	0	2
		Lecane closterocerca	0	0	0	0	0	0	0	0	0	0	0	0	1
	Lepadellidae	*Colurella*	0	0	0	0	0	2	0	0	0	0	0	0	0
		Lepadella biloba	0	0	0	0	0	1	0	0	0	0	0	0	2
	Synchaetidae	*Synchaeta sp.*	0	0	0	0	0	0	0	0	0	0	0	0	2
	Testudinellidae	*Testudinella patina*	0	0	0	0	0	2	0	0	0	0	0	0	0
	Trichocercidae	*Trichocerca sp.*	0	0	0	0	0	0	0	0	0	0	0	0	1
CNIDARIA		*Hydra sp.*	0	0	0	0	0	0	0	0	0	0	0	0	1
PLATYHELMINTHES															
	TURBELLARIA	*cf. Mesostoma sp.*	0	0	0	0	0	2	0	0	0	0	0	0	0
ANNELIDA	**OLIGOCHAETA**	Oligochaeta spp.	0	0	0	0	0	0	0	0	0	0	0	3	0
MOLLUSCA															
GASTROPODA	**Pomatiopsidae**	*Coxiella (Coxiella) sp*	0	0	2	0	0	0	0	0	0	1	0	0	0
ARTHROPODA															
ARACHNIDA															

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024
ACARIFORMES		Hydracarina spp.	0	0	0	0	3	0	0	1	1	0	0	0	2
ORIBATIDA		Oribatida spp	0	0	0	1	0	0	1	0	0	0	0	3	2
CRUSTACEA															
COPEPODA															
Cyclopoida	**Cyclopidae**	*Apocyclops dengizicus*	0	0	2	0	0	0	0	0	0	1	0	0	0
		Mesocyclops brooksi	0	0	0	0	0	0	0	0	0	0	0	1	1
		Metacyclops arnaudi	0	0	3	0	0	0	0	0	0	0	0	0	0
		Metacyclops cf. laurentiisae	0	0	3	0	0	0	0	0	0	0	0	0	0
		Metacyclops sp. a	0	3	0	0	0	0	0	0	1	0	0	0	0
		Metacyclops sp. b	0	0	0	0	0	0	0	0	1	0	0	0	0
		copepodites	2	0	4	0	0	3	0	0	2	3	0	3	3
		nauplii	0	0	4	0	0	4	0	0	0	0	0	0	4
Calanoida	**Centropagidae**	*Boeckella triarticulata s.l.*	0	0	0	4	3	3	0	3	0	0	0	4	1
		Calamoecia clitellata	0	0	0	0	0	0	3	0	0	0	0	0	1
		Calamoecia trilobata	3	0	0	0	0	0	0	0	0	0	0	0	0
		Calamoecia sp.	0	0	0	0	0	0	0	0	1	0	0	0	0
		calanoid copepodites	0	0	0	4	3	2	2	2	0	0	0	3	0
		calanoid nauplii	0	0	0	3	1	3	4	4	0	0	0	3	0
Harpacticoida		*indet. sp./juv.*	0	0	0	0	0	1	0	0	0	0	0	0	1
CLADOCERA	**Chydoridae**	*Alona rigidicaudis*	0	0	0	0	0	0	0	0	0	0	0	2	0
	Daphnidae	*Daphnia (s. str.) carinata s.l.*	0	0	0	1	4	2	0	0	0	0	0	0	1
		Daphnia (Daphniopsis) truncata	0	0	1	0	0	0	0	0	0	0	0	0	0
		Daphnia (Daphniopsis) wardii	0	0	0	0	0	0	0	0	0	4	0	0	0
		Daphnia (Daphniopsis) sp.	0	4	0	0	2	0	1	0	0	0	0	0	0
		Simocephalus elizabethae	0	0	0	0	0	0	0	0	0	0	0	1	1
	Macrothricidae	*Macrothrix sp.*	0	0	0	0	1	1	0	0	0	0	0	0	0
	Moinidae	*Moina sp.*	0	0	0	1	0	0	0	0	0	0	0	0	0
	Sididae	*Latonopsis cf. brehmi*	0	0	0	0	0	0	0	0	0	0	0	2	1
OSTRACODA	**Ostracoda**	*Australocypris sp.*	0	0	1	0	0	0	0	0	0	3	0	0	0
		Bennelongia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
		Cypretta sp.	0	0	0	0	0	0	0	0	0	0	0	0	1

