Buntine-Marchagee Natural Diversity Recovery Catchment (BMRC)

Wetland Invertebrate Fauna Monitoring: August 2005.

Report to

Department of Conservation & Land Management,
Mid-West Regional Office

by

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January 2006

Aquatic Research Laboratory
School of Animal Biology

THE UNIVERSITY OF WESTERN AUSTRALIA
FACULTY OF
Natural and
Agricultural Sciences

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Frontispiece: *Site W011& W012* (Photo by A.W. Storey 24th August 2004)

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Recommended Reference Format

ARL (2006). Buntine-Marchagee Natural Diversity Recovery Catchment (BMRC): Wetland Invertebrate Fauna Monitoring: August 2005. Unpublished report to Department of Conservation & Land Management, Mid-West Regional Office by Aquatic Research Laboratory, University of Western Australia. January 2006.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

EXECUTIVE SUMMARY

The Buntine-Marchagee catchment in the Northern Wheatbelt Region has been nominated a Recovery Catchment under the State Salinity Strategy. Recovery catchments have been selected as a key measure for biodiversity conservation and 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. To this end, water chemistry and aquatic invertebrate fauna of twenty wetlands in the Buntine-Marchagee Natural Diversity Recovery Catchment (BMRC) were sampled in August 2005 by the School of Animal Biology, The University of Western Australia. The primary goal for the BMRC project is "to maintain the 2006 richness, distribution, abundance and condition of biodiversity assets threatened by salinity within the Buntine-Marchagee catchment for the next 20 years". The aquatic invertebrate and water quality samples collected in 2005 will build on a data collected in 2003 and 2004 to help establish the condition against which future changes may be assessed.

The specific aims of the project were to identify the resident fauna of the 21 wetlands to the lowest possible taxonomic level, determine conservation status of the fauna of each wetland, compare biodiversity and invertebrate assemblages amongst wetlands, relate differences in fauna to differences in water quality, and make comparisons with samples previously collected from wetlands in the BMRC in November 2003 and August 2004.

Analysis of physico-chemical data placed the wetlands into four main groups. The primary source of variation was salinity, with hypersaline sites separating from fresh/brackish sites. A range of parameters also related to these differences, including percent cover of vegetation, reeds/rushes and exposed/open sediment. Vegetative cover decreased with increasing salinity, and concomitantly the cover of exposed sediment increased. SPS203 showed considerable separation from other wetlands on the basis of its considerably high dissolved oxygen levels.

A total of 135 taxa were recorded from the 21 wetlands in August 2005, in comparison to 150 and 68 taxa collected during the August 2004 and November 2003 aquatic surveys, respectively. Allowing for common taxa, this provides an overall total of 202 taxa known from the BMRC. Of the species recorded, 37% 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 species comprised nine species of Rotifera, one Platyhelminthes (flat worm), two species of Gastropoda (snails), 17 species of Copepoda, six species of Cladocera (water fleas), ten Ostracoda (seed shrimp), two types of Conchostraca (clam shrimp), and three Anostraca (fairy shrimp). Of the 85 'temporary' fauna, there was one Nematoda (round worm), one Oligochaeta (segmented worm), five Arachnida (mites), one Amphipoda (side swimmers), one Isopoda (water slaters), 21 taxa of Chironomidae (non-biting midges), 15 types of other Diptera (larval flies), two Trichoptera (caddisflies), two Ephemeroptera, seven Odonates (damselflies & dragonflies), one Lepidoptera (moth larvae), and 28 taxa of Coleoptera (water bugs and beetles).

Analysis of the aquatic invertebrate fauna of the wetlands demonstrated a clear and consistent separation of sites into the same general groupings as identified from physico-chemical parameters (*viz.* fresh/brackish and hypersaline), indicating that water quality likely was a major influence on invertebrate composition. Consistent with previous years' findings, generally the 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. 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, two native species of *Parartemia*, *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.

Physico-chemical parameters that consistently related to the separation of sites on faunal composition were conductivity, percent cover of vegetation and of submerged macrophytes, and extent of open/exposed sediment, with the latter increasing with increasing salinity, and the attributes of vegetative cover decreasing with increasing salinity.

Comparison of assemblage composition in the 2005 samples with the 2004, 2003 and 1999 (SAP) samples detected considerable differences, particularly with greater diversity in the 1999 samples. Taxa richness was generally lower in 2005 than all previous surveys of the BMRC wetlands. Invertebrate community change appeared to be influenced greatly by changes in salinity, particularly at SPS203; salinity at this site was 4.2 ppt in 1999 and approx 70 ppt in 2004, with taxa richness declining from 54 taxa in 1999 to 9 in 2004. Differences may also be attributable to differing intensity of field sampling by personnel with varying levels of experience, seasonal differences in composition reflecting different successional stages in each wetland, or inter-annual variation in water regime reflecting differing winter rainfall. Some wetlands showed little change over time (i.e. W002 & W004).

Characterisation of wetlands showed strong relationships between total invertebrate faunal biodiversity and wetland salinity (conductivity) and extent of vegetative cover/exposed sediments of the wetlands. These parameters appear to provide good ability to predict biodiversity, and may prove useful as efficient and inexpensive parameters to measure in preference to the more expensive, time consuming and technically challenging invertebrate fauna monitoring, which should only be applied on an infrequent basis.

The Swan River goby, *Pseugobius olorum*, was collected from W009 during the current study. No fish had previously been recorded from wetlands within the BMRC. 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. It occurs in estuaries, rivers, and both freshwater and hypersaline lakes. While the swan river goby is generally associated with coastal water bodies, it does penetrate long distances inland (i.e. Blackwood, Warren, Hay and Kalgan river systems), and occurs in some isolated lakes (e.g. lakes Jasper, Maringup, Towerrinning, Saide, Powell, Moates, Gardner and Angove). It is usually found over mud bottom, and sometimes amongst weeds or adjacent to rocky areas.

Overall, the samples collected in August 2005 constitute a robust data set, which provides useful insights into aquatic faunal biodiversity and causal relationships. Additional samples from these and adjacent wetlands, particularly fresh/brackish wetlands in future years, will provide greater insights into their conservation significance, a better understanding of seasonal and inter-annual variation, and will provide the basis for ongoing monitoring, against which future changes may be assessed. Priority wetlands chosen for future monitoring based on their high biodiversity include, the hypersaline wetlands W002, W061, W004, W070, and W019, and the fresher water sites W011, W072, W020, W010, and W009.

INTRODUCTION

Background:

The Buntine-Marchagee Natural Diversity Recovery Catchment (BMRC) is located in the Northern Wheatbelt Region, in the vicinity of the towns of Dalwallinu and Coorow, approximately 250 km NNE of Perth. The BMRC 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 primary goal for the BMRC project is **"maintain the 2006 richness, distribution, abundance and condition of biodiversity assets threatened by salinity within the Buntine-Marchagee catchment for the next 20 years".** It is recognised that achieving this goal will require management of a range of degradation issues besides salinity.

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, 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.

BMRC wetlands were again sampled in August 2004 by the School of Animal Biology, U.W.A. Following good winter rains in mid-2004, a total of twenty wetlands were sampled, 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.

The *Aquatic Research Laboratory*, University of Western Australia, was again contracted in 2005 to sample the same 20 wetlands and provide a comparison with 2003 and 2004 data. An additional site (W020) was also sampled during the current study.

Objectives:

This report details the results of the macro- and micro- invertebrate sampling of 21 wetlands within the Buntine-Marchagee Natural Diversity Recovery Catchment during

August 2005, and provides an analysis and consideration of these results. It also includes a comparison amongst wetlands using fauna and other selected parameters, and a between-year comparison with 2004, 2003 and SAP data.

METHODS

Field Methods

Wetlands were selected by staff of the Mid-West Regional Office of the Department of Conservation and Land Management, Geraldton, to cover the range of wetlands found within the BMRC from fresh through to hypersaline (Figure 1). Sampling was undertaken between the 22nd and 25th of August 2005.

A number of wetland characteristics were recorded from each wetland. Water depth was measured using a graduated pole, with both average (m) and maximum depths (m) being recorded. The extent of vegetative cover was visually appraised, with percent riparian cover, percent samphire cover, percent macrophyte cover, and percent reed/rush cover being recorded. In addition, the percent of open sediment (with no vegetative cover) was also noted. The presence of a salt crust or benthic mat within wetlands was recorded, with both thickness (mm) and percent cover observed.

The invertebrate sampling methodology was consistent with that used by CALM in a survey of 200 wetlands between Kalbarri and Esperance as part of the State Salinity Action Plan (SAP) 1996 (Cale *et al.* 2004), and as used to sample the eight wetlands in 2003 and the 20 wetlands in 2004 (Storey *et al.* 2004a and b). To maximise the number of wetlands sampled, only one site was sampled (with two net types) at each of the detailed wetlands. This is consistent with the SAP spatial survey project but varies from the two sites per wetland sampled in the SAP monitoring project. Sampling involved the collection of both macro- and micro-invertebrates. The following protocol is largely taken from wetlands monitoring in the wheatbelt of south-west Western Australia: site descriptions, waterbirds, aquatic invertebrates and groundwater data by Cale *et al.* (2004).

The "benthic" subsample was collected through 50 metres of vigorous discontinuous sweeping over a distance of approximately 200 metres with a 250 µm mesh pond net on a D-shaped frame (350 mm wide and 250 mm high). All identified wetland habitats ≤ 1 m deep between the shore and centre of the wetland were sampled including water column, submerged vegetation, bottom sediment, along submerged logs and around tree trunks. Lake substrates were vigorously disturbed with repeated sweeping. Contents of the pond-net were emptied into a bucket several times during sampling to reduce resistance of the net in the water. After elutriation and removal of large debris, the sample was preserved in 70% ethanol.

The "planktonic" subsample was collected by 50 metres of more gentle, discontinuous sweeping over a 200 m distance with a 50 µm mesh pond net of the same sized frame in the same habitat, other than benthos. The sample was preserved in 1-2% formaldehyde (i.e. 37% formaldehyde solution diluted 10x to give 4% formaldehyde and then mixed with wet sample) for two to four days before being washed and transferred into 70% ethanol.

The nets were thoroughly rinsed, air-dried and changed between lakes to eliminate the risk of transfer of material between lakes and to allow for any specimens accidentally transferred into subsequent samples to be identified (desiccated) and excluded from analysis. Bulk, labelled, preserved samples were returned to the School of Animal Biology, The University of Western Australia for processing and identification.

Vertebrate wetland fauna were also recorded at the time of survey for each wetland. Waterbird counts were made using Pizzey and Doyle (1980). Frogs were surveyed by comparing any calls heard on the day of sampling with audio files for south-west species (Roberts undated). During the breeding season, male frogs make advertisement calls unique to their species to attract mates. Any fish caught in sweep nets were identified to species.

A number of physico-chemical parameters were measured *in situ* with a Yeo-Kal portable Water Quality Analyser (model 611), including dissolved oxygen (%), pH and water temperature (ºc). Water samples for laboratory analyses were collected from midway through the water column prior to disturbance by sampling. Electrical conductivity (mS/m), chlorophyll a, total dissolved nitrogen, total dissolved phosphorus, colour and turbidity were measured from samples of solution (250 ml) and filter paper (GFC) delivered to the Environmental Chemistry Laboratory of the Chemical Centre (W.A.).

Sample Processing

Macroinvertebrate subsamples were separated into three size fractions using 2 mm, 500 µm and 250 µm sieves. Representatives of each species (or morphospecies) were picked out using a dissecting microscope with 10 – 50x magnification and the species scored for abundance on a log scale (1 animal = 1, 1-10 animals = 2, 11 – 100 = 3, 101 – 1000 = 4, etc.). 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'.

Macro- and micro-invertebrates were identified to the lowest taxon possible and names reconciled with those used in the State Salinity Strategy Biological survey reports (Cale *et al.* 2004). Rotifers were identified to morphospecies and ranked for abundance accordingly. Specimens that appeared desiccated were considered to be cross contamination from other sites and were excluded from further analysis. Identifications and abundance data were entered onto an excel spreadsheet and provided to Midwest CALM.

The 21 macroinvertebrate subsamples were processed at the School of Animal Biology, The University of Western Australia using in-house expertise. The 21 microinvertebrate subsamples were sent to Dr Russ Shiel, School of Environmental Biology, University of Adelaide, S.A. for identification. Data on faunal composition of the microfauna was then returned to the School of Animal Biology for statistical analysis along with the macroinvertebrate data. Specific taxonomic expertise was contracted for Chironomidae (Dr Don Edward, U.W.A), and Hydracarina (Dr Mark Harvey, Museum of Western Australia).

Sample Storage

A reference collection was compiled and included additional species to those collected during previous surveys of the BMRC. Wherever possible, both male and female specimens were provided. This invertebrate voucher collection allowed for the accuracy of identifications to be verified by CALM Science specialists whilst also providing a basis for further research and future monitoring.
Reference collection specimens were stored in appropriate vials in 70% ethanol and clearly labelled with identification level and site details. The collection was lodged at the Woodvale Wildlife Research Centre.

Sites Sampled

Sites sampled in the BMRC during August 2005 are listed in Table 1, indicating sites previously sampled.

Table 1: The wetlands sampled in August 2005, listing site code, name of land holder, size, and whether previously sampled.

Site Number	Land Manager	Size (ha)	Previously sampled		
			SAP 1999	2003	2004
W001	Doley	9.4			✓
W002	Doley	15.8		✓	✓
W004	Dobson	1.7		✓	✓
W006	Dobson	0.8		✓	✓
W007	Mailey	100.4	✓		✓
W008	Mailey	6.9	✓		✓
W009	Hunt	1.0		✓	✓
W010	Hunt	0.5		✓	✓
W011[1]	Hunt	20.6		✓	✓
W015	Kaus	0.0			✓
W016	Kaus	3.0			✓
W018	Counsel	59.6		✓	✓
W019	Counsel	2.4		✓	✓
W020	Hunt	30.8			
W052	Stacy	0.1			✓
W056	CALM (NR)	1.8			✓
W061	LGA (CR)	3.8			✓
W070	Barnes	17.7			✓
W071	Bean	16.6			✓
W072	LGA (CR)	0.5?			✓
SPS201	CALM (NR)	4.7	✓		DRY
SPS203	CALM (NR)	4.7	✓		✓

Site photos for the 20 common wetlands sampled in 2004 can be found in Storey *et al.* (2004b). The additional 2005 site (W020) is shown in Plate 1.

[1] At the request of CALM, sampling at site W011 also included the western part of site W012. This wetland was adjacent to W011, separated by a low point, and had been connected under higher water levels. At the time of sampling, water was flowing from W011 into W012 via a connecting stream.

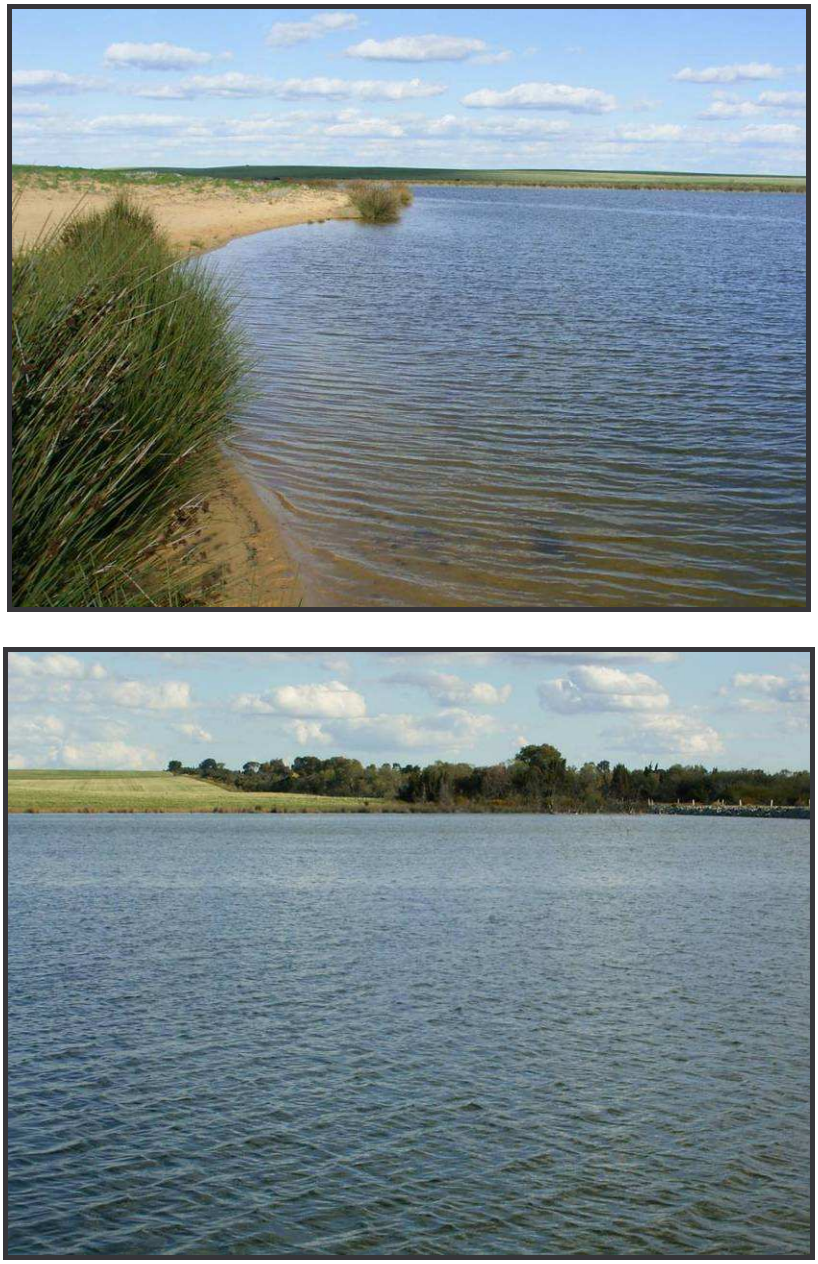

Plate 1. The additional wetland sampled in August 2005 (W020), showing areas of fringing vegetation (top) and open water (bottom).

Statistical Analyses

Background

The aim of analyses was to characterise the wetlands based on invertebrate assemblages determined from samples collected in August 2005, to assess the variation and redundancy of the aquatic invertebrates between the wetlands and to consider these results in comparison with the physico-chemical parameters measured. Results and interpretation will then be used by CALM to prioritise resources to maximise biodiversity protection. Analysis were to be conducted using both presence/absence and abundance data sets, with comparisons between these measures.