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024
		Diacypris sp. b	0	0	1	0	2	1	0	0	2	0	0	0	0
		Limnocythere sp.	0	0	0	0	0	2	0	0	1	0	0	0	0
		Mytilocypris sp.	0	0	0	0	1	1	0	1	0	0	0	0	0
		Reticypris sp.	4	2	1	0	0	1	1	1	0	0	0	0	0
		cf. Sarscypridopsis sp.	0	0	0	0	0	0	0	0	4	3	0	0	1
		indet. juvenile	0	0	0	0	0	3	0	0	3	0	0	1	1
ANOSTRACA	**Artemiidae**	*Artemia nr parthogenetica*	1	0	0	0	0	0	0	0	0	0	0	0	0
		Artemia franciscana	0	0	0	0	0	0	5	0	0	0	0	0	0
	Parartemidae	*Parartemia contracta*	3	0	0	0	0	0	0	0	0	0	0	0	0
AMPHIPODA	**Ceinidae**	*Austrochiltonia subtenius*	0	2	0	3	2	4	2	4	4	2	0	4	4
INSECTA															
DIPTERA	**Chironomidae**	Chironomid spp. (P)	0	0	2	0	3	0	0	0	0	3	0	0	2
	Chironominae	*Chironomus occidentalis*	0	0	0	0	0	0	0	0	0	0	0	2	0
		Chironomus aff. altermans	2	0	0	2	3	0	2	0	3	0	0	3	3
		Tanytarsus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0
		Tanytarsus fuscithorax	0	0	0	3	4	3	0	0	4	0	0	3	4
		Tanytarsus semibarbitarsus	0	4	0	0	0	0	0	0	0	4	0	0	0
		Tanytarsus barbitarsus	0	0	4	0	0	0	4	3	0	0	0	0	0
		Cryptochironomus griseidorsum	1	0	0	0	3	0	0	0	1	0	0	0	0
		Dicrotendipes conjunctus	0	0	0	4	4	2	0	2	3	0	0	3	3
		Polypedilum nubifer	2	0	0	4	4	3	0	0	0	0	0	1	3
		Cladopelma curtivalva	0	0	0	0	0	0	0	0	0	1	0	2	0
		Kiefferulus intertinctus	0	0	0	0	0	0	0	0	0	0	0	2	0
		?Paratanytarsus sp.	0	0	0	0	3	0	0	0	0	0	0	0	0
	Tanypodinae	*Procladius villosimanus*	0	0	0	0	3	2	0	0	0	0	0	3	3
		Procladius paludicola	2	4	3	2	3	3	0	3	3	3	0	2	0
		Ablabesmyia notabilis	0	0	0	0	0	0	0	0	0	0	0	1	0
		Paramerina levidensis	0	0	0	0	0	0	0	0	0	0	0	2	3
	Orthocladiinae	*Orthocladiinae spp. V46*	0	0	0	0	0	0	0	0	0	0	0	2	3
		Paralimnophyes sp. V42	0	3	0	2	0	0	0	0	2	0	0	0	2
		Corynoneura sp. V49	0	0	0	0	0	0	0	0	0	0	0	3	3
	Culicidae	*Culicinae spp. (L)*	0	0	0	0	0	2	0	0	0	0	0	0	3
		Culex sp.	0	0	0	0	0	0	0	0	4	0	0	0	0
		Anopheles sp.	0	0	0	0	0	0	0	0	1	0	0	0	1
	Ceratopogonidae	Ceratopogonid spp. (P)	0	0	0	0	0	0	0	0	1	0	0	0	0