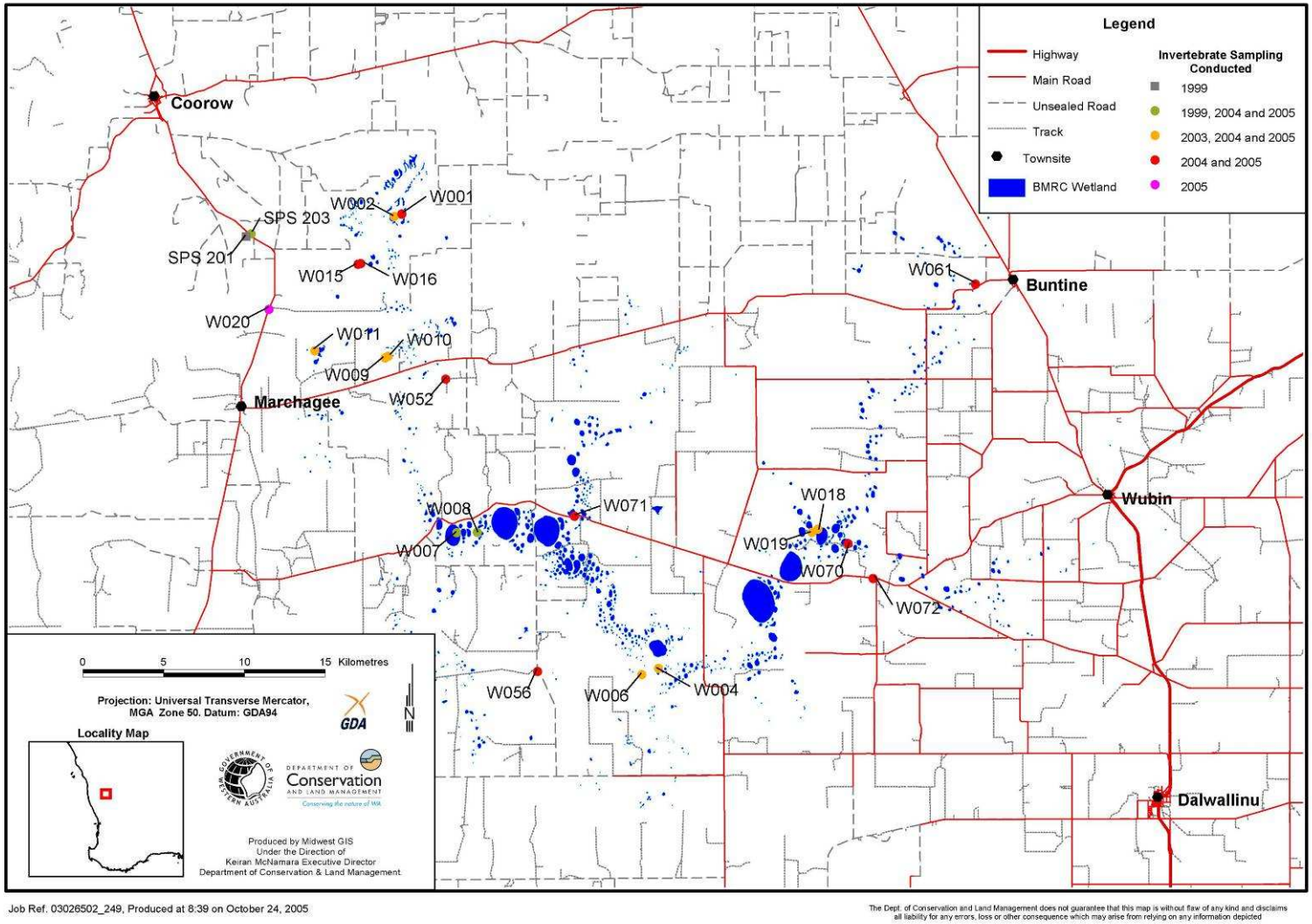

Figure 1. Buntine-Marchagee Biodiversity Recovery Catchment, showing the location of the 21 wetlands sampled in August 2005, 20 from August 2004, eight from November 2003 and the additional four wetlands sampled for the Salinity Action Plan (SAP) sampling program in September 1999.

Methods of statistical analysis followed those of Storey *et al.* (2004a and b) for wetlands sampled in the BMRC, and previously used by Storey (1998) for assessing spatial and temporal variation and conservation significance of wetlands in the Byenup-Muir peat swamp system, southwestern Australia. To this end, similar categories for assessing conservation significance, and comparable multivariate approaches for ordination and classification of data were utilised.

However, statistical approaches varied from these previous studies in one respect; all taxa were coded as either 'Permanent' or 'Temporary' residents rather than 'Macroinvertebrates' or 'Microinvertebrates'. In this way, taxa were classified by features of their ecology rather than simply their size, thus providing information about ecosystem function. Classification was dependent on whether taxa possess a drought-resistant stage (*i.e.* spores, eggs, means to dehydrate or protect themselves from dehydration) and so are always present in the system ('Permanent Residents'), or lack such abilities and need to reinvade each time the wetland dries and then becomes inundated ('Temporary Taxa'). This separated the microfauna and some macroinvertebrates (Platyhelminthes, Gastropods, Conchostracans, and Anostracans) from all other taxa without drought-resistant life stages. Analyses were then performed individually on 'Permanent', 'Temporary' and total fauna (permanent and temporary residents combined). This approach has been adopted previously by the authors for analysis of macro- and micro-invertebrate datasets from intermittently flowing streams in semi-arid regions (Jones Creek in the northern Goldfields) (WRM 2005), and was recommended as a monitoring approach by Smith *et al.* (2004).

Specifically, analyses were required to address:

1. Which wetlands have the most biodiversity? How does this ranking vary when different taxon types are considered? (eg. 'permanent' versus 'temporary' invertebrates)
2. What is the conservation significance of each taxa, assemblage and wetland?
3. What species are common across a number of wetlands? What species are unique to individual (or group of) wetlands?
4. Which of the 2005 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?
5. What is the similarity / dissimilarity between the parameters measured at each of the wetlands, with a measure of this?
6. What is the correlation between conservation significance/biodiversity/wetland groupings/species to the other parameters (eg. basic water parameters and surrounding vegetation type) measured in 2005?
7. What differences and similarities are there from the data available for those twenty wetlands sampled in 2004, the eight wetlands sampled in 2003 and the four wetlands sampled in 1999 during the SAP spatial project?
8. 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?

Analyses Performed

Analyses used to address the specific issues identified in the brief are described below.

Multivariate Analyses

PRIMER (v5) software package (Clarke & Gorley 2001) was used to classify and ordinate sites on physico-chemical parameters and invertebrate assemblages. This package was also used to investigate relationships between invertebrate assemblages and physico-chemical parameters. Approaches used include:

1. Describing patterns amongst the physico-chemical and fauna assemblage data using cluster and ordination techniques based on Bray-Curtis similarity matrices. The clustering technique uses a hierarchical agglomerative method where samples of similar assemblages are grouped and the groups themselves form clusters at lower levels of similarity. A group average linkage was used to derive the resultant dendrogram. Multi-Dimensionsal Scaling (MDS) was used to ordinate the data (Clarke & Warwick 2001). Ordinations were depicted as two-dimensional scatter plots based on site by site similarity matrices.
2. For any groups found in 1 or selected *a priori* (*i.e.* year or salinity type), 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 (*e.g.* 2004 vs. 2005 or hypersaline vs. brackish wetlands) 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 %).
3. The SIMPER routine was used to examine which taxa were contributing to the differences 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.
4. The relationship between the environmental and biotic data was assessed by visualisation; the numeric value of key environmental data were superimposed onto MDS ordinations, as circles of differing sizes – so-called 'bubble plots', whereby the size of the bubble reflects the magnitude of the variable at a site
5. The BIOENV routine was used to calculate the smallest subset of environmental variables explaining the greatest percentage of variation in the ordination patterns based on fauna.

Wetland physico-chemistry similarity

Multivariate analysis using ordination and classification was applied to the August 2005 data to group wetlands based on physico-chemical properties and indicate groups of similar/dissimilar sites.

Between-year comparisons on environmental data were analysed using Principal Components Analysis (PCA) to discern patterns, gradients and similarities in water quality both over time and between sites. PCA transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called *principal components*. The first principal component accounts for as much of the variability in the data as possible and each succeeding component accounts for as much of the remaining variability as possible. The starting point for a PCA is a correlation matrix based upon Euclidean distance.

PCA ordinations were performed using untransformed data. For visualisation, the numeric value of key environmental variables was superimposed onto the PCA ordinations, as 'bubble plots'.

Variables used in analyses are detailed in Table 2.

Table 2: Measured and derived physico-chemical parameters used in multivariate analyses

Variable	Units	Description
Dissolved Oxygen	%	Percentage concentration of oxygen dissolved in the water column
Water Temperature	^{o}C	Temperature of the water in each wetland
Conductivity	ms/m	Electrical conductivity of the water
pH	#	Acidity of the water
Depth	m	Water depth at the gauge
Salt Crust	cm	Thickness of the salt crust on the bed of the lake
Benthic mat	cm	Thickness of microbial mat on the bed of the lake
Vegetative cover	%	Percent of wetland covered by vegetation
Sediment cover	%	Percent of wetland covered by exposed sediment
Cover by flooded riparian vegetation	%	Percent of wetland covered by inundated riparian vegetation
Samphire cover	%	Percent of wetland covered by Samphire
Macrophyte cover	%	Percent of wetland covered by submerged aquatic macrophytes
Reed/rush cover	%	Percent of wetland covered by emergent reeds and rushes
Benthic mat cover	%	Percent of wetland covered by benthic microbial mat
Total nitrogen	mg/L	Concentration of nitrogen in the water column
Total phosphorus	mg/l	Concentration of phosphorus in the water column
Water colour	TCU	Colour of water indicative of dissolved tannins
Water turbidity	NTU	Amount of fine suspended sediment in the water column
Chlorophyll-a	mg/l	Concentration of chlorophyll-a – indicative of algae growth in the water column

Wetland biodiversity

Wetland biodiversity was assessed by ranking wetlands according to taxa richness for permanent, temporary and total fauna composition, whereby, within each faunal element, the wetland with the most species was given the highest rank score (i.e. "21"), and the wetland with the least species was given the lowest rank score of "1". For tied ranks, the score was shared (i.e. two wetlands with the same number of species were given the same score). Wetlands were then ordered in descending order based on the mean of their rank scores across taxonomic levels, with results tabulated and graphed.

Conservation significance

Taxa were assigned to one of four conservation categories:

C = common taxa recorded from other states/territories or from overseas;
S = endemic to southwestern Australia, but commonly occurring;
L = endemic to southwestern Australia, but with a restricted occurrence; and
I = indeterminate status due to insufficient taxonomic information.

Taxa distributions
Determination of which taxa were common or unique to each wetland and across wetlands was achieved by cross-tabulation of taxa by sites.

Wetland fauna similarity
Multivariate pattern analysis (PRIMER) was performed using ordination and classification techniques to group wetlands according to temporary, permanent and total fauna assemblages on presence/absence and abundance data sets. This approach indicates groups of similar/dissimilar sites based on fauna. The similarity measures calculated across wetlands were used to determine levels of similarity/dissimilarity within and between groups of wetlands identified from the analyses. Results were presented as classification dendrograms and ordination scatterplots.

Inter-relationships amongst faunal attributes and physico-chemistry
Bubble plots and the BIOENV routine in PRIMER were used to examine relationships between conservation significance, biodiversity and wetland groupings and the physico-chemical parameters collected for each wetland.

Between-year comparisons
Between-year similarities in the invertebrate assemblages of the eight wetlands sampled originally in November 2003, and again in August 2004 and August 2005 were investigated using the same multivariate techniques (ordination and classification). Comparison between the four SAP wetlands sampled in 1999 and all subsequent years was also undertaken in the same manner. Since samples collected in 2003, 2004 and 2005 were processed by the same laboratory, and therefore taxonomy standardised, comparative analyses were performed on both abundance and presence/absence data. However, a more conservative approach using only presence/absence data was taken for comparison of 2005 samples with 1999 data, since different laboratories undertook identifications in these years.

Wetland Characterisation
To assess the effectiveness of future management actions within the BMRC, it is desirable to identify parameters that are easy, inexpensive and rapid to measure. With respect to surveying aquatic fauna, which may be regarded as expensive, time consuming and technically demanding in terms of taxonomic expertise, it was desirable to identify any such monitoring parameters that reflected faunal differences between wetlands. To this end, linear regression was undertaken on a number of wetland and physico-chemical characteristics in relation to aspects of biodiversity. Such analysis establishes a statistical relationship that can be used in a predictive capacity.

RESULTS

Physico-chemistry

August 2005

The physico-chemical characteristics of each wetland are detailed in Appendix 1. Climatic conditions over the sampling period were similar to those reported during August 2004. That is, weather conditions were dominated by heavy cloud cover, showers, relatively cold air temperatures and strong westerly winds. In particular, the winds resulted in substantial wave action in the wetlands, particularly the broad, open basins, resulting in highly turbid water, with fine sediment being suspended in the water column. Following early winter rains in May/June, the region was subjected to a dry period between July and early August during which water levels in the wetlands likely receded. However, renewed winter rains several weeks prior to sampling in mid-August replenished the wetlands. Therefore, it is possible some wetlands dried for a brief period prior to sampling.

To provide a means of comparison, water quality was assessed against the guidelines for the protection of aquatic ecosystems (ANZECC/ARMCANZ 2000)[2], 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). The default trigger values for physical and chemical stressors applicable to south-west Western Australia are provided in Table 3.

Table 3. 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.

In natural systems, pH is determined by atmospheric and geological factors (*e.g.* the result of inundation of limestone-rich or, conversely, humus-rich substrates) and to some extent, rates of primary productivity. Anthropogenic determinants include acid rock drainage (ARD), acid sulphate soils, acid deposition (*e.g.* acid rain) and agriculture. Most river systems in Western Australia have a natural pH range circum-neutral. According to the ANZECC/ARMCANZ (2000) guidelines, pH in wetlands within south-west WA should be between 7.0 and 8.5. Of the sites sampled during the current study, only nine

[2] 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. ANZECC/ARMCANZ (2000) recommends developing system-specific guidelines in new areas for which there is adequate reference condition data.

were within the guidelines (Appendix 1). Three sites recorded acidic pH values, including W001, W002, and W072, whilst the remainder were basic.

Consistently low dissolved oxygen concentrations were recorded from BMRC wetlands during August 2005, with all sites recording values well below the recommended ANZECC/ARMCANZ guidelines (2000). DO levels ranged between 13.4 % (W052) and 77.3 % (SPS203).

Dissolved oxygen (DO) levels may be used as an indicator of overall water quality and hence ecosystem health. DO concentration in any water body is the net result of biological processes (respiration and photosynthetic rates) and physical re-aeration (*e.g. via* wind action). Physical processes include re-aeration, which is the exchange of oxygen between the surface of the water and the atmosphere, at the water-air interface. Biological processes include metabolic rates, *i.e.* photosynthesis and respiration by aquatic biota. In waterbodies where rates of metabolism are high (*e.g.* where high algal or plant growth occurs), DO levels may drop overnight as a result of high rates of respiration. Large amounts of organic material in wetlands provide suitable conditions for microbial growth and increased rates of decomposition and hence low overnight DO.

Water temperatures ranged from 9.1 (W001) to 20.9 °c (SPS203), likely reflecting differences in water depth (i.e. shallower wetlands have greater daily ranges in temperature), time of day when sampled (wetlands sampled in the morning will likely be cooler than those sampled in the afternoon), and water colour (tannin-stained water tends to absorb more heat than clear water).

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 tanin 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) in ten of the 21 BMRC wetlands sampled in August 2005, with the highest levels recorded from W052 (9.8 mg/L), W002 (4.5 mg/L), W070 (3.9 mg/L), W015 (3.5 mg/L), and W009 (2.9 mg/L) (Figure 2 and Appendix 1). The guideline for total phosphorus (0.060 mg/l), was exceeded only in two sites, W016 (0.13 mg/l) and W007 (0.09 mg/L) (Figure 3 and Appendix 1).

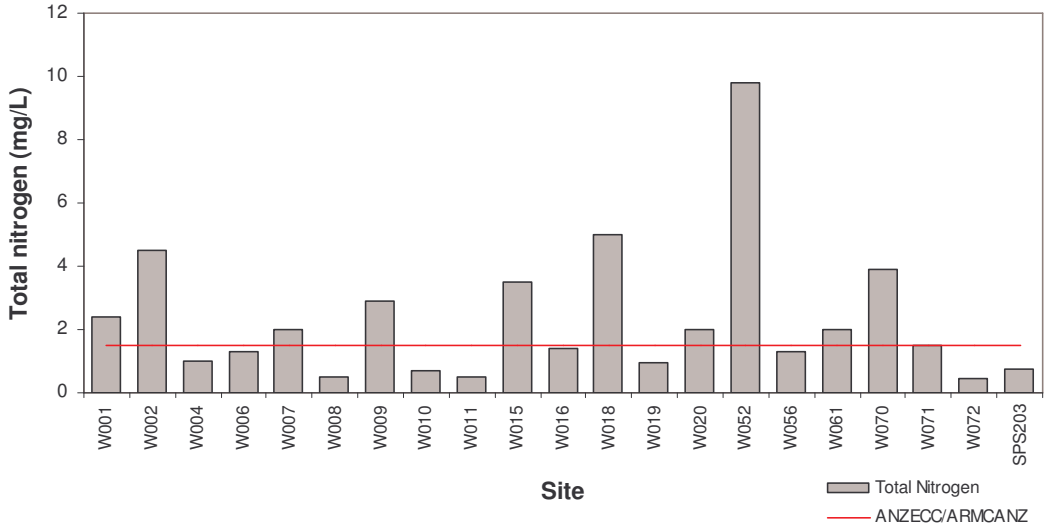

Figure 2. Total nitrogen levels (mg/L) recorded from BMRC wetlands during 2005, with respect to ANZECC/ARMCANZ (2000) water quality guidelines.

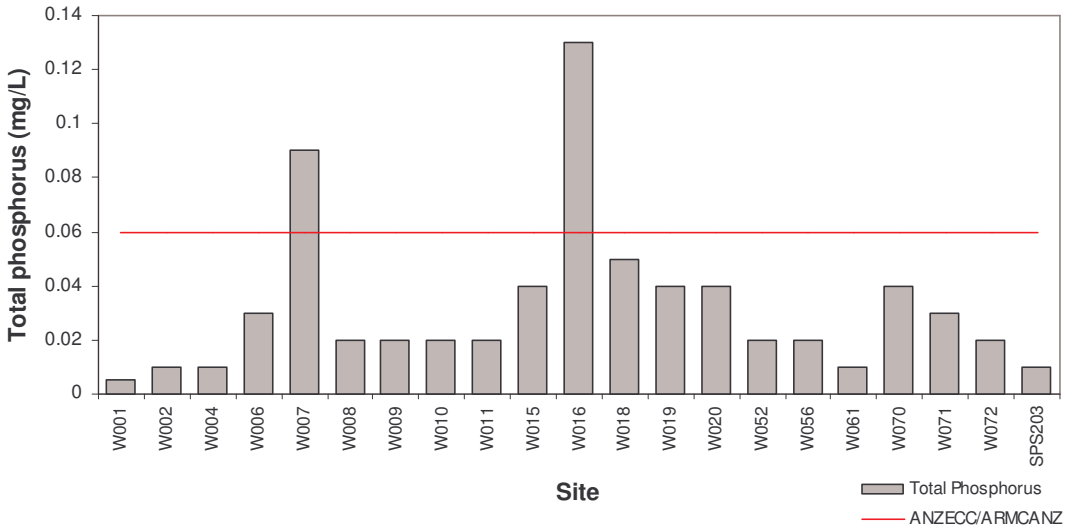

Figure 3. Total phosphorus levels (mg/L) recorded from BMRC wetlands during 2005, with respect to ANZECC/ARMCANZ (2000) water quality guidelines.

Classifying wetlands to a trophic status is a useful means of summarising nutrient data in that it provides an indication of current wetland status, allows comparisons amongst wetlands and may be used to assess change in a wetland over time. There are a number of schemes whereby wetlands may be classified to a trophic status based on nutrient concentrations (e.g. Wetzel 1983; OECD 1982; Salas & Martino 1991). The classification by Wetzel (1983) is from the classic text on limnology based on temperate northern hemisphere lakes, and uses ranges in concentrations of Total-P, Total-N and inorganic N (Table 4). The OECD classification is based on a survey of a large number of lakes, mainly from northern temperate areas, particularly glacial lakes from high latitudes. The system was produced by qualitatively classifying each lake to a trophic state, and then using measurements of nutrient concentrations and loads, chlorophyll-a and Secchi disc transparency to set boundary values and the mean and variance of each parameter for each trophic category (Davis *et al.* 1993).

A similar approach was used by the Pan American Centre for Sanitary Engineering and Environmental Sciences (CEPIS; Salas & Martino, 1991) to develop a classification system for warm-water tropical lakes (Table 5). Forty lakes were individually assigned to a trophic state based on qualitative criteria, and site-measurements of mean annual total phosphorus were then used to determine standards (means $\pm$ standard deviations) for each category. For the CEPIS study, warm-water lakes were defined as lakes with a minimum temperature of greater than 10 ^{o}C, with a minimum annual average of 15 ^{o}C. All wetlands sampled in the current study were considered to be warm-water sites and therefore, the classification by CEPIS is most appropriate.

Table 4. Classification of lake trophic status based on ranges in nutrient concentration (mg/l) (Wetzel, 1983).

Category	Total P (& Ortho P)	Total N	Inorganic N
Ultra-oligotrophic	0 – 0.005	0 – 0.25	0 – 0.20
Oligo-mesotrophic	0.005 – 0.01	0.25 – 0.60	0.20 – 0.40
Meso-eutrophic	0.01 – 0.03	0.30 – 1.10	0.30 – 0.65
Eutrophic	0.03 – 0.1	0.50 – 1.50	0.50 – 1.50
Hyper-eutrophic	> 0.1	> 1.50	> 1.50

Table 5. Mean annual total phosphorus levels (mg/l) for each trophic category under the OECD (1982) and CEPIS (Salas & Martino, 1991) classifications (means and range over 2 standard deviations).

	Category		
	Oligotrophic	Mesotrophic	Eutrophic
OECD	0.008	0.0267	0.084
($\pm$ 2 SD)	(0.003 – 0.022)	(0.08 – 0.091)	(0.017 – 0.424)
CEPIS	0.021	0.0396	0.1187
($\pm$ 2 SD)	(0.010 – 0.045)	(0.021 – 0.074)	(0.028 – 0.508)

There are currently no W.A. or Australian-specific guidelines for determining trophic status of aquatic systems. OECD and CEPIS do not classify lake trophic status according to total nitrogen. However, based on Wetzel (1983) guidelines, 11 sites from this study classified as eutrophic on total nitrogen concentrations. Thirteen of the 21 sites had concentrations above 1.1 mg/l (upper limit for meso-eutrophic). Eleven of the 21 wetlands were above 1.5 mg/l (Appendix 1) and therefore classified as hyper-eutrophic according to Wetzel (1983). Spot measurements of total phosphorus exceeded the 0.021 mg/l threshold in nine wetlands, and therefore fell within the mesotrophic range according to the CEPIS classification (Table 5).

Classification of sites on standardised physico-chemical parameters detected four main groups of sites (Figure 4). Ordination showed a clear separation of wetlands in ordination space (Figure 5), with a clear separation of groups derived from the cluster analysis. Within these groups, there was some further separation of sites. For example, W009 and W010 separated from W020 and W052 within Group One. W016 and W015 also showed some separation from W072 and W011 within Group Four, while W007 was an outlier from Group Three.

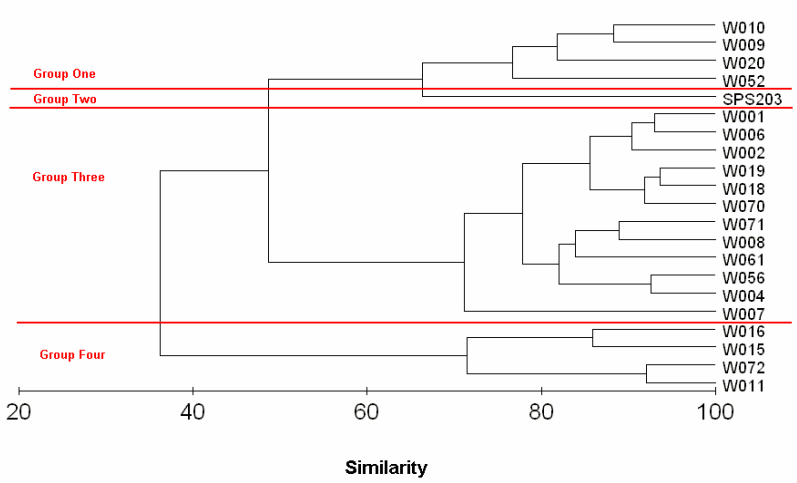

Figure 4. Cluster analysis dendrogram of the 21 sites using standardised physico-chemical parameters, indicating the four main groupings to be superimposed on site ordination.

ANOSIM detected significant separation of cluster groups in ordination space (Global R = 0.968; significance level of sample statistic = 0.1%). Pairwise comparisons with ANOSIM detected significant differences between Group One and Three, Group One and Four, and Group Three and Four (Table 6).

The main separation of sites in ordination space was of hypersaline from fresher sites (Figure 5 and Table 6). Gradients in physico-chemical parameters were evident (Figure 6). Conductivity was clearly highest in Group Three (hypersaline sites). Colour was highest from sites W015 and W016, which may explain their slight separation from other sites within Group Four. The high turbidity recorded from W007 may also help to explain its slight separation from other hypersaline sites within Group Three. Finally, SPS203 recorded considerably higher dissolved oxygen levels than all other sites within the BMRC, likely contributing to its separation from other hypersaline wetlands (Figure 6). A number of factors may explain the high oxygen levels recorded from SPS203. It is likely this site had recently become inundated prior to sampling, with aquatic fauna having not yet recolonised. The absence of fauna means dissolved oxygen was not being used up (i.e. low respiration levels). In addition, the shallow depths and high wind and wave action likely contributed to increased oxygen concentrations within this wetland.

Table 6. ANOSIM results showing pairwise comparisons of groups based on physico-chemical parameters. * = significantly different, ns = not significantly different.

	1	2	3	4
1				
2	ns			
3	*	ns		
4	*	ns	*	

While there was high variation in between-site pairwise similarity values, similarity of physico-chemical characteristics between BMRC wetlands sampled in 2005 was generally quite high (Table 7). Similarity ranged from 10% (between W001 and W014) to 93% (between W018 and W019) (Table 7).

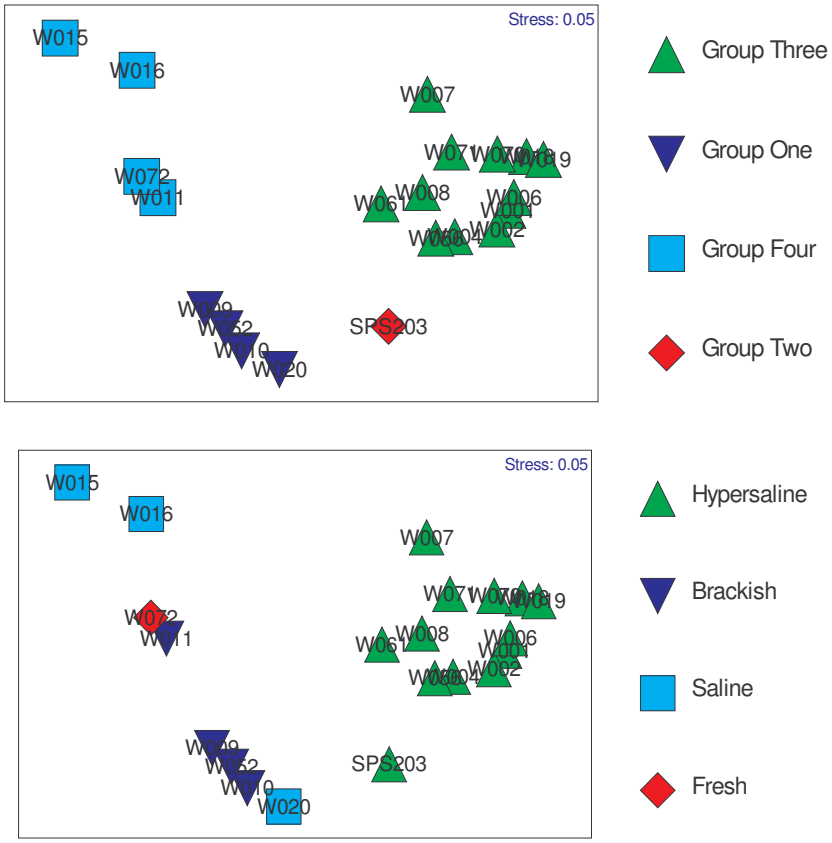

Figure 5. MDS ordination of the 21 wetlands. Ordination utilised standardised physico-chemical variables, sites are labelled by site number, coloured by groupings from the cluster analysis (top) and salinity groupings (bottom). Stress was 0.05.

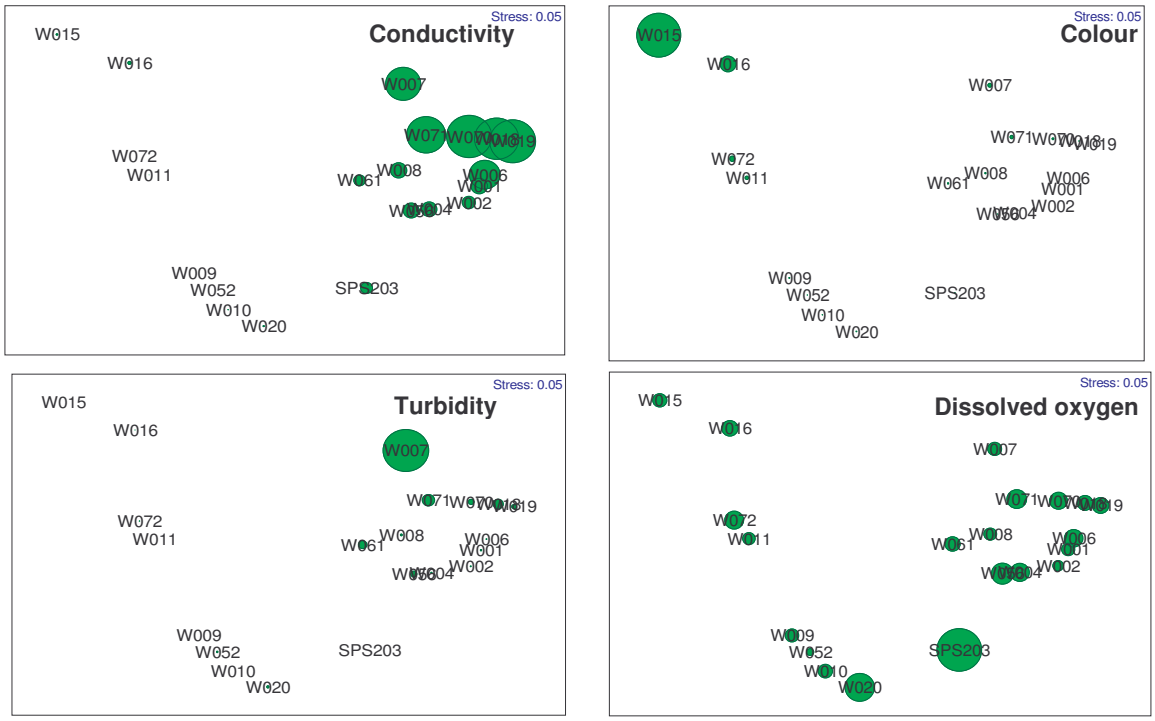

Figure 6. Bubble plots showing the influence of a number of physico-chemical parameters on the ordination.

Table 7. Matrix of association values, with each value indicating pairwise similarity between each wetland, calculated using the Bray-Curtis association measure on standardised physico-chemical parameters.

	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072
W002	92.46																			
W004	86.61	89.57																		
W006	93.04	88.24	83.90																	
W007	63.42	63.09	66.47	63.41																
W008	80.27	82.90	87.07	80.79	79.18															
W009	39.20	45.36	51.35	36.50	37.87	52.97														
W010	40.36	44.64	53.38	38.60	39.93	55.03	88.28													
W011	36.36	39.51	46.50	35.03	36.37	51.62	74.00	65.59												
W015	10.14	10.42	13.67	11.90	27.18	25.97	38.35	30.01	64.32											
W016	24.15	24.42	27.68	25.91	38.35	40.02	50.99	44.03	76.00	85.92										
W018	86.62	80.44	76.88	89.95	70.40	74.91	29.28	30.68	26.66	13.55	27.53									
W019	86.33	80.15	75.68	90.49	65.15	74.07	27.08	29.13	25.71	11.51	25.53	93.58								
W020	44.33	48.00	56.05	40.05	43.07	57.28	78.40	85.11	60.22	25.17	39.20	36.50	32.75							
W052	41.23	47.08	51.60	36.81	43.37	54.99	79.51	77.98	63.40	27.74	40.70	34.79	29.51	72.49						
W056	81.21	83.27	92.54	77.93	73.68	85.97	52.43	54.48	47.52	16.00	30.01	75.11	70.67	59.65	56.47					
W061	72.18	73.19	77.46	69.60	80.43	86.06	57.35	59.11	55.11	27.37	41.33	67.33	62.32	62.36	62.85	83.97				
W070	86.42	80.25	77.26	89.01	73.78	81.48	35.40	37.25	33.24	19.87	33.62	93.02	90.67	41.26	38.02	74.85	70.82			
W071	79.28	78.95	78.20	79.27	84.01	88.90	42.54	44.59	41.17	26.64	40.41	84.56	80.44	48.27	48.04	79.29	81.64	88.36		
W072	33.60	36.19	44.59	32.24	33.59	48.21	69.33	60.47	92.02	67.80	77.57	23.88	23.04	56.00	57.78	46.57	50.91	30.46	38.41	
SP203	63.61	67.78	75.43	62.28	54.83	70.69	63.44	71.35	49.42	18.29	32.32	53.94	53.02	76.83	53.86	77.58	72.22	58.98	60.21	48.21

Comparisons with 2003 and 2004 data

Principal Components Analysis (PCA) on the 20 samples from 2004 and 2005 reduced the large physico-chemical dataset to five principal components, with 49% of the variation being explained by PC1, PC2 and PC3 (Table 8).

Table 8. Eigenvalues, percent of variance and cumulative percent of variance explained by the five components from PCA performed on standardised physico-chemical parameters recorded from the BMRC in 2003, 2004 & 2005.

PC	Eigenvalues	% Variation	Cumulative % Variation
1	4.06	21.4	21.4
2	2.66	14.0	35.4
3	2.59	13.6	49.0
4	1.83	9.6	58.6
5	1.56	8.2	66.8

PCA ordinations of physico-chemical parameters showed no clear separation of 2004 from 2005 data (Figure 7). Variables contributing to PC1 were percent vegetation (eigenvectors for veg. cover were negative) and sediment cover. Generally, hypersaline sites separated from others along PC1 and comprised greater sediment and less vegetation cover. Similarly, sites sampled in 2005 showed changes in wetland morphology with respect to vegetation characteristics, comprising less vegetation cover and greater sediment (Figure 7), effectively reducing aquatic habitat for invertebrate communities. The fresh granite outcrop site (W072) sampled in 2005 fell within other hypersaline wetlands based on its reduction in extent of vegetation since 2004. The reduction in vegetation cover between years can be seen at site W052, which has undergone a considerable reduction in the extent of *Typha* since 2004, probably due to intentional clearing for stock access (Plate 2). The accurate identification of *Typha* to species level was not possible given its senescent condition.

Variables contributing to PC2 were percent benthic mat cover and thickness (eigenvectors were negative), depth, and total nitrogen concentration. Site W011 separated from all other BMRC wetlands along this principal component, and comprised greater benthic mat thickness and percent cover (Figure 7). The nutrient rich wetland W052, separated from other sites based on its high nitrogen levels (Figure 7). Both W011 and W052 showed little between-year variation in physico-chemical and wetland characteristics.

Principal Components Analysis (PCA) on the eight samples from 2003, 2004 and 2005, reduced the large physico-chemical dataset to five principal components, with over 70% of the variation being explained by PC1, PC2 and PC3 (Table 9).

Table 9. Eigenvalues, percent of variance and cumulative percent of variance explained by the five components from PCA performed on standardised physico-chemical parameters recorded from the BMRC in 2003, 2004 & 2005.

PC	Eigenvalues	% Variation	Cumulative % Variation
1	3.01	33.5	33.5
2	2.04	22.6	56.1
3	1.26	14.0	70.1
4	0.86	9.5	79.7
5	0.76	8.4	88.1

Plate 2. Site W052 showing the reduction in the extent of *Typha* between 2004 (top) and 2005 (bottom).

PCA ordinations of physico-chemical parameters showed a clear separation of 2003 from 2005 data, along principal component one (Figure 8). Variables contributing to PC1 were depth and chlorophyll *a* (eigenvectors for chlorophyll were negative). Samples from 2005 were shallower and comprised greater chlorophyll a levels than those from 2003 (Figure 8). August 2004 samples were generally intermediate between 2003 and 2005, and showed considerable overlap with 2005. Sites W018 and W019 from 2005 separated from all other samples based on the high chlorophyll *a* levels from these samples (Figure 8).

Variables contributing to PC2 were total nitrogen and conductivity. As would be expected, hypersaline sites separated from brackish wetlands along this principal component (Figure 8). Site W011 showed some separation from other wetlands within the BMRC as a result of its low nitrogen concentration.

Generally, water depth was highest in 2003 and lowest in 2005, with 2004 samples occupying an intermediate position (Figure 9). This is despite sampling being conducted later in the year during 2003 when wetlands would be expected to recede under drying weather conditions. Generally, depths were more variable in 2004 than 2005, reflecting influences of local rainfall and hydrology, degree of groundwater interaction and evaporation. Plate 3 shows the reduction in water levels between 2004 and 2005 at site W018.