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024
		Ceratopogoniinae spp.	0	1	0	0	3	2	3	4	3	0	0	0	0
		Dasyheleinae spp.	0	0	0	0	0	0	0	0	0	0	0	0	3
	Dolichopodidae	Dolichopodiae spp.	0	0	0	0	3	2	0	1	2	0	0	0	2
	Ephydridae	Ephydridae spp.	0	0	3	0	1	0	0	0	3	3	0	0	0
		Ephydridae spp. (P)	0	0	0	1	3	0	0	0	2	0	0	0	0
	Muscidae	Muscidae spp. (P)	0	0	0	1	3	0	0	0	0	0	0	0	1
	Psychodidae	Psychodidae spp.	0	0	0	0	0	0	0	0	3	0	0	0	0
	Stratiomyidae	Stratiomyidae spp.	0	0	0	1	3	0	0	0	0	3	0	1	1
	Tabanidae	Tabanidae spp.	0	0	0	0	0	0	1	0	2	0	0	0	2
	Tipulidae	Tipulidae spp.	0	0	0	0	2	0	0	0	0	0	2	0	0
TRICHOPTERA	**Leptoceridae**	*Triplectides australis*	0	0	0	0	2	2	0	0	0	0	0	0	0
		Triplectides australicus	0	0	0	2	0	0	0	0	0	0	0	2	2
		Notalina spira	0	0	0	2	0	2	0	3	0	0	0	0	1
		Oecetis sp.	0	0	0	0	0	2	0	3	0	0	0	2	0
EPHEMEROPTERA	**Caenidae**	*Tasmanocoenis tillyardi*	0	0	0	0	0	0	0	0	0	0	0	2	0
	Baetidae	Baetidae spp. (imm)	0	0	0	0	0	0	0	0	0	0	0	2	0
ODONATA															
ANISOPTERA		Anisoptera (imm) spp.	0	0	0	0	0	0	0	0	1	0	0	0	0
	Libellulidae	*Orthetrum caledonicum*	0	0	0	2	0	0	0	0	0	0	0	1	0
		Diplacodes haematodes	0	0	0	0	0	3	0	0	2	0	0	2	2
	Aeshnidae	*Hemianax papuensis*	0	0	0	3	0	0	0	0	1	0	0	2	2
		Adversaeschna brevistyla	0	0	0	0	1	2	0	0	0	0	0	0	0
ZYGOPTERA		*Zygoptera spp. (imm.)*	0	1	0	0	0	0	0	0	0	0	0	0	0
	Lestidae	*Austrolestes annulosus*	0	0	0	3	2	0	0	0	0	0	0	3	3
		Austrolestes analis	0	0	0	0	1	0	0	0	2	0	0	4	0
COLEOPTERA	**Dytiscidae**	*Necterosoma penicillatum*	0	0	0	0	0	2	0	0	0	0	0	0	0
		Necterosoma sp. (L)	0	2	2	2	2	3	3	0	1	0	0	0	0
		Allodessus bistrigatus	0	0	0	0	1	0	0	0	0	0	0	0	1
		Megaporus sp (L)	0	0	0	0	0	0	0	0	0	0	0	0	1
		Rhantus sp (L)	0	0	0	0	3	0	0	0	0	0	0	0	0
		Onychohydrus sp (L)	0	0	0	0	0	0	0	0	0	0	0	2	0
		Hyphydrus elegans	0	0	0	0	0	0	0	0	0	0	0	1	0
	Hydrophilidae	*Berosus sp. (L)*	0	2	0	0	0	2	0	0	0	3	0	0	0
		Berosus nutans	0	0	0	0	2	1	0	0	0	0	0	0	1

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024
		Helochares sp. (L)	0	0	0	0	0	0	0	0	0	0	0	0	1
		Limnoxenus sp (L)	0	0	0	0	0	0	0	0	2	0	0	0	0
	Hydraenidae	*Hydraena sp.*	0	0	0	0	0	0	0	0	0	0	0	0	1
	Staphylinidae	Staphylinidae sp.	0	0	0	0	2	0	0	0	0	0	0	0	0
HEMIPTERA	**Corixidae**	Corixidae juv.	2	0	0	4	3	2	0	0	1	0	0	2	3
		Micronecta robusta	0	0	0	0	0	0	0	0	1	0	0	0	0
		Micronecta spA (lined)	1	0	0	4	4	3	0	2	0	0	0	0	1
		Micronecta spB (dull)	0	0	0	3	0	0	0	0	0	0	0	0	0
		Agraptocorixa sp. (F)	0	0	0	3	0	0	0	0	0	0	0	2	1
	Notonectidae	*Anisops thienemanni*	0	0	0	3	2	0	0	3	2	0	0	0	1
		Anisops sp. (imm & F)	0	0	0	3	3	1	0	3	2	0	0	3	3
		Notonecta sp.	0	0	0	4	2	3	3	3	0	0	0	2	2
	Mesoveliidae	*Mesovelia sp*	0	0	0	0	0	0	0	0	2	0	0	2	1
	Ochteridae	*Ochterus sp.*	0	1	0	0	0	0	0	0	0	0	0	0	0
	Velidae	*Microvelia peramoena*	0	0	0	0	0	0	0	0	0	0	0	0	2
	Pleidae	*Paraplea brunni*	0	0	0	0	0	0	0	0	0	0	0	2	0
LEPIDOPTERA	**Pyralidae**	Nymphulinae spp.	0	2	0	0	0	0	0	0	0	0	0	0	0
		Taxa richness	**12**	**13**	**16**	**29**	**40**	**42**	**15**	**20**	**36**	**14**	**1**	**44**	**60**

Table A2-3. October 2008.