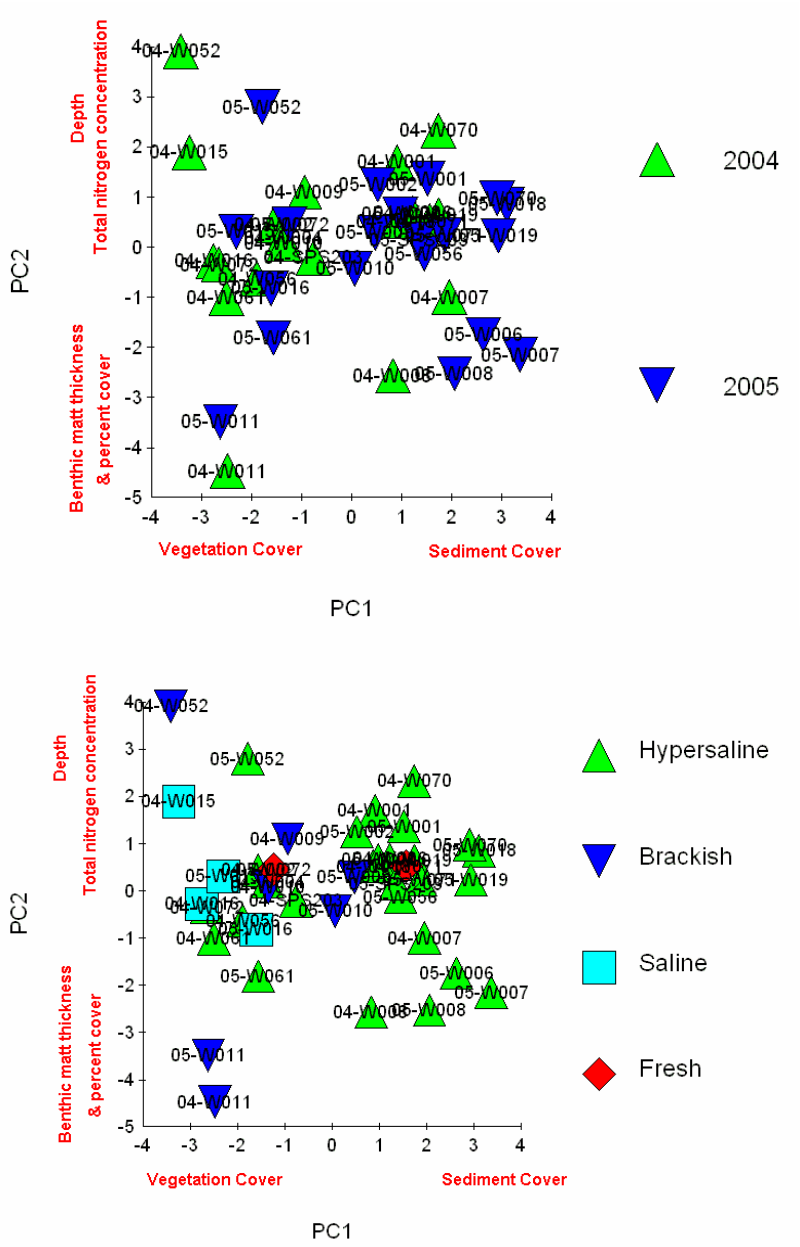

Figure 7. Two-dimensional PCA ordination plots of physico-chemical variables for BMRC wetlands surveyed in 2004 & 2005, showing years (top) and salinity type (bottom). Variables contributing to principal components are presented in red.

Given the higher water levels within BMRC wetlands in 2003, conductivity (salinity) would be expected to be lowest as a result of dilution effects. However, this was not always the case, with sites W011 and W010 having higher conductivities in 2003 than 2004 and 2005. Conductivity was considerably higher within W018 and W070 in 2005 than 2004 (Figure 9). This is likely due to evapoconcentration effects within the wetlands since water depth was notably lower in 2005. High temporal variability in the concentration of dissolved salt is a common phenomenon in the majority of aquatic ecosystems in Australia, even those which are not undergoing salinisation (Hart *et al.* 2003; Nielson *et al.* 2003). Wetlands and river systems experience a concentration effect, with higher salinities at lower depths (or flows) and lower salinities at higher depths (or flows) (Hart *et al.* 2003; Nielson *et al.* 2003).

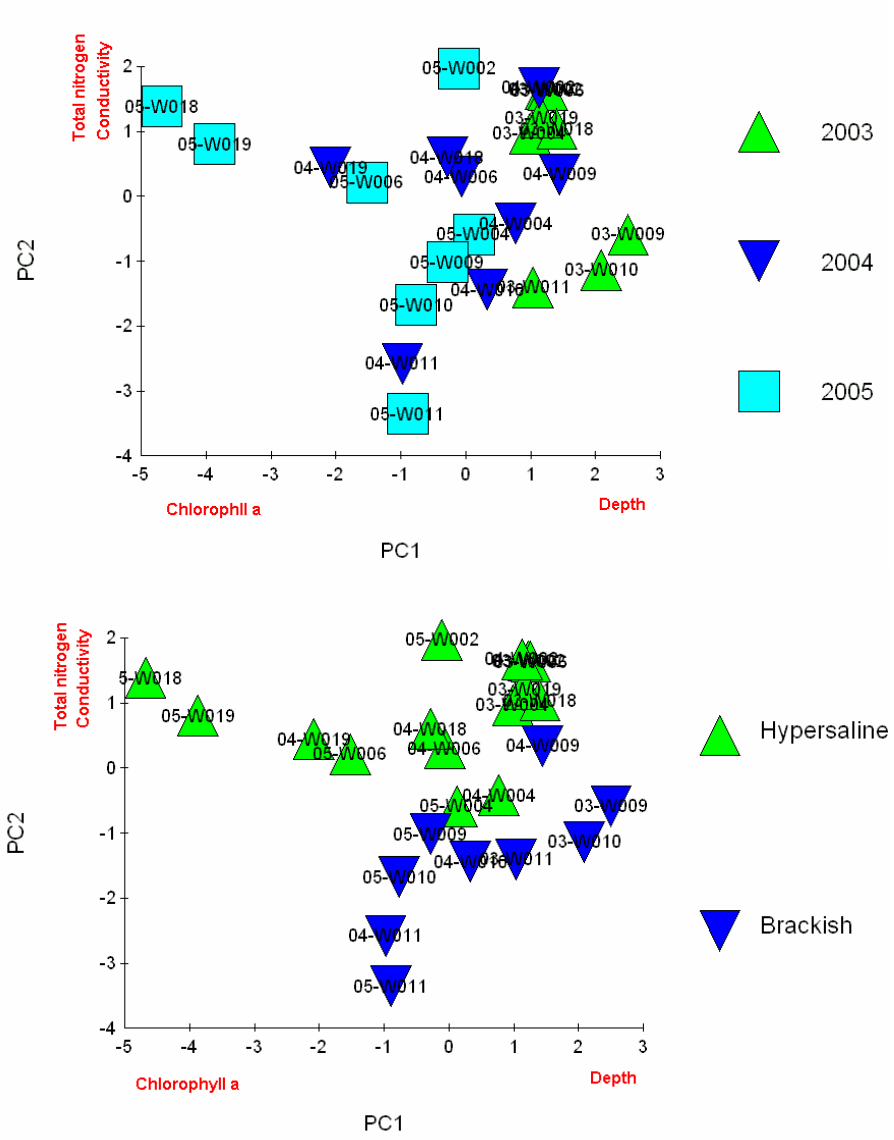

Figure 8. Two-dimensional PCA ordination plot of physico-chemical variables for the eight BMRC wetlands surveyed in 2003, 2004 & 2005, showing years (top) and salinity (bottom).

The notably lower conductivity at SPS203 in 2005, compared with 2004 (Figure 9), is likely a result of recent rainfall filling this site only a short time before sampling in 2005, with salts likely still held in sediments and not yet dissolved within the water column.

Total phosphorus concentrations have generally increased within BMRC wetlands since 2003 (Figure 9). Once again, this is likely to be due to evapoconcentration effects and lower water levels. The lower water levels recorded during 2005 would result in a concentration of stored phosphorus within wetlands. The highest phosphorus levels were recorded from W016 in 2004. This wetland was actually deeper in 2005.

Dissolved oxygen levels were considerably lower in the current survey than during August 2004 (Figure 9). Generally, this may be explained by the lower water levels and reduced vegetation cover in 2005. As previously noted, SPS203 had noticeably higher DO levels than all other wetlands sampled in 2005.

Plate 3. W018 showing the reduction in water levels between 2004 (top) and 2005 (bottom), with water receded from marginal vegetation in 2005, and with the establishment of a salt crust along the exposed beachline.

Aquatic Invertebrate Fauna

August 2005

Taxonomy

A total of 135 taxa were recorded from the 21 wetlands in August 2005 (Table 10), in comparison to 150 and 68 taxa collected during the August 2004 and November 2003 aquatic surveys, respectively. Allowing for common taxa, this provides an overall total of 202 taxa known from the BMRC.

Of the species recorded, 37% 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 species comprised nine species of Rotifera (Plate 4), one Platyhelminthes (flat worm; Plate 5), two species of Gastropoda (snails; Plate 6), 17 species of Copepoda (Plate 7), six species of Cladocera (water fleas; Plate 9), ten Ostracoda (seed shrimp; Plate 10), two types of Conchostraca (clam shrimp; Plate 11), three Anostraca (fairy shrimp; Plate 8), and one Oligochaeta (segmented worm) (Table 10). 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 1985).

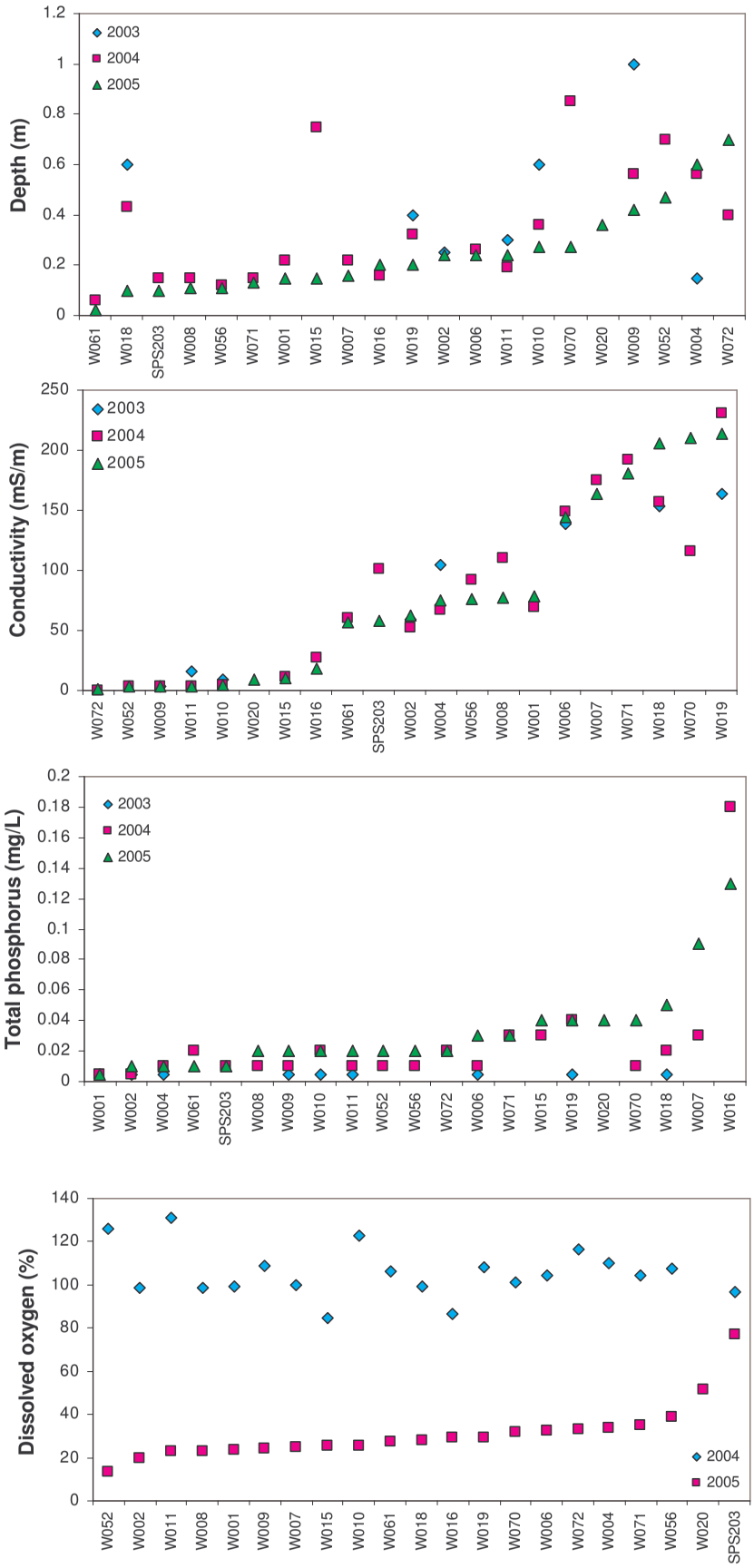

Figure 9. Plots showing change in some physico-chemical parameters over time.

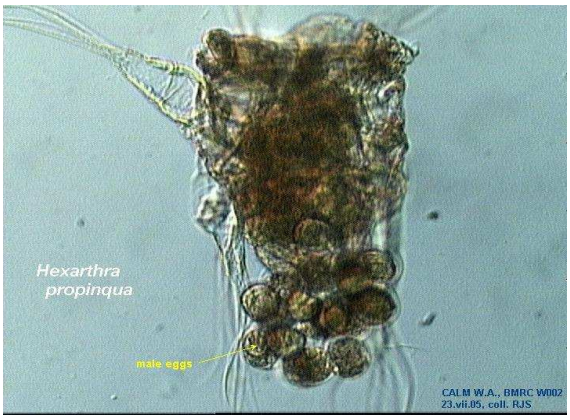

Plate 4. Rotifer. Photo taken by Russ Shiel.

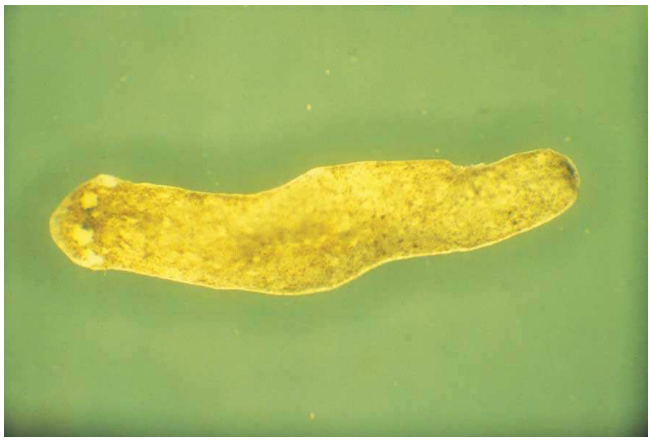

Plate 5. A flatworm (Platyhelminthes).

Plate 6. *Coxiella* (Gastropoda).

Plate 7. A Harpactacoid Copepod. Photo by Lisa Chandler

Plate 8. Artemia (Anostraca).

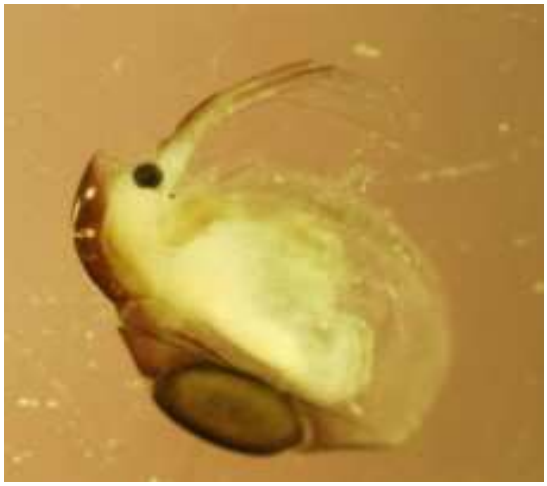

Plate 9. A water flea (Cladocera) collected from the BMRC. Photo taken by Lisa Chandler.

Plate 10. The Ostracod *Australocypris insularis*, collected from the BMRC. Photo taken by Russ Shiel.

Plate 11. A Conchostraca.

Of the 84 'temporary' fauna, there was one Nematoda (round worm; Plate 12), five Arachnida (mites), one Amphipoda (side swimmers; Plate 13), one Isopoda (water slaters; Plate 14), 21 taxa of Chironomidae (non-biting midges; Plate 15), 15 types of other Diptera (larval flies; Plate 16), two Trichoptera (caddisflies; Plate 17), two Ephemeroptera (mayflies; Plate 19), seven Odonates (damselflies & dragonflies; Plates 20 & 21), one Lepidoptera (moth larvae), and 22 taxa of Coleoptera (beetles; Plates 22 & 23), and six species of Hemiptera (water bugs; Plate 18).

Plate 12. Nematoda.

Plate 13. Amphipod.

Plate 14. Isopod

Plate 15. A Chironomid larvae.

Plate 16. Diptera (Ceratopogonid larvae). Photo by Lisa Chandler.

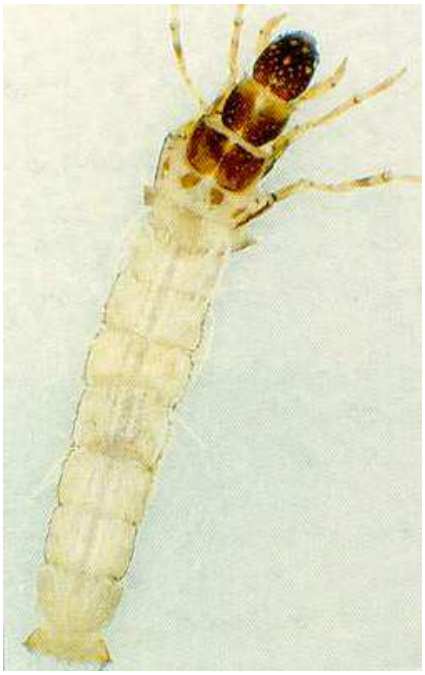

Plate 17. A Leptocerid Trichoptera.

Plate 18. Hemiptera (*Agraptacorixa*).

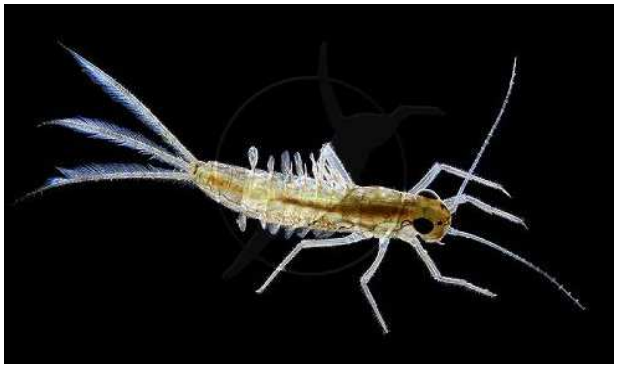

Plate 19. Ephemeroptera (*Cloeon*).

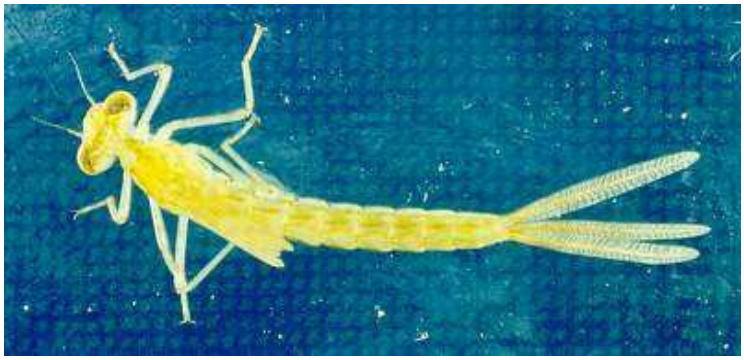

Plate 20. A Zygoptera Odonate (damselfly larvae).

Plate 21. An Anisopteran Odonate (dragonfly larvae).

Plate 22. A Dytiscid Coleoptera (*Sternopriscus*). Photo by Lisa Chandler.

Plate 23. Hydrophilid Coleoptera (*Berosus*). Photo by Lisa Chandler.

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.

Taxa Richness

Of the 135 taxa, only 17 occurred at more than five sites (13%), and these tended to be taxa not taken to species level, but comprising pupae and larvae which couldn't be

identified further. Other commonly occurring taxa included the Ostracod *Diacypris* sp., the Amphipod *Austrochiltonia subtenuis*, the Tanyponid Chironomid *Procladius paludicola*, and the Corixid *Micronecta robusta* (Table 10)

Of the remaining taxa occurrences, five taxa occurred at five sites, 12 at four sites, 14 at three sites, 27 at two sites and 58 taxa (43% of taxa) were singletons occurring at only one site (Table 10).

Overall, fresher water sites (fresh-brackish/low saline), contained a greater number of taxa, including W011 (43 taxa), W072 (37), W010 (35), W015 (34), W052 (31), W020 (30), W009 (29), and W016 (27) (Figure 10).

The number of permanent resident taxa varied greatly between sites (Figure 10), with the highest taxa richness being recorded from W011 (17 taxa), W072 (13), W016 (10) and W004 (9 taxa). Similarly, surveys in August 2004 recorded high numbers of microinvertebrates from W011 (18 taxa) and W072 (20). No permanent taxa were collected from W007 or W018 during the current study (Figure 10). In addition, no microinvertebrates have been recorded from W006 over the entire three-year sampling period (2003, 2004 or 2005).

The highest taxa richness of temporary macroinvertebrates were generally recorded from the fresher sites, including W010 (29), W011 (26), W072 (24), W052 (22), and W009 (21). Hypersaline BMRC wetlands tended to support the lowest number of temporary taxa, including W071 (0), W007 (1), W008 (1), W056 (1), W001 (2), W006 (2), W070 (2), and SPS203 (2).

The majority of sites comprised a greater number of temporary taxa than permanent residents (Figure 10). However, sites for which permanent residents outnumbered temporary taxa were all hypersaline.

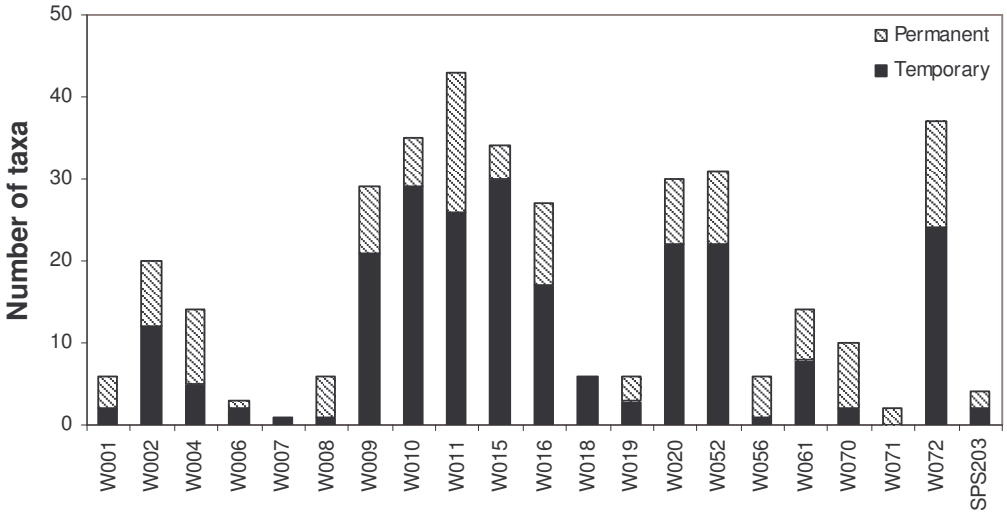

Figure 10: Number of taxa of permanent residents, temporary residents and total number of invertebrate taxa taken from each site in August 2005.

Table 10. Abundance (log_{10} scale where 1 = 1 individuals, 2 = 2-10, 3 = 11-100 and 4 = > 101) of each taxon at each site, giving total number of taxa and numbers of southwest Western Australia common endemic and restricted endemic taxa. The level of endemism of each taxa is indicated, where C = common taxa recorded from other states/territories/overseas, S = endemic to southwestern Australia, but commonly occurring, L = endemic to southwestern Australia, but with a restricted occurrence, I = indeterminate status due to insufficient taxonomic information, ? = awaiting taxonomic identification, and EXOT = introduced species). Suffixes after species names refer to larval (L) and pupal (P) forms.

Order	Family	Species	Cons	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072	SPS203
ROTIFERA	**Bdelloidea**																							
		indet. contr. sp.	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Monogononta	**Brachionidae**	*Brachionus plicatilis*	C	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0
	Hexarthridae	*Hexarthra propinqua*	C	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Hexarthra **n. sp**	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Proalidae	*Proales daphnicola* **N.R WA**	C	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		?Proales sp.	C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Notommatidae	*Cephalodella gibba*	C	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
	Testudinellidae	*Testudinella patina*	C	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
		indet. contr. rotifer	I	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
PLATYHELMINTHES																								
	TURBELLARIA	*cf. Mesostoma sp*	C	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
NEMATODA		Nematoda spp	C	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
ANNELIDA	**OLIGOCHAETA**	*Oligochaeta spp*	C	0	0	2	0	0	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0
MOLLUSCA																								
GASTROPODA	**Physidae**	*Physa acuta*	EXOT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
	Pomatiopsidae	*Coxiella (Coxiella) sp*	C	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
ARTHROPODA																								
ARACHNIDA																								
ACARIFORMES																								
	Trombidioidea	Trombidioidea spp	I	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Halacaridae	Halacaridae spp	I	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Hydryphantidae	Hydryphantidae spp	I	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	ORIBATIDA	Oribatida spp	I	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
PARASTIFORMES	**Mesostigmata**	Mesostigmata spp	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
CRUSTACEA																								

Order	Family	Species	Cons	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072	SPS203
COPEPODA	**Cyclopoida**	*Apocyclops dengizicus*	C	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	3	0	0	0	0
		Meridiecyclops baylyi	I	0	0	3	0	0	2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3
		Mesocyclops cf. *brooksi*	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0
		Metacyclops mortoni	I	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
		Mesocyclops sp.	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
		cyclopoid copepodites	I	0	3	4	0	0	2	2	0	3	2	3	0	0	0	3	3	4	2	1	3	0
		cyclopoid nauplii	I	0	3	2	0	0	1	0	0	3	0	3	0	0	0	2	0	3	0	0	2	0
	Calanoida	*Boeckella triarticulata*	C	0	2	0	0	0	0	3	3	0	0	0	0	0	4	3	0	0	0	0	0	0
		Calamoecia clitellata	C	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0
		Calamoecia trilobata	C	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		indet cal. female	I	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
		calanoid copepodites	I	4	0	0	0	0	0	3	2	3	0	0	0	0	3	2	0	0	2	0	1	0
		calanoid nauplii	I	3	0	0	0	0	0	3	2	3	0	0	0	0	3	0	0	0	3	0	0	0
	Harpacticoida																							
	Ameiridae	*Nitocra* sp. 1	I	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
	Cletodidae	*Cletocamptus deitersi*	C	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Canthocamptidae	*Mesochra bayli*	C	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
		harpac. nauplii	I	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0
CLADOCERA	**Chydoridae**	*Alona rigidicaudis*	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Daphnidae	*Daphnia carinata*	C	0	2	0	0	0	0	0	0	3	0	0	0	0	2	4	0	0	0	0	2	0
		Daphniopsis truncata	C	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
		Daphniopsis sp. [no ephippia]	I	0	0	0	0	0	0	0	0	3	0	2	0	0	2	0	0	1	0	0	0	0
	Macrothricidae	*Macrothrix breviseta*	C	0	0	0	0	0	0	2	0	2	0	0	0	0	0	1	0	0	0	0	2	0
	Moinidae	*Moina sp.*	C	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0
OSTRACODA	**Ostracoda**	*Australocypris* cf. *insularis*	C	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	2	3	0	0	0	0
		Diacypris sp.	I	0	0	0	0	0	4	0	0	0	4	3	0	0	0	0	4	2	2	2	0	0
		Heterocypris sp.	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
		Limnocythere mowbrayensis	C	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Mytilocypris sp.	C	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
		Platycypris baueri	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
		Reticypris sp.	I	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		cf. *Sarscypridopsis* sp.	C	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Order	Family	Species	Cons	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072	SPS203
		indet. ostracod sp.	I	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
		indet. juv. ostracod	I	0	0	2	0	0	0	0	2	0	0	0	0	1	2	1	0	0	0	0	2	1
CONCHOSTRACA		*Caenaseriella packardi*	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
	Limnadiidae	*Limnadia sp* (too juvenile)	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
ANOSTRACA	**Artemiidae**	*Artemia parthogenetica*	EXOT	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0
	Parartemidae	*Parartemia contracta*	S	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Parartemia ?longicaudata	S	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AMPHIPODA	**Ceinidae**	*Austrochiltonia subtenuis*	C	0	1	0	0	0	0	5	3	4	3	2	0	0	5	4	0	0	0	0	0	1
ISOPODA	**Oniscoidea**	Oniscoidea spp	C	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INSECTA																								
DIPTERA	**Chironomidae**	Chironomid spp. (P)	I	0	0	0	0	0	0	0	2	2	2	2	0	0	0	1	0	1	0	0	0	0
	Chironominae	*Chironomus occidentalis*	L	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
		Chironomus aff. alternans	C	0	0	0	0	0	0	0	3	0	4	0	0	0	2	2	0	0	0	0	0	0
		Tanytarsus fuscithorax	C	0	0	0	0	0	0	2	4	4	3	0	0	0	0	4	0	0	0	0	0	0
		Tanytarsus semibarbitarsus	C	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Tanytarsus barbitarsus	C	0	0	2	0	0	0	0	0	0	0	4	2	0	0	0	2	2	0	0	0	0
		Cryptochironomus griseidorsum	C	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0
		Dicrotendipes conjunctus	S	0	0	0	0	0	0	0	2	2	0	0	0	0	3	0	0	0	0	0	0	0
		Polypedilum nubifer	C	0	0	0	0	0	0	0	3	3	0	0	0	0	2	0	0	0	0	0	0	0
		Polypedilum (Pentapedilum) leei	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		?Cladopelma sp.	L	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1
		Kiefferulus intertinctus	C	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
	Tanypodinae	*Procladius villosimanus*	S	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
		Procladius paludicola	C	0	0	0	0	0	0	0	3	4	3	0	0	0	3	3	0	3	0	0	0	0
		Ablabesmyia notabilis	C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
		Paramerina ?levidensis	C	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0
	Orthocladiinae	*?Limnophyes pullulus*	C	0	0	0	0	0	0	3	0	2	0	0	0	0	2	4	0	0	0	0	0	0
		Orthocladiinae ?VSC11	I	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladiinae V66	I	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
		Orthocladiinae sp. BM2	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
		Corynoneura sp.	C	0	0	0	0	0	0	2	0	1	0	0	0	0	0	1	0	0	0	0	0	0
	Culicidae	Culicinae spp. (L)	I	0	0	0	0	0	0	0	0	0	3	1	0	0	1	0	0	0	0	0	3	0

Order	Family	Species	Cons	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072	SPS203
		Culicinae spp. (P)	I	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0
	Ceratopogonidae	Ceratopogoniinae spp.	I	2	2	2	0	0	0	3	4	3	3	2	3	1	3	3	0	3	0	0	3	0
		Ceratopogonid spp. (P)	I	1	2	0	0	0	0	2	3	0	1	1	0	0	2	2	0	1	0	0	3	0
		Dasyheleinae spp. (L)	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Forcipomyiinae spp (L)	I	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0
	Tabanidae	Tabanidae spp.	I	0	2	0	0	0	0	0	0	1	2	0	2	0	0	0	0	0	0	0	2	0
	Stratiomyidae	Stratiomyidae spp	I	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ephydridae	Ephydridae spp	I	0	0	0	0	0	0	1	2	0	2	4	0	0	0	0	0	2	0	0	1	0
		Ephydridae spp. (P)	I	0	0	2	0	0	0	2	2	0	0	3	0	0	0	0	0	0	0	0	0	0
	Dolichopodidae	Dolichopodiae spp	I	0	0	0	0	0	0	1	4	0	0	3	0	0	0	0	0	0	0	0	0	0
	Psychodidae	Psychodidae spp	I	0	0	0	0	0	0	2	3	0	1	0	0	0	2	0	0	0	0	0	0	0
	Muscidae	Muscidae spp	I	0	1	0	0	0	0	0	1	0	1	1	3	2	1	0	0	0	1	0	0	0
		Muscidae spp (P)	I	0	2	0	2	1	1	0	2	0	2	2	3	2	1	0	0	0	3	0	0	0
	Tipulidae	Tipulidae spp.	I	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
TRICHOPTERA	**Leptoceridae**	*Triplectides australicus*	C	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
		Notalina spira	C	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0
EPHEMEROPTERA	**Caenidae**	*Tasmanocoenis tillyardi*	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Baetidae	*Cloeon sp*	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
ODONATA																								
ANISOPTERA	**Libellulidae**	*Orthetrum caledonicum*	C	0	0	0	0	0	0	1	0	2	0	0	0	0	0	2	0	0	0	0	2	0
	Aeshnidae	*Hemianax papuensis*	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
	Hemicorduliidae	*Hemicordulia tau*	C	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0
ZYGOPTERA	**Lestidae**	*Austrolestes annulosus*	C	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0
		Austrolestes psyche	C	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Coenagrionidae	*Ischnura heterosticta*	C	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0
		Coenagrionidae spp (juv)	I	0	0	0	0	0	0	0	0	1	1	0	0	0	1	2	0	0	0	0	0	0
LEPIDOPTERA	**Pyralidae**	Nymphulinae spp	C	0	1	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
COLEOPTERA	**Dytiscidae**	*Necterosoma penicillatus*	C	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Necterosoma sp. (L)	I	0	3	0	0	0	0	0	3	3	0	1	0	0	0	1	0	1	0	0	0	0
		Sternopriscus mulimaculatus	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
		Sternopriscus sp. (L)	I	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0
		Allodessus bistrigatus	C	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	2	0

Order	Family	Species	Cons	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072	SPS203
		Antiporus gilberti	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
		Rhantus sp (L)	C	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
		Platynectes sp (L)	C	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	1	0
		Tribe Bidessini (L)	I	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
		Onychohydrus sp (L)	I	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Hydrophilidae	*Berosus* sp. (L)	I	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
		Berosus munitipennis	C	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
		Berosus macumbensis	C	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
		Berosus nutans	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Berosus sp. (damaged)	I	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Helochares sp. (L)	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Helochares tenuistriatus	S	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Limnoxenus sp (L)	C	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	2	0
		Tribe Anacaenini spp	I	0	0	0	0	0	0	0	3	1	2	0	0	0	0	0	0	0	0	0	0	0
	Scirtidae	*Scirtidae spp (L)*	C	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Brentidae	Brentidae spp	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Limnichidae	Limnichidae spp	I	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEMIPTERA	**Corixidae**	*Micronecta robusta*	C	0	0	0	0	0	0	3	2	2	0	0	0	0	2	1	0	0	0	0	2	0
		Agraptocorixa eurynome	C	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0
	Notonectidae	*Anisops thienemanni*	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
		Anisops sp juveniles & females	C	0	0	0	0	0	0	2	1	1	0	0	0	0	2	3	0	0	0	0	1	0
	Mesoveliidae	*Mesovelia sp*	C	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Saldidae	Saldidae spp	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
		Number of taxa		**6**	**20**	**14**	**3**	**1**	**6**	**29**	**35**	**43**	**34**	**27**	**6**	**6**	**30**	**31**	**6**	**14**	**10**	**2**	**37**	**4**

Wetland biodiversity was assessed by ranking wetlands according to taxa richness for 'permanent', 'temporary' and total faunal composition, and then ordering sites on the mean of the ranks across taxonomic levels (Table 11, Figure 11). Similar patterns in wetland biodiversity were found between 2004 and 2005 (Figure 12). Fresher water sites (i.e. W011, W072, and W052) consistently recorded the highest taxa diversity rankings. Hypersaline sites, such as W007, W071 and W006, in contrast had the lowest rankings, reflecting low species diversity from these sites (Table 11, Figure 11).

Table 11. Rank scores for wetlands according to species diversity, based on 'permanent', 'temporary' and total fauna diversity, with wetlands in ascending order according to the mean of individual rank scores across taxonomic levels. The wetland with the highest species diversity was given a rank score of "21" and the lowest diversity a score of "1".

Site	Temporary Resident	Permanent Residents	Total Fauna	Mean Rank
W011	19	21	21	20.33
W072	18	20	20	19.33
W052	17	18	17	17.33
W010	20	12	19	17.00
W020	17	16	16	16.33
W015	21	8	18	15.67
W016	14	19	14	15.67
W009	15	16	15	15.33
W002	13	16	13	14.00
W004	10	18	12	13.33
W061	12	12	14	12.67
W070	8	16	10	11.33
W001	8	8	9	8.33
W019	9	6	9	8.00
W056	4	10	9	7.67
W008	4	10	9	7.67
W018	11	2	9	7.33
SPS203	8	5	4	5.67
W006	8	3	3	4.67
W071	1	5	2	2.67
W007	4	2	1	2.33

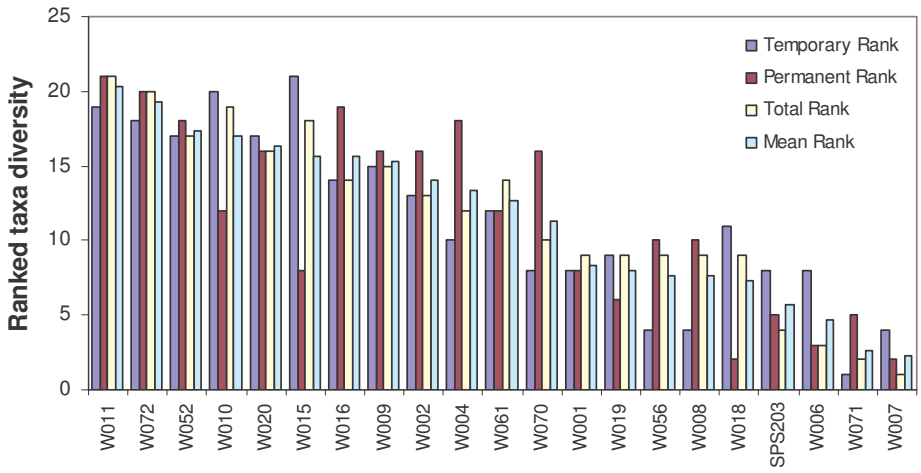

Figure 11: Rank scores for wetlands on species diversity, using 'permanent', 'temporary' and total invertebrate fauna, with wetlands in descending order of mean individual rank scores.

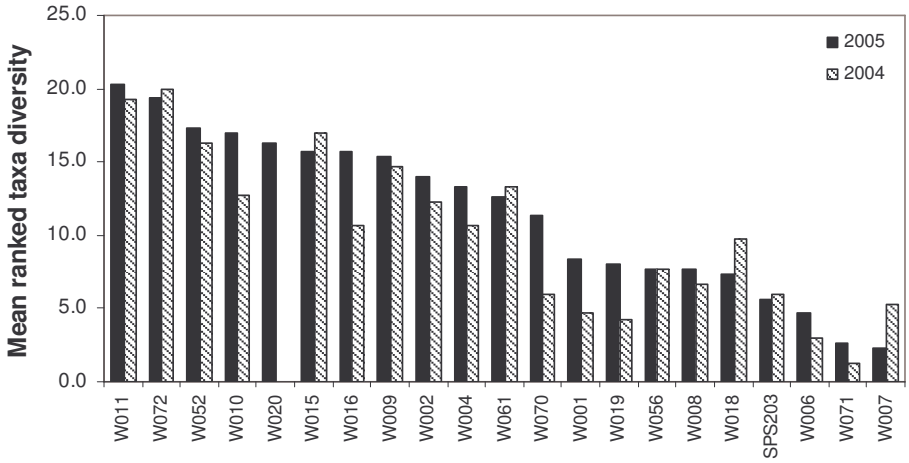

Figure 12. Mean ranked scores across all taxonomic groups from 2005 and 2004.