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W019	W023	W024
PROTISTA														
Ciliophora		*Euplotes sp.*	0	0	0	0	0	0	0	0	1	0	0	0
Rhizopoda	**Arcellidae**	*Arcella discoides*	0	0	0	0	0	0	0	0	0	0	0	1
ROTIFERA														
Bdelloidea		indet. bdelloid	0	0	0	0	0	3	0	0	0	0	0	0
Monogononta	**Brachionidae**	*Brachionus plicatilis s.l.*	0	0	0	0	0	4	3	3	0	0	0	0
		Brachionus quadridentatus	0	0	0	0	0	2	0	0	0	0	0	0
	Hexarthridae	*Hexarthra fennica*	0	0	0	0	0	0	0	3	0	0	0	0
	Lecanidae	*Lecane a*	0	0	0	0	0	1	0	0	0	0	0	0
	Testudinellidae	*Testudinella patina*	0	0	0	0	0	2	0	0	0	0	0	1
PLATYHELMINTHES														
	TURBELLARIA	*cf. Mesostoma sp.*	0	0	0	0	0	1	0	0	0	0	0	0
ANNELIDA	**OLIGOCHAETA**	Oligochaeta spp.	0	0	0	4	0	0	0	0	0	2	3	0
MOLLUSCA														
GASTROPODA	**Pomatiopsidae**	*Coxiella (Coxiella) sp*	0	0	3	0	0	0	0	0	0	0	0	0
ARTHROPODA														
ARACHNIDA														
ACARIFORMES		Hydracarina spp.	0	0	0	0	0	2	0	0	0	0	2	1
ORIBATIDA		Oribatida spp	0	0	0	0	0	0	0	1	0	1	3	0
CRUSTACEA														
COPEPODA														
Cyclopoida	**Cyclopidae**	*Apocyclops dengizicus*	0	0	0	0	0	0	1	0	0	0	0	0
		Mesocyclops brooksi	0	0	0	0	0	0	0	0	0	0	0	1
		Metacyclops cf. laurentiisae	0	0	3	0	0	0	0	0	0	0	0	0
		Metacyclops sp. a	0	1	0	0	0	0	0	0	0	0	0	0
		copepodites	0	0	4	0	0	2	3	0	0	0	0	3
		nauplii	0	0	3	0	0	0	0	0	0	0	0	4

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W019	W023	W024
Calanoida	**Centropagidae**	*Boeckella triarticulata s.l.*	0	0	0	3	3	3	0	2	0	0	4	1
		Calamoecia clitellata	0	0	0	0	0	0	2	0	0	0	0	0
		Calamoecia trilobata	0	0	0	0	0	0	0	0	0	0	0	0
		calanoid copepodites	0	0	1	3	3	3	3	2	0	0	0	0
		calanoid nauplii	0	0	0	4	4	3	4	4	0	0	3	0
Harpacticoida		indet. sp./juv.	0	0	0	0	0	0	1	0	0	0	1	0
CLADOCERA	**Chydoridae**	*Alona rigidicaudis*	0	0	0	0	0	0	0	0	0	0	3	0
		Alona sp. [n. sp. or aberrant?]	0	0	0	0	0	1	0	0	0	0	0	0
		Pleuroxus foveatus	0	0	0	0	0	0	0	0	0	0	0	1
	Daphnidae	*Ceriodaphnia cornuta*	0	0	0	0	0	0	0	0	0	0	0	1
		Daphnia (s. str.) carinata s.l.	0	0	0	0	0	1	0	1	0	0	0	0
		Daphnia (Daphniopsis) truncata	0	3	0	0	0	0	0	0	0	0	0	0
		Daphnia (Daphniopsis) wardii	0	4	1	0	0	0	0	0	0	0	0	0
		Simocephalus elizabethae	0	0	0	0	0	0	0	0	0	0	0	1
	Macrothricidae	*Macrothrix sp.*	0	0	0	0	2	1	0	0	0	0	1	0
OSTRACODA	**Ostracoda**	*Australocypris sp.*	0	0	1	0	0	0	0	0	0	0	0	0
		Bennelongia sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Cypretta sp.	0	0	0	0	0	0	0	0	0	0	0	1
		Diacypris sp. b	0	0	1	0	0	1	0	0	0	0	0	0
		Mytilocypris sp.	0	0	0	0	1	0	0	0	0	0	0	0
		Platycypris sp.	0	0	1	0	0	0	0	0	0	0	0	0
		Reticypris sp.	0	3	2	0	0	1	3	2	0	0	0	0
		cf. Sarscypridopsis sp.	0	0	0	0	0	0	0	0	2	0	1	0
		Stenocypris sp.	0	0	0	0	0	0	0	0	0	0	0	1
		indet. juvenile	0	0	0	0	0	0	0	0	2	0	2	2
ANOSTRACA	**Artemiidae**	*Artemia nr parthogenetica*	0	2	0	0	0	2	4	0	0	0	0	0
AMPHIPODA	**Ceinidae**	*Austrochiltonia subtenius*	0	0	0	3	3	4	3	5	4	0	4	5
INSECTA														
DIPTERA		Unknown diptera (P)	0	1	0	0	0	0	0	0	0	0	0	0
	Chironomidae	Chironomid spp. (P)	0	2	3	2	3	0	3	0	3	0	2	2