Conservation Significance of Invertebrate Fauna

The conservation status of fauna was based on levels of endemicity and rarity. Of the 135 taxa recorded during the current survey, 51% (68 taxa) were cosmopolitan in distribution, occurring across Australia and overseas, 43% (57 taxa) were indeterminate due to insufficient information, 4% (6 taxa) were considered as commonly occurring southwest endemics (*viz.* the conchostracan *Caenaseriella packardi*, the Anostracans *Parartemia contracta* and *P. ?longicaudata*, the Chironomids *Dicrotendipes conjunctus* and *Procladius villosimanus*, and the Hydrophilid Coleoptera *Helochares tenuistriatus*), 1% (2 taxa) were considered to be rarely occurring southwest endemics (*viz.* the Chironomids *Chironomus occidentalis* and *?Cladopelma sp.*), and 1% (2 taxa) were classed as exotics, having been accidentally introduced (the Anostracan *Artemia parthenogenetica* and the Gastropod *Physa acuta* (Table 10).

Only eight of the 21 sites sampled in August 2005 supported taxa considered endemic to the southwest of the state, and with most sites supporting only one of these taxa (Table 10 and Figure 13). Sites W010 and W011 had the greatest number of southwest common and southwest restricted endemic taxa. The hypersaline sites tended to support predominantly cosmopolitan and indeterminate species.

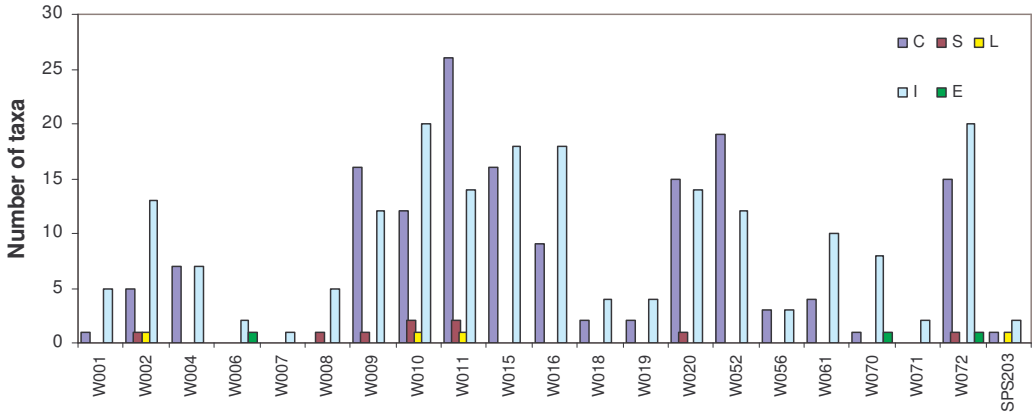

Figure 13. Conservation significance of fauna (C = cosmopolitan, S = south-west common endemic, L = south-west locally restricted endemic, I = indeterminate, and E = exotic).

Most taxa recorded are considered tolerant of a wide range of environmental conditions and are common, ubiquitous and frequently encountered in wetland systems within Western Australia. Of note, however, were a number of microcrustaceans. The rotifer, *Hexarthra propinqua*, collected from W002, was first recorded from Australia in this wetland during the November 2003 aquatic invertebrate surveys, although it has a sporadic distribution in Europe and central Asia. It was also recorded in 2004 from W001. An additional species of *Hexarthra* was also collected from W072 during the current study, and is a species new to science. It is morphologically distinct from *H. propinqua*, and has trophi dentition (8/9 unci teeth) asymmetry which does not match any known species worldwide (see Plate 24).

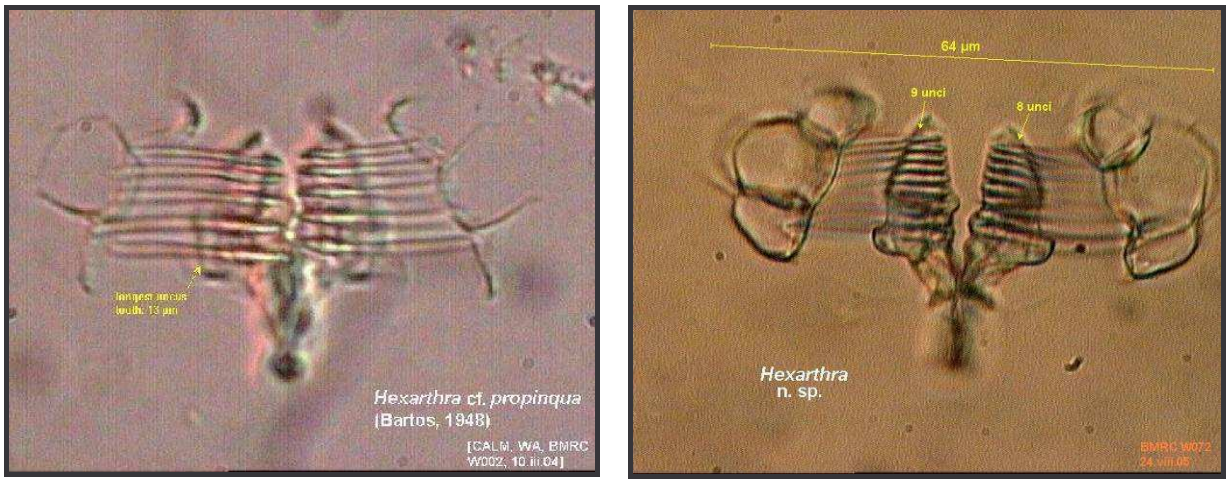

Plate 24. Comparative photos showing the different trophi dentition between *Hexarthra propinqua* and the new *Hexarthra* species collected from W072. Photos by Russ Shiel.

The presence of the rotifer *Proales daphnicola* from BMRC site W009 constitutes the first record of this species from Western Australia, having previously been known from NSW, Victoria and Tasmania. It is a cosmopolitan species with a known distribution including Europe, Africa, Asia and North America. *P. daphniocola* is an epizoite on *Daphnia* and other cladocerans, feeding primarily on algae and protists (occasionally small rotifers) on the carapace or from the surrounding plankton. Its identification has been confirmed by scanning electron microscopy (SEM) of its trophi by the world proalid specialist, Willem De Smet, in Antwerp (Plate 25).

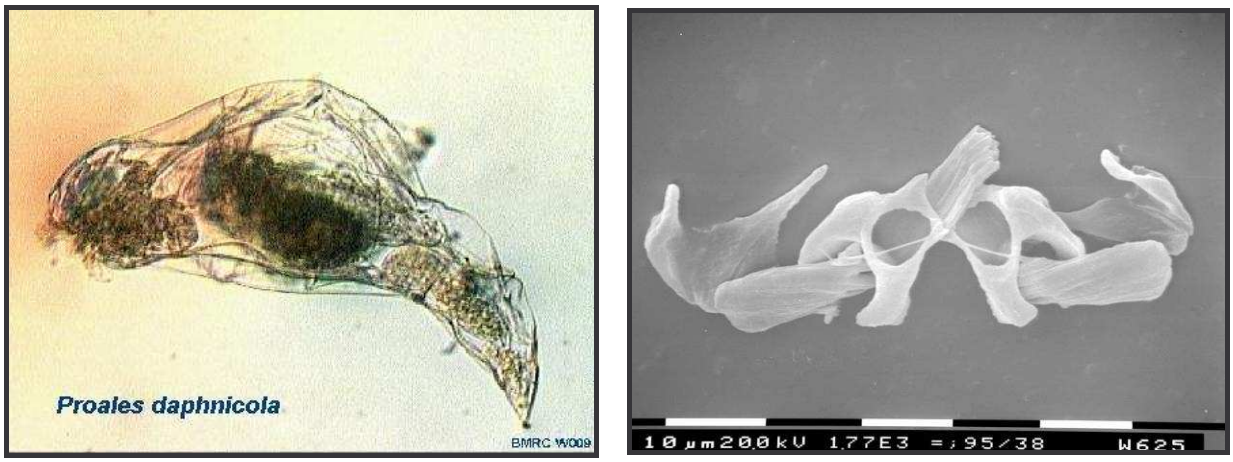

Plate 25. *Proales daphnicola*; whole animal (left, photo by Russ Shiel) and SEM photo of its trophy (right, photo by Willem De Smet).

The rotifer *Trichocerca obtusidens*, found from site W052 in 2004, was not collected this year. This specimen had previously not been formally recorded from Australia, despite three prior records from billabongs/fresh waters in NSW and VIC. This species probably has a pan-continental distribution, but appears relatively rare.

Also of note, were a number of Chironomid species. For example, ?Cladopelma sp. nov., appears to be a new species to science, and has been consistently recorded from wetlands within the BMRC. It was first recorded from W011 in November 2003, again from sites W011 and W052 in August 2004, and again from W011 and SPS203 in August 2005. An additional species collected during the current study from W072, Orthocladiinae sp. BM2, was not recognised as any of the previously recorded Orthocladiinae species.

Conchostracans, along with other Branchiopods, are important members of the temporary pool community, and are able to persist by remaining dormant during the dry season and typically avoid desiccation through drought-resistant stages (such as eggs). They have only passive means of dispersal (Bayly 1997). The conchostracan species listed as ?*Cyzicus* sp. from the 2004 surveys has now been accurately identified as *Caenaseriella packardi* (Brian Timms pers. comm.), and was again recorded from W072. This species is not a true granite outcrop specialist. *Limnadia* sp., also collected from the Gnamma site (W072), had not been previously recorded from the BMRC. However, this clam shrimp occurs throughout the southern half of the continent, and is common to granite outcrop pools throughout Western Australia (Bayly 1997).

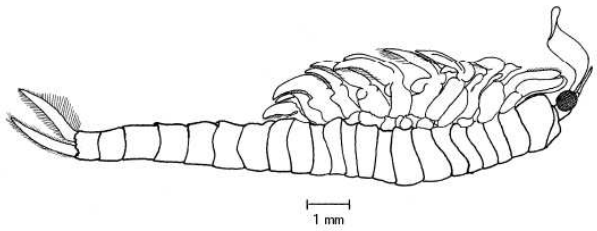

Figure 14. *Parartemia* spp.

Anostracans are among the most primitive of all living organisms, with fossils from this Order dating back to the Miocene epoch of the Caenozoic era, nearly 25 million years ago. A number of south-western endemic Anostracans have been found within the BMRC. *Parartemia contracta* was recorded in both 2004 and 2005. This species is common from acidic saline waters (Timms 2004), and as such was collected from W002, one of the most acidic wetlands within the BMRC. *P. serventyi*, on the other hand, prefers neutral to basic conditions (Timms 2004), and was recorded from sites with higher pH during 2004 surveys. It was not recorded during the current study. An additional species of *Parartemia* was found from site W008 this year. Although juvenile, this species was considered to be *P. ?longicaudata* (Brian Timms pers. comm.), a south-western taxon, common to the Wheatbelt. Biological preference by this species is for conditions similar to those reported from W008. That is, a preference for large, saline lakes, dominated by benthic mats (Timms 2004). Figure 14 shows the basic body shape of *Parartemia* species.

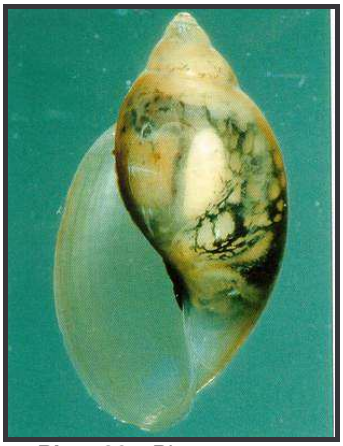

Plate 26. *Physa*

Finally, two introduced exotic species were recorded during the current study; the gastropod *Physa acuta* (Plate 26) and the brine shrimp *Artemia parthenogenetica.* The exotic aquatic snail was collected from the Gnamma outcrop (site W072) in both 2004 and 2005. Native to Europe, the Nearctic Region and the Neotropical region, *P. acuta* is thought to have been introduced by European settlers (Smith 1996). It is now found across the continent, and appears to be actively spreading (Smith 1996). It is a long-established occupant of wetlands and river systems within various parts of southwestern Australia. Although they lack an operculum, *Physa* are able to survive dry periods by sealing their shells with a mucus plug, known as an epiphragm.

The method of introduction of the brine shrimp, *Artemia parthenogenetica,* within Australia, is currently contentious, with some holding the view that they were intentionally introduced for aquaculture (e.g. Williams 1981). More recently, the view that *Artemia* spread by natural means from Asia has gained wide support (e.g. McMaster 2002 and Timms 2004). The spread of *Artemia* into natural waterways where they will likely co-occur with native anostracans is of concern. They seem particularly suited to conditions common to wetlands of the BMRC, showing a preference for hypersaline waters. *Artemia* are also able to persist in temporary wetlands by laying drought-resistant eggs which remain viable within sediments.

The yabby (Plate 27), *Cherax destructor* (Clark), a native to eastern Australia, was first introduced to Nareembeen in the Western Australian Wheatbelt District, approximately 280 km to the east of Perth, in 1932 (Morrissy and Cassels 1992). This species has proved to be a highly successful invasive species and has since spread throughout much of the southwest of the state. Its presence in natural aquatic systems is of concern owing to its highly aggressive nature and superior competitive ability (Lynas *et al* 2004, Lynas *et al.* submitted). This species is also tolerant of a wide range of environmental conditions, has the ability to exploit a wide variety of different aquatic habitats, including semi-permanent swamps, billabongs, irrigation channels, and deeper, permanent streams and rivers (Austin 1985), and produces a large number of offspring. Yabbies are known from the BMRC and were recorded from W052 in 2004. Although not collected during the current study, they are likely to still be present in the system. Yabbies are burrowing crayfish adapted to long-term population survival in the fluctuating environments of impermanent wetlands.

Plate 27. The yabby, *Cherax destructor* (Photo by Jess Lynas 2002).

Multivariate Analysis of Permanent Fauna

Abundance data

Of the 21 sites sampled in August 2004, two contained no permanent fauna (W007 & W018), leaving 19 sites to be analysed. Cluster analysis separated sites into seven main groups (Figure 15). There were some outliers within these major groupings, however, including W002 (hypersaline & acidic) from fresh-brackish/basic-neutral sites within Group One, and W011 (brackish) from higher salinity wetlands of Group Two. Generally, hypersaline sites tended to separate from the fresher water sites based on abundance of their permanent fauna communities (Figures 15 & 16). When superimposed on the MDS, only some groups showed good separation in ordination space (Figure 16).

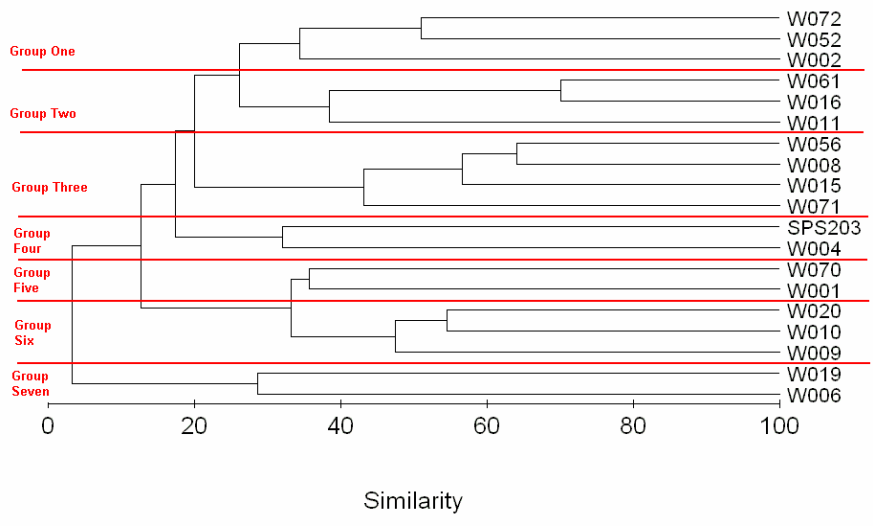

Figure 15. Cluster dendrogram using permanent fauna log_{10} abundance data, indicating the seven main groupings.

Pairwise comparisons of groups using ANOSIM detected significant separation between only three combinations of groups; Groups One and Three, Groups Two and Three, and Groups Three and Six (Table 12).

Table 12. ANOSIM results showing pairwise comparisons of groups based on abundance of temporary fauna. * = significantly different, ns = not significantly different.

	1	2	3	4	5	6	7
1							
2	ns						
3	*	*					
4	ns	ns	ns				
5	ns	ns	ns	ns			
6	ns	ns	*	ns	ns		
7	ns	ns	ns	ns	ns	ns	

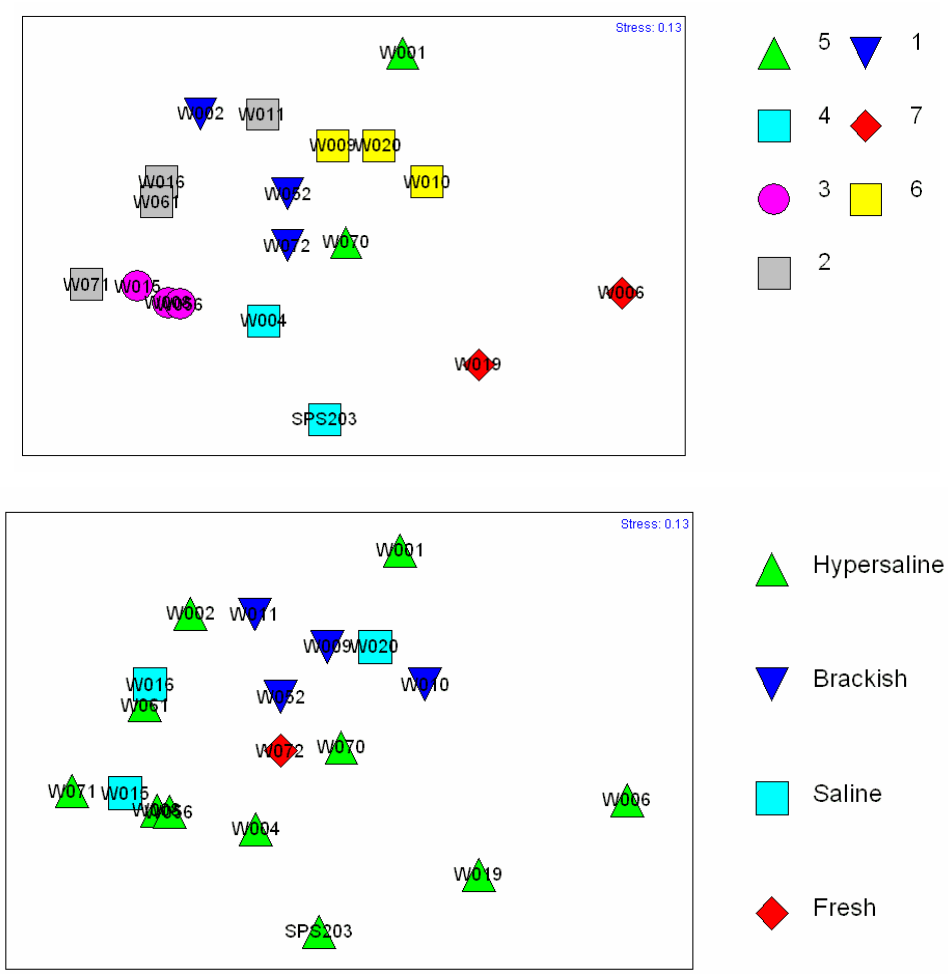

Figure 16: MDS ordination of the 19 wetlands using permanent fauna $\log_{10}$ abundance data, with sites labelled by site codes, and coloured by *a posteriori* groupings from cluster analysis (top), and salinity type (bottom). Stress was 0.13.

The abundance of a number of permanent taxa influenced the separation of sites (Figure 17). For example, the cyclopoid Copepod, *Apocyclops dengizicus*, was only recorded from sites within Group Two; cyclopoid copepodites were found in greater abundance from wetlands of Groups One, Two, Three and Four; and, the highest abundances of the Calanoid Copepod *Boeckella triarticulata* was recorded from Groups One and Six.

Between-site pairwise similarity was generally low, with a number of sites showing 0% similarity (Table 13). This is perhaps a reflection of the high number of singletons within the permanent fauna communities. That is, 46% of permanent taxa were recorded from only one site within the BMRC. The highest pairwise similarity was 70%, and was calculated between sites W016 and W061 (Table 13).

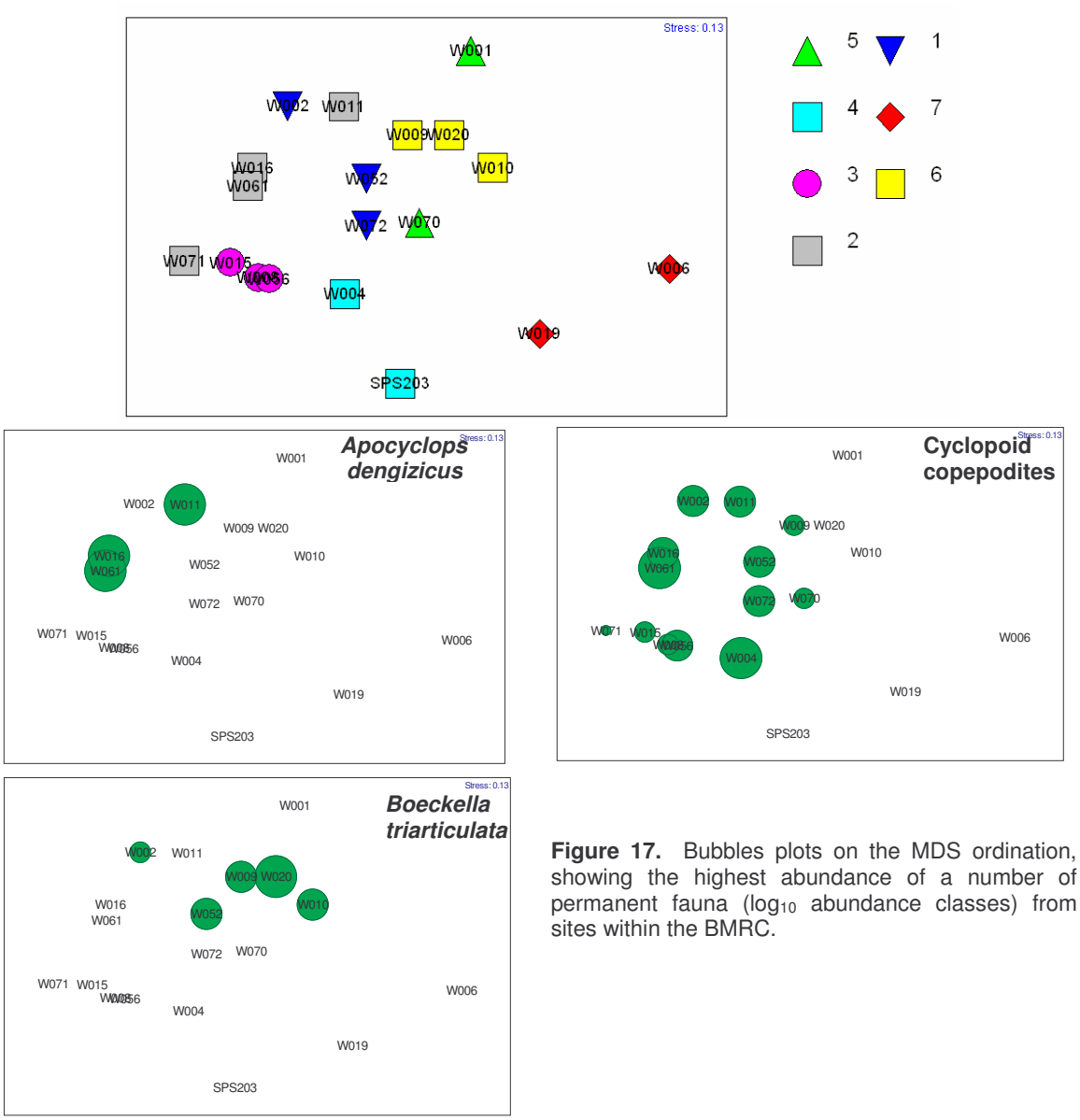

Figure 17. Bubbles plots on the MDS ordination, showing the highest abundance of a number of permanent fauna (log_{10} abundance classes) from sites within the BMRC.

Presence/absence data

Classification of permanent fauna on presence/absence data separated the 19 sites into seven main groups (Figure 18). Once again there were outliers to these major groupings, with W001 (acidic & hypersaline) separating from the fresher water wetlands within Group Five, and the hypersaline W002 being an outlier from fresh/brackish sites of Group Six. Generally, hypersaline sites grouped together. Cluster analysis groupings showed some separation in ordination space (Figure 19). In general, the ordination of permanent fauna on presence/absence data demonstrated very similar patterns to abundance data, with comparable group membership and comparable position of samples in ordination space.

ANOSIM detected significant separation between groups (Global R = 0.878, significance of sample statistic = 0.1%). However, pairwise comparisons showed that not all groups were significantly separate from each other, with differences detected between groups 2, 5 and 6 (Table 14).

Table 13. Matrix of association values with each value indicating percent pairwise similarity amongst each wetland, calculated using the Bray-Curtis association measure on permanent fauna log_{10} abundance data

	W001	W002	W004	W006	W008	W009	W010	W011	W015	W016	W019	W020	W052	W056	W061	W070	W071	W072
W002	17.65																	
W004	0.00	23.26																
W006	0.00	0.00	0.00															
W008	0.00	18.75	32.26	0.00														
W009	36.36	18.60	9.52	0.00	12.90													
W010	33.33	11.76	12.12	0.00	0.00	42.42												
W011	22.22	25.00	22.22	0.00	11.54	31.75	14.81											
W015	0.00	25.81	13.33	0.00	63.16	13.33	0.00	7.84										
W016	0.00	26.09	26.67	0.00	35.29	17.78	0.00	42.42	30.30									
W019	0.00	0.00	16.67	28.57	0.00	0.00	13.33	0.00	0.00	0.00								
W020	36.36	18.60	9.52	0.00	0.00	52.38	54.55	41.27	0.00	17.78	8.33							
W052	12.12	41.86	28.57	0.00	19.35	38.10	36.36	34.92	13.33	22.22	8.33	38.10						
W056	0.00	16.22	44.44	0.00	64.00	11.11	0.00	10.53	50.00	41.03	0.00	0.00	16.67					
W061	0.00	31.58	37.84	0.00	38.46	10.81	0.00	34.48	32.00	70.00	0.00	5.41	27.03	45.16				
W070	35.71	10.53	10.81	20.00	30.77	37.84	28.57	31.03	32.00	20.00	10.53	27.03	21.62	25.81	25.00			
W071	0.00	8.00	8.33	0.00	46.15	8.33	0.00	4.44	50.00	22.22	0.00	0.00	8.33	33.33	31.58	31.58		
W072	4.76	26.92	35.29	0.00	15.00	19.61	14.29	27.78	10.26	18.52	6.06	19.61	50.98	13.33	21.74	13.04	6.06	
SPS203	0.00	0.00	32.00	0.00	28.57	0.00	12.50	0.00	0.00	0.00	28.57	8.00	8.00	31.58	0.00	0.00	0.00	5.88

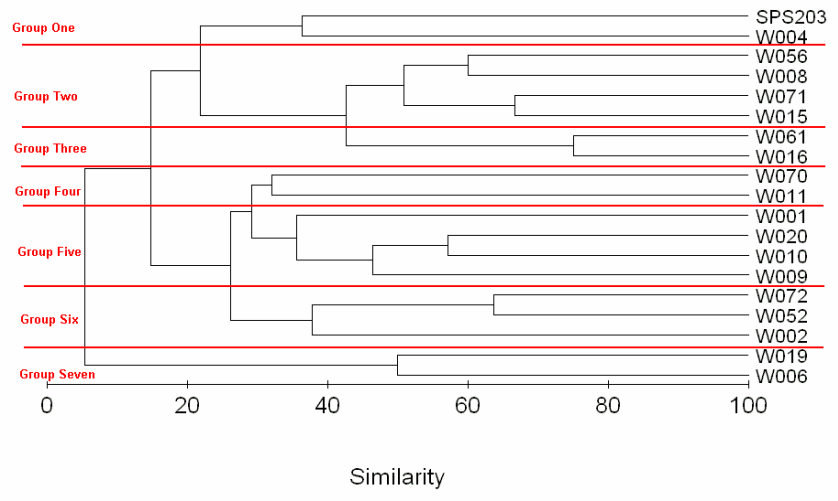

Figure 18. Cluster dendrogram using permanent fauna presence/absence data, indicating the seven main groupings.

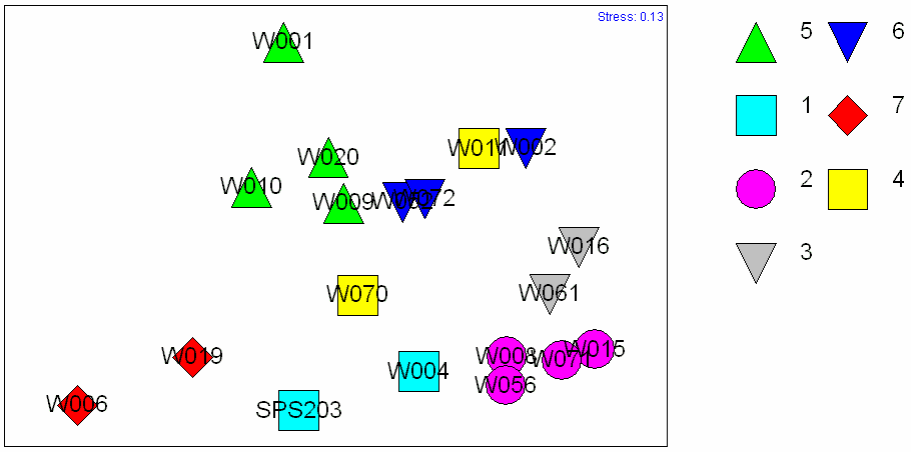

Figure 19. MDS ordination using permanent fauna presence/absence data, with sites labelled by site codes, and coloured by *a posteriori* groupings from cluster analysis. Stress was 0.13.

Table 14. ANOSIM results showing pairwise comparisons of groups based on presence/absence of permanent fauna. * = significantly different, ns = not significantly different.

	1	2	3	4	5	6	7
1							
2	ns						
3	ns	ns					
4	ns	ns	ns				
5	ns	*	ns	ns			
6	ns	*	ns	ns	*		
7	ns	ns	ns	ns	ns	ns	

As for the abundance data for permanent fauna, between-site pairwise similarity using presence/absence was generally low, with a number of sites showing 0% similarity (Table 15). The highest similarity was again between sites W061 and W016 (75% similarity).

Table 15. Matrix of association values indicating percent pairwise similarity amongst each wetland, calculated using the Bray-Curtis association measure on permanent fauna presence/absence data.

	W001	W002	W004	W006	W008	W009	W010	W011	W015	W016	W019	W020	W052	W056	W061	W070	W071	W072
W002	16.67																	
W004	0.00	23.53																
W006	0.00	0.00	0.00															
W008	0.00	30.77	42.86	0.00														
W009	33.33	25.00	11.76	0.00	15.38													
W010	40.00	14.29	13.33	0.00	0.00	42.86												
W011	19.05	24.00	23.08	0.00	18.18	32.00	17.39											
W015	0.00	33.33	15.38	0.00	44.44	16.67	0.00	9.52										
W016	0.00	22.22	31.58	0.00	40.00	22.22	0.00	44.44	28.57									
W019	0.00	0.00	33.33	50.00	0.00	0.00	22.22	0.00	0.00	0.00								
W020	33.33	25.00	11.76	0.00	0.00	50.00	57.14	40.00	0.00	22.22	18.18							
W052	15.38	47.06	33.33	0.00	28.57	47.06	40.00	38.46	15.38	21.05	16.67	47.06						
W056	0.00	15.38	57.14	0.00	60.00	15.38	0.00	9.09	44.44	40.00	0.00	0.00	14.29					
W061	0.00	28.57	40.00	0.00	54.55	14.29	0.00	34.78	40.00	75.00	0.00	14.29	26.67	54.55				
W070	33.33	12.50	11.76	22.22	30.77	37.50	28.57	32.00	33.33	22.22	18.18	25.00	23.53	30.77	28.57			
W071	0.00	20.00	18.18	0.00	57.14	20.00	0.00	10.53	66.67	33.33	0.00	0.00	18.18	57.14	50.00	40.00		
W072	11.76	28.57	36.36	0.00	22.22	28.57	21.05	33.33	11.76	17.39	12.50	28.57	63.64	11.11	21.05	19.05	13.33	
SPS203	0.00	0.00	36.36	0.00	28.57	0.00	25.00	0.00	0.00	0.00	40.00	20.00	18.18	28.57	0.00	0.00	0.00	13.33

Multivariate Analysis of Temporary Fauna

Abundance data

Site W071 contained no temporary fauna and was therefore omitted from multivariate analysis. Classification of 20 wetlands within the BMRC separated sites into five major groups based on their abundances of temporary fauna (Figure 20). In a similar way to other analyses, the fresher water sites separated from saline and hypersaline sites (Group Three).

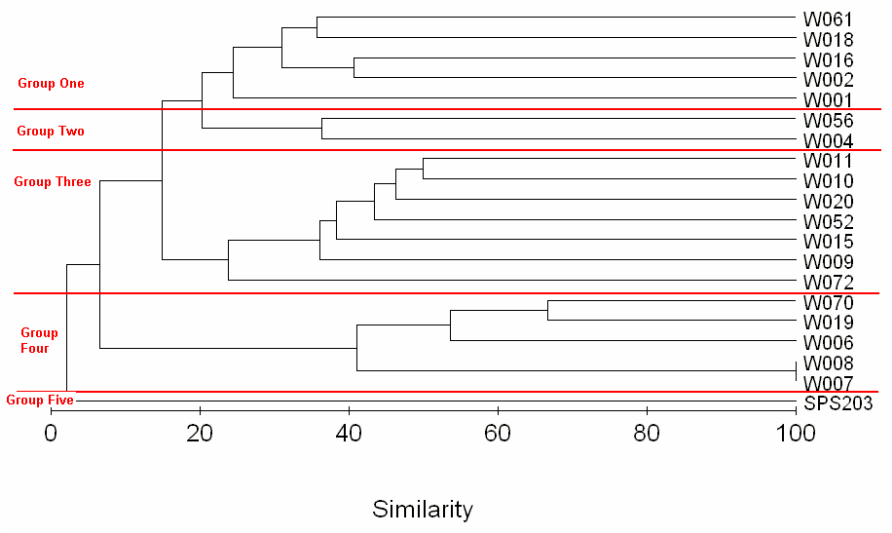

Figure 20. Cluster dendogram using temporary fauna abundance data, indicating the five main groups.

Groups were significantly separate in ordination space (Figure 21; ANOSIM, (Global R = 0.907, significance level of sample statistic = 0.1%). Pairwise comparisons found significant separation between all groups, with the exception of Group Five reflecting the small group size (Group 5 contained one site only) (Table 16).

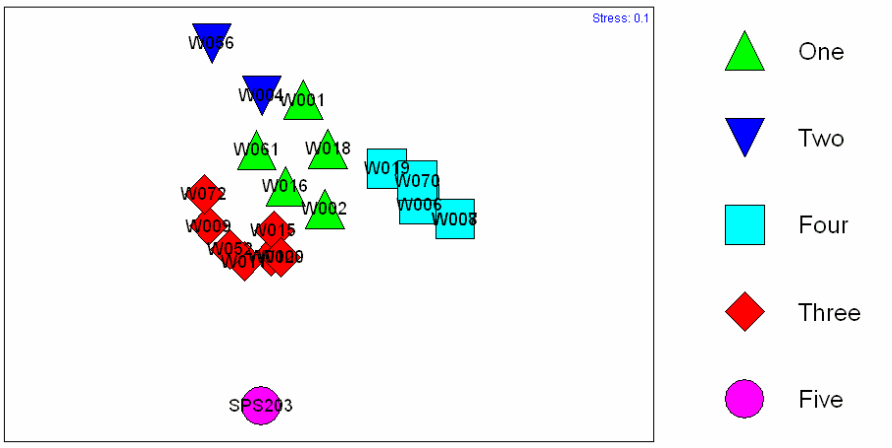

Figure 21. MDS ordination using temporary fauna $\log_{10}$ abundance data, with sites labelled by site codes, and coloured by *a posteriori* groupings from cluster analysis. Stress was 0.1.

Table 16. ANOSIM results showing pairwise comparisons of groups based on abundance of temporary fauna. * = significantly different, ns = not significantly different.

	1	2	3	4	5
1					
2	*				
3	*	*			
4	*	*	*		
5	ns	ns	ns	ns	ns

The classification of sites into groups was influenced both physico-chemistry and vegetation characteristics of wetlands (Figure 22). Salinity exerted considerable influence on the ordination, with all fresher water sites (Group Three) comprising a significantly different temporary faunal community to the hypersaline wetlands (Figure 22). SPS203, which displayed the least similar invertebrate structure to all other wetlands, recorded the highest dissolved oxygen levels in 2005 (Figure 22). In addition, vegetation cover was highest in sites within Group Three (the fresher wetlands).