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W019	W023	W024
	Chironominae	*Chironomus occidentalis*	0	0	0	0	1	0	0	0	0	0	0	0
		Chironomus aff. altermans	0	0	0	2	0	2	0	0	4	0	3	3
		Tanytarsus fuscithorax	0	0	0	4	3	4	0	0	4	0	3	3
		Tanytarsus barbitarsus	2	0	4	0	0	0	4	0	0	2	0	0
		Cryptochironomus griseidorsum	0	0	0	3	3	0	0	1	0	0	0	0
		Dicrotendipes conjunctus	0	0	0	4	4	3	0	0	3	0	3	3
		Polypedilum nubifer	0	0	0	3	4	3	0	2	0	0	3	2
		Cladopelma curtivalva	0	0	0	0	0	0	0	0	0	0	2	3
	Tanypodinae	*Procladius villosimanus*	0	0	0	3	3	0	0	0	0	0	2	3
		Procladius paludicola	0	4	3	3	3	4	3	1	3	0	2	3
		Ablabesmyia notabilis	0	0	0	0	0	0	0	0	0	0	2	3
		Paramerina levidensis	0	0	0	1	0	0	0	0	1	0	3	3
	Orthocladiinae	*Orthocladiinae spp. V46*	0	0	0	0	0	0	0	0	0	0	1	0
		Paralimnophyes sp. V42	0	1	0	1	0	0	0	0	0	0	1	2
		Cricotopus albitarsus	0	0	0	2	0	0	0	0	0	0	0	0
		Corynoneura sp. V49	0	0	0	0	0	0	0	0	0	0	2	3
	Culicidae	Culicinae spp. (L)	0	0	2	0	1	0	0	0	2	0	0	0
		Culicinae spp. (P)	0	0	0	3	0	0	0	0	0	0	0	0
		Culex sp.	0	0	0	0	0	0	0	0	0	0	1	2
		Anopheles sp.	0	0	0	0	0	0	0	0	3	0	3	0
	Ceratopogonidae	Ceratopogonid spp. (P)	0	3	0	0	0	0	0	1	0	0	0	0
		Ceratopogoniinae spp.	1	3	3	1	2	3	3	3	2	2	2	2
	Dolichopodidae	Dolichopodiae spp.	0	0	2	0	2	2	2	0	0	0	0	0
	Ephydridae	Ephydridae spp.	0	0	0	2	0	0	0	0	0	0	0	0
	Muscidae	Muscidae spp.	0	1	0	0	0	1	0	0	0	0	1	0
		Muscidae spp. (P)	0	0	0	0	0	0	0	0	1	0	0	0
	Stratiomyidae	Stratiomyidae spp.	0	2	0	3	3	2	0	0	2	0	0	2
	Tabanidae	Tabanidae spp.	0	0	2	0	0	0	0	1	0	0	0	0
TRICHOPTERA	**Leptoceridae**	*Triplectides australis*	0	0	0	2	0	0	0	0	0	0	0	0
		Triplectides australicus	0	0	0	0	2	3	0	0	2	0	2	2
		Notalina spira	0	1	0	2	2	2	0	3	0	0	0	0
		Oecetis sp.	0	0	0	0	0	3	0	1	0	0	0	0
		Leptoceridae spp. (imm*)*	0	0	0	0	0	0	0	0	0	0	2	2
	Hydroptilidae	*Acritoptila sp.*	0	0	0	0	0	0	0	0	0	0	1	0
EPHEMEROPTERA		Ephemeroptera spp. (imm)	0	0	0	0	0	0	0	0	0	0	2	2
	Caenidae	*Tasmanocoenis tillyardi*	0	0	0	0	0	0	0	0	0	0	1	0

Order	Family	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W019	W023	W024
	Baetidae	Baetidae spp. (imm)	0	0	0	0	0	0	0	0	0	0	0	1
ODONATA														
ANISOPTERA	**Libellulidae**	*Orthetrum caledonicum*	0	0	0	0	0	0	0	0	0	0	1	0
		Diplacodes haematodes	0	0	1	0	0	2	0	0	3	0	2	0
	Aeshnidae	*Hemianax papuensis*	0	0	0	0	0	2	0	0	0	0	2	2
		Adversaeschna brevistyla	0	0	0	0	1	0	0	0	0	0	0	0
ZYGOPTERA		*Zygoptera spp. (imm.)*	0	0	0	0	1	0	0	1	0	0	0	2
	Lestidae	*Austrolestes annulosus*	0	0	0	3	1	3	0	0	0	0	2	2
		Austrolestes analis	0	0	0	2	0	0	0	0	2	0	3	0
COLEOPTERA	**Dytiscidae**	*Necterosoma penicillatum*	0	2	0	0	0	0	0	0	0	0	0	0
		Necterosoma sp. (L)	0	3	0	0	2	3	3	0	0	0	2	2
		Sternopriscus mulimaculatus	0	0	0	0	0	1	0	0	0	0	0	0
		Sternopriscus sp. (F)	0	0	0	1	2	0	0	0	0	0	0	0
		Allodessus bistrigatus	0	0	0	0	0	0	0	2	0	0	0	0
		Antiporus sp (L)	0	0	0	0	0	0	0	0	1	0	0	0
		Platynectes decempunctatus	0	0	0	0	0	0	0	1	0	0	0	0
		Tribe Bidessini (L)	0	0	0	0	0	0	0	0	0	0	2	0
		Onychohydrus sp (L)	0	0	0	0	0	0	0	0	0	0	2	1
		Dytiscidae spp. (L imm.)	0	0	0	0	0	2	0	0	0	0	0	0
		Limbodessus inornatus	0	0	0	0	0	0	0	0	1	0	0	0
	Hydrophilidae	*Berosus sp. (L)*	0	2	1	0	1	2	0	0	0	0	0	1
		Helochares sp. (L)	0	0	0	0	0	0	0	0	1	0	2	1
		Limnoxenus sp (L)	0	0	0	0	0	0	0	0	2	0	0	0
		Paracymus pygmaeus	0	0	0	0	0	0	0	0	1	0	0	0
	Limnichidae	Limnichidae spp	0	0	0	0	0	0	0	0	0	0	0	2
	Carabidae	Carabidae sp.	0	0	0	1	0	0	0	0	1	0	0	0
HEMIPTERA	**Corixidae**	Corixidae juv.	0	0	0	3	4	4	0	2	2	0	2	3
		Corixidae spp. (P)	0	1	0	0	0	0	0	0	0	0	0	0
		Micronecta robusta	0	0	0	0	0	3	0	0	0	0	1	0
		Micronecta spA (lined)	0	0	0	2	4	0	0	0	2	0	0	0
		Agraptocorixa sp. (F)	0	0	0	2	0	0	0	0	0	0	1	2
	Notonectidae	*Anisops thienemanni*	0	0	0	2	3	0	0	2	0	0	0	0
		Anisops sp. (imm & F)	0	0	0	3	4	0	0	4	2	0	2	2
		Notonecta sp.	0	0	0	3	4	4	0	3	2	0	3	3
		Notonectidae spp. (imm)	0	0	0	0	0	0	0	0	0	0	3	3

Order	*Family*	*Species*	*W001*	*W002*	*W004*	*W009*	*W010*	*W011*	*W012*	*W013*	*W015*	*W019*	*W023*	*W024*
	Mesoveliidae	*Mesovelia sp*	0	0	0	0	0	0	0	0	2	0	0	0
	Velidae	*Microvelia peramoena*	0	0	0	0	0	0	0	0	2	0	2	0
	Pleidae	*Paraplea brunni*	0	0	0	0	0	0	0	0	0	0	2	0
LEPIDOPTERA	**Pyralidae**	Nymphulinae spp.	0	1	0	0	1	0	0	0	1	0	1	0
		Taxa richness	**2**	**19**	**19**	**32**	**32**	**40**	**16**	**24**	**31**	**4**	**51**	**47**

Appendix 3. Vertebrate species recorded during the 2008 surveys

Table A3-1. August 2008.

Family & Common Name	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
FROGS															
Tadpoles	indeterminate														
Myobatrachidae															
Bleating frog	*Crinia pseudinsignifiera*				*	*							*	*	
Banjo frog	*Limnodynastes dorsalis*				*								*		
Hylidae															
Motorbike frog	*Litoria moorei*														
Slender tree frog	*Litoria adelaidensis*														
FISH															
Gobiidae															
Swan River Goby	*Pseudogobius olorum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BIRDS															
Anatidae															
Shelduck	*Tadorna tadornoides*	0	0	0	1	0	0	0	1	0	0	0	0	0	2
Chestnut teal	*Anas castanea*	0	0	0	0	0	0	0	0	0	0	0	20	0	0
Grey teal	*Anas gracilis*	0	0	4	2	0	0	21	0	0	0	0	7	0	0
Pacific black duck	*Anas superciliosa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardhead	*Aythya australis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink-eared duck	*Malacorhynchus membranaceus*	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Blue-billed duck	*Oxyura australis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Musk duck	*Biziura lobata*	0	0	0	0	0	0	2	1	0	0	0	0	0	0
Wood duck	*Chenonetta jubata*	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Black swan	*Cygnus atratus*	0	2	0	0	0	0	0	0	0	0	0	1	0	0
Phalacrocoracidae															
Little black cormorant	*Phalacrocorax sulcirostris*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Podicipedidae															
Australasian grebe	*Podiceps novaehollandiae*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rallidae															
Coot	*Fulica atra*	0	0	0	0	0	0	0	0	0	0	0	3	2	0
Bush-hen	*Gallinula olivacea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charadriidae															
Black-fronted dotterel	*Charadrius melanops*	0	0	0	0	1	0	1	0	0	0	0	0	0	6
Red-kneed dotterel	*Erythrogonys cinctus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-capped plover	*Charadrius ruficapillus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banded lapwing	*Vanellus tricolor*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recurvirostridae															
Black-winged stilt	*Himantopus himantopus*	0	0	0	2	2	6	0	0	0	2	2	0	0	2
Red-necked avocet	*Recurvirostra novaehollandiae*	0	0	0	0	0	0	2	0	0	0	0	0	0	0
	Number of taxa	**0**	**2**	**1**	**5**	**3**	**1**	**4**	**2**	**0**	**1**	**1**	**7**	**2**	**3**

Table A3-2. September 2008.

Family & Common Name	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
FROGS															
Tadpoles	indeterminate						*	*							
Myobatrachidae															
Bleating frog	*Crinia pseudinsignifiera*												*		
Banjo frog	*Limnodynastes dorsalis*												*	*	
Hylidae															
Motorbike frog	*Litoria moorei*				*								*	*	
Slender tree frog	*Litoria adelaidensis*												*	*	
FISH															
Gobiidae															
Swan River Goby	*Pseudogobius olorum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BIRDS															
Anatidae															
Shelduck	*Tadorna tadornoides*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chestnut teal	*Anas castanea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grey teal	*Anas gracilis*	0	6	0	2	0	0	14	0	0	0	0	0	0	0
Pacific black duck	*Anas superciliosa*	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Hardhead	*Aythya australis*	0	0	0	10	0	0	0	0	0	0	0	3	0	0
Pink-eared duck	*Malacorhynchus membranaceus*	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Blue-billed duck	*Oxyura australis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Musk duck	*Biziura lobata*	0	1	0	0	0	0	0	3	0	0	0	3	1	0
Wood duck	*Chenonetta jubata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black swan	*Cygnus atratus*	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Phalacrocoracidae															
Little black cormorant	*Phalacrocorax sulcirostris*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Podicipedidae															
Australasian grebe	*Podiceps novaehollandiae*	0	0	0	*	0	0	0	0	0	0	0	0	0	0
Rallidae															
Coot	*Fulica atra*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bush-hen	*Gallinula olivacea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charadriidae															
Black-fronted dotterel	*Charadrius melanops*	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Red-kneed dotterel	*Erythrogonys cinctus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-capped plover	*Charadrius ruficapillus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banded lapwing	*Vanellus tricolor*	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Recurvirostridae															
Black-winged stilt	*Himantopus himantopus*	0	0	0	0	0	6	11	0	0	5	0	0	0	0
Red-necked avocet	*Recurvirostra novaehollandiae*	0	0	0	0	0	0	5	0	0	0	0	0	0	0
	Number of taxa	**0**	**2**	**0**	**4**	**0**	**1**	**5**	**1**	**0**	**1**	**0**	**7**	**5**	**0**

Table A3-3. October 2008.

Family & Common Nam	Species	W001	W002	W004	W009	W010	W011	W012	W013	W015	W016	W019	W023	W024	W074
FROGS															
Tadpoles	indeterminate													*	
Myobatrachidae															
Bleating frog	*Crinia pseudinsignifera*														
Banjo frog	*Limnodynastes dorsalis*												*		
Hylidae															
Motorbike frog	*Litoria moorei*				*				*						
Slender tree frog	*Litoria adelaidensis*												*	*	
FISH															
Gobiidae															
Swan River Goby	*Pseudogobius olorum*	0	0	0	0	0	0	0	0	0	0	0	1	0	0
BIRDS															
Anatidae															
Shelduck	*Tadorna tadornoides*	0	3	0	2	0	0	2	7	0	0	0	0	0	0
Chestnut teal	*Anas castanea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grey teal	*Anas gracilis*	0	0	2	7	0	0	0	0	0	0	0	19	0	0
Pacific black duck	*Anas superciliosa*	0	0	0	8	0	4	0	0	0	0	0	4	0	0
Hardhead	*Aythya australis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink-eared duck	*Malacorhynchus membranaceus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue-billed duck	*Oxyura australis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Musk duck	*Biziura lobata*	0	0	0	0	0	0	0	1	0	0	0	2	0	0
Wood duck	*Chenonetta jubata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black swan	*Cygnus atratus*	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Phalacrocoracidae															
Little black cormorant	*Phalacrocorax sulcirostris*	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Podicipedidae															
Australasian grebe	*Podiceps novaehollandiae*	0	0	0	1	0	0	0	6	0	0	0	0	0	0
Rallidae															
Coot	*Fulica atra*	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Bush-hen	*Gallinula olivacea*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charadriidae															
Black-fronted dotterel	*Charadrius melanops*	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Red-kneed dotterel	*Erythrogonys cinctus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-capped plover	*Charadrius ruficapillus*	0	2	0	0	0	0	10	0	0	0	0	0	0	0
Banded lapwing	*Vanellus tricolor*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recurvirostridae		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black-winged stilt	*Himantopus himantopus*	0	4	0	4	2	12	80	2	0	0	0	0	0	0
Red-necked avocet	*Recurvirostra novaehollandiae*	0	0	0	0	0	0	16	0	0	0	0	0	0	0
	Number of taxa	**0**	**3**	**1**	**7**	**1**	**2**	**4**	**7**	**0**	**0**	**0**	**7**	**1**	**0**

Appendix 4. List of invertebrates that emerged from bentonite wetland sediments 41 days after flooding. Values are log10 abundance classes where 1 = 1 individual, 2 = 2-10 individuals, 3 = 10 – 100, and so on.

Table A4-1. W057.

	Days of flooding																																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Protista: flagellates	0	0	1	2	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3
Protista: Ciliophora (green)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	0	0	0	0	0	0
Protista: Ciliophora (transparent)	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
Rotifera																																									
Notommatidae: *Cephalodella catellina*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other																																									
Nematoda	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algal filaments																																									
Macrophytes emerging																																									

Table A4-2. W058.

	Days of flooding																																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Protista: flagellates	0	0	0	0	0	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Protista: Ciliophora (green)	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Protista: Ciliophora (transparent)	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2
Rotifera																																									
Notommatidae: *Cephalodella catellina*	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Other																																									
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algal filaments																																									
Macrophytes emerging																																									

Table A4-3. W059.

	Days of flooding																																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Protista: flagellates	0	0	0	0	1	2	2	2	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3
Protista: Ciliophora (green)	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Protista: Ciliophora (transparent)	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
Rotifera																																								
Notommatidae: *Cephalodella catellina*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2
Other																																								
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Algal filaments																																								
Macrophytes emerging																																								