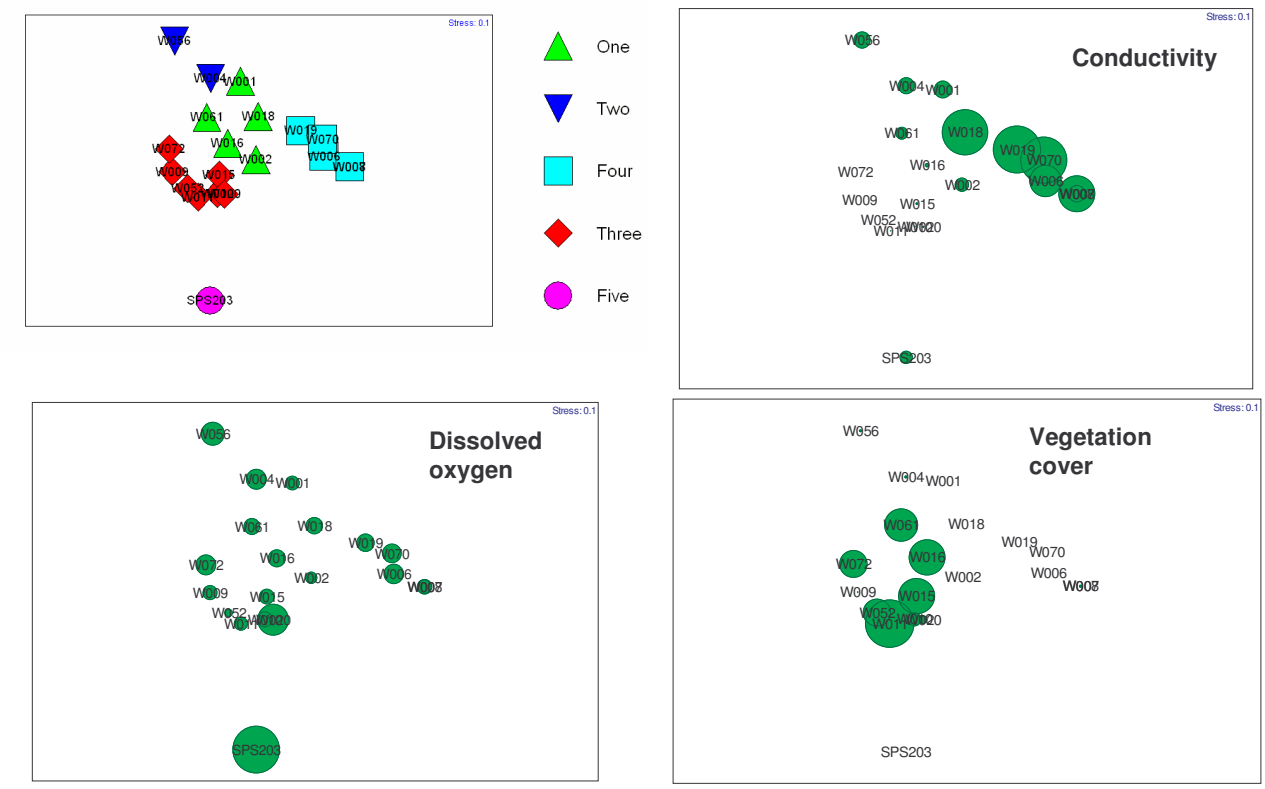

Figure 22. Bubble plots, showing the influence of physico-chemistry and wetland characteristics on the temporary fauna ordination using abundance data.

Greater between-site pairwise similarity was recorded within the temporary fauna, when compared with permanent resident taxa, using $\log_{10}$ abundance data (Tables 13 and 17). Sites W007 and W008 were 100% similar, with the only temporary fauna recorded being muscids.

Table 17. Matrix of association values with each value indicating percent pairwise similarity amongst each wetland, calculated using the Bray-Curtis association measure on temporary fauna log_{10} abundance data.

	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072
W002	24.00																			
W004	33.33	12.90																		
W006	0.00	16.00	0.00																	
W007	0.00	8.70	0.00	50.00																
W008	0.00	8.70	0.00	50.00	100.00															
W009	12.77	15.15	15.09	0.00	0.00	0.00														
W010	7.89	23.16	14.63	5.26	2.70	2.70	32.48													
W011	6.90	18.18	12.50	0.00	0.00	0.00	34.34	50.00												
W015	9.84	27.50	11.94	6.56	3.39	3.39	27.45	45.80	37.17											
W016	15.00	40.68	26.09	10.00	5.26	5.26	22.22	32.73	15.22	33.68										
W018	23.53	38.89	34.78	23.53	13.33	13.33	10.34	13.79	11.59	22.22	27.45									
W019	25.00	29.63	14.29	50.00	33.33	33.33	4.08	10.26	3.33	12.70	19.05	52.63								
W020	13.33	21.88	7.84	8.89	4.65	4.65	44.19	45.22	47.42	34.00	20.25	17.86	12.77							
W052	12.00	17.39	7.14	0.00	0.00	0.00	41.76	38.33	47.06	36.19	16.67	9.84	3.85	44.94						
W056	0.00	0.00	36.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.26	25.00	0.00	0.00	0.00					
W061	35.29	22.22	34.78	0.00	0.00	0.00	17.24	25.29	23.19	30.56	35.29	35.71	10.53	25.00	29.51	25.00				
W070	0.00	23.08	0.00	57.14	40.00	40.00	0.00	7.79	0.00	9.68	14.63	44.44	66.67	8.70	0.00	0.00	0.00			
W071	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
W072	13.04	18.46	7.69	4.35	0.00	0.00	34.48	18.97	20.41	25.74	17.50	21.05	4.17	23.53	20.00	0.00	17.54	0.00	0.00	
SPS203	0.00	8.33	0.00	0.00	0.00	0.00	4.35	2.67	7.02	3.33	5.13	0.00	0.00	4.55	4.08	0.00	0.00	0.00	0.00	0.00

Presence/absence data

Classification of the temporary fauna on presence/absence data, found an extra group, separating the 20 sites into six main groups (Figure 23). BMRC sites W061 and W001 separated into a further group based on presence/absence data. Sites were once again separated primarily on the basis of salinity, with the fresher water sites forming a distinct group.

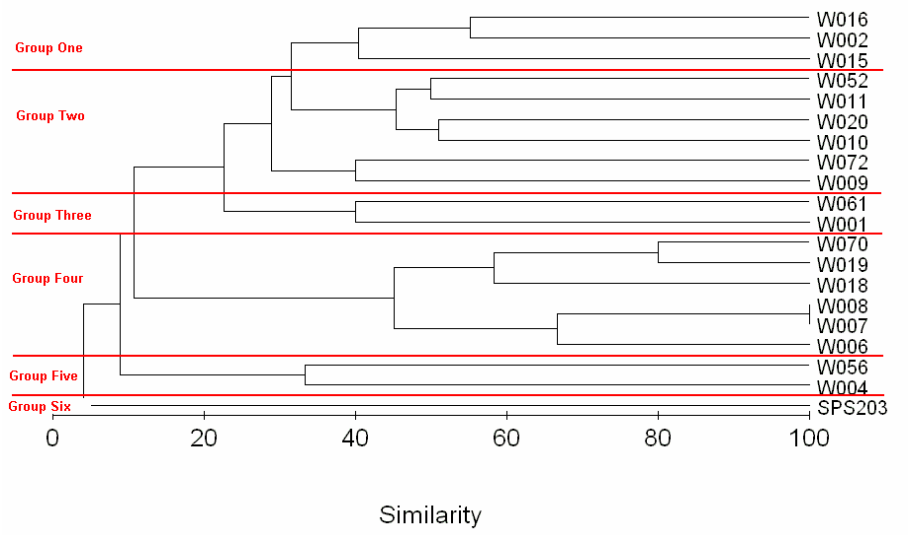

Figure 23. Cluster dendrogram of the 20 sites using temporary presence/absence data, indicating the six main groupings.

Groups were significantly separate in ordination space (Figure 24; ANOSIM, Global R = 0.893, significance level of sample statistic: 0.1%). Sites within Group Two (the fresher wetlands) were significantly separate from all other groups, with the exception of Group Six. Once again, SPS203 (Group Six) was not significantly separate from other groups based on the presence/absence of temporary taxa (Table 18).

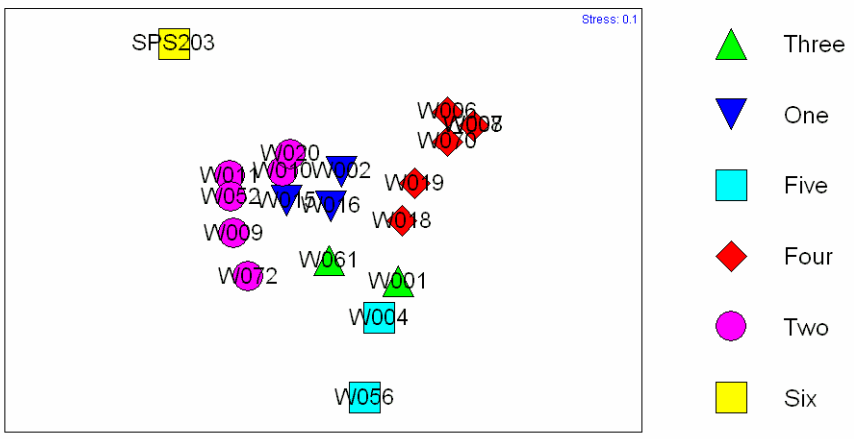

Figure 24. MDS ordination using temporary fauna presence/absence data, with sites labelled by site codes, and coloured by *a posteriori* groupings from cluster analysis. Stress was 0.1.

The MDS ordination and separation of sites into distinct groups was influenced by the presence/absence of certain temporary taxa (Figure 25). Of particular interest, is the presence of a number of species within fresher water sites (Group Two), which were absent from hypersaline wetlands. These include, the anisopteran *Orthetrum caledonicum* (dragonfly), the chironomid *Tanytarsus fuscithorax*, the corixid *Micronecta robusta*, and the trichopteran *Notalina spira* (Figure 25). Odonates (dragonflies and damselflies), such as *O.caledonicum* are generally indicator species and are sensitive to salt and pollution. They are most common amongst trailing riparian vegetation and macrophytes. Therefore, their absence from hypersaline wetlands which are primarily characterised by high sediment cover and low vegetative cover is not surprising. The chironomid *T. fuscithorax* is a freshwater species and has been used as an indicator for salt. Furthermore, Anderson & Weir (2004) suggest the distribution and abundance of *Micronecta* species can be used to monitor water quality within lentic systems. *Micronecta* are common from well vegetated, still and shallow freshwater wetlands within Australia. Trichoptera, such as *N. spira*, generally are found in a variety of aquatic habitats, but are highly sensitive to pollution and intolerant of high salinity.

In contrast, a number of Diptera larvae were dominant within wetlands of Groups Three, Four and Five (hypersaline sites), including the chironomid *Tanytarsus barbitarsus*, and muscid larvae (Figure 25). Diptera are considered relatively tolerant of pollution and salinity, and *T. barbitarsus* in particular is salt tolerant.

Table 18. ANOSIM results showing pairwise comparisons of groups based on presence/absence of temporary fauna. * = significantly different, ns = not significantly different.

	1	2	3	4	5	6
1						
2	*					
3	ns	*				
4	*	*	*			
5	ns	*	ns	*		
6	ns	ns	ns	ns	ns	

Between-site pairwise similarity was generally greater using presence/absence than abundance data for temporary fauna (Table 19).

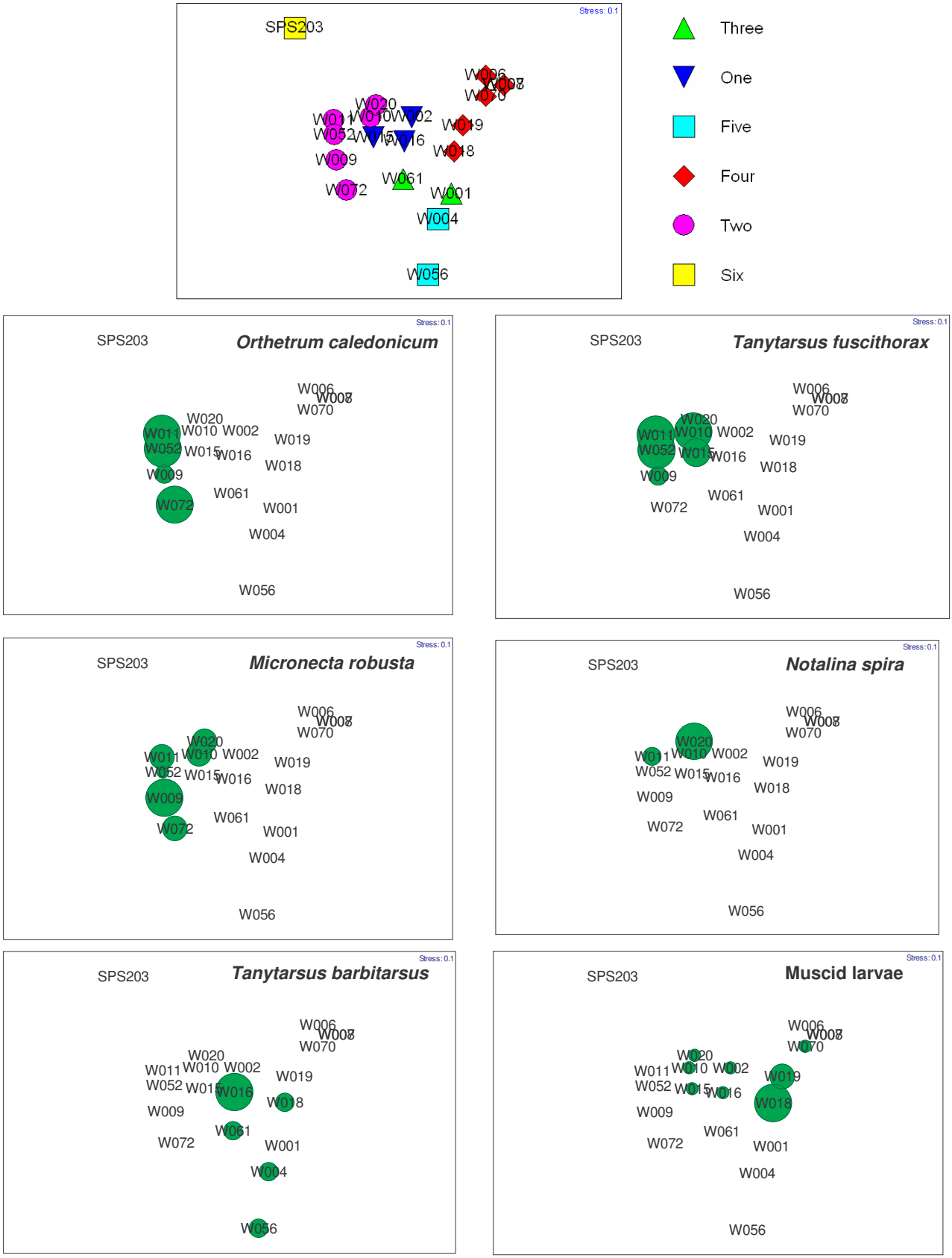

Figure 25. Bubble plots showing the influence of the presence/absence of certain temporary taxa on the site groupings, including *Orthetrum caledonicum*, *Tanytarsus fuscithorax*, *Micronecta robusta*, *Notalina spira*, *Tanytarsus barbitarsus* and muscid larvae.

Table 19. Matrix of association values indicating percent pairwise similarity amongst each wetland, calculated using the Bray-Curtis association measure on temporary fauna presence/absence data.

	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W072
W002	28.57																		
W004	28.57	11.76																	
W006	0.00	14.29	0.00																
W007	0.00	15.38	0.00	66.67															
W008	0.00	15.38	0.00	66.67	100.00														
W009	17.39	18.18	15.38	0.00	0.00	0.00													
W010	12.90	29.27	17.65	6.45	6.67	6.67	40.00												
W011	7.14	21.05	12.90	0.00	0.00	0.00	38.30	47.27											
W015	12.50	38.10	11.43	6.25	6.45	6.45	31.37	47.46	35.71										
W016	21.05	55.17	27.27	10.53	11.11	11.11	31.58	43.48	18.60	42.55									
W018	25.00	44.44	36.36	25.00	28.57	28.57	7.41	17.14	12.50	22.22	34.78								
W019	40.00	40.00	25.00	40.00	50.00	50.00	8.33	18.75	6.90	18.18	30.00	66.67							
W020	16.67	29.41	7.41	16.67	8.70	8.70	37.21	50.98	50.00	38.46	30.77	21.43	24.00						
W052	16.67	23.53	7.41	0.00	0.00	0.00	41.86	43.14	50.00	34.62	25.64	7.14	8.00	40.91					
W056	0.00	0.00	33.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.11	28.57	0.00	0.00	0.00				
W061	40.00	30.00	30.77	0.00	0.00	0.00	20.69	32.43	23.53	31.58	48.00	28.57	18.18	20.00	33.33	22.22			
W070	0.00	28.57	0.00	50.00	66.67	66.67	0.00	12.90	0.00	12.50	21.05	50.00	80.00	16.67	0.00	0.00	0.00		
W072	15.38	16.67	6.90	7.69	0.00	0.00	40.00	22.64	24.00	29.63	24.39	20.00	7.41	26.09	21.74	0.00	18.75	0.00	
SPS203	0.00	14.29	0.00	0.00	0.00	0.00	8.70	6.45	14.29	6.25	10.53	0.00	0.00	8.33	8.33	0.00	0.00	0.00	0.00

Multivariate Analysis of Total Invertebrate Fauna

Abundance data

Classification of the total fauna on abundance data separated the 21 sites into four main groups, with the fresher water sites (fresh-brackish) separating from the saline and hypersaline sites (Figure 26). MDS based on these four main cluster groups showed clear separation in ordination space (Figure 27). The influence of salinity on the invertebrate communities within BMRC wetlands can be seen in Figure 27. However, salinity is not the only factor contributing to differences in taxa between sites since ANOSIM of cluster groups was significant (Global R = 0.738, significance level of sample statistic = 0.1%, Table 20), but ANOSIM of salinity type was not (Global R – 0.0773, significance level of sample statistic = 24%). All cluster groups were significantly separate from each other (Table 20).

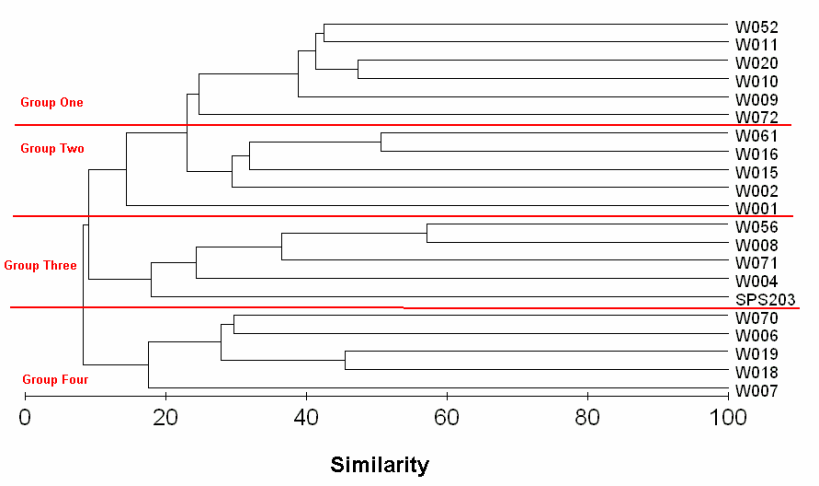

Figure 26. Cluster dendogram of the 21 sites on $\log_{10}$ abundance of total fauna, indicating the four main groups.

Within the major groupings, there were four outliers. The only fresh site sampled from the BMRC, W072, showed some separation from other fresher water sites within Group One. The highly acidic gypsum wetland, W001, was an outlier from Group Two. SPS203, which separated from all other sites based on physico-chemistry, also showed some separation from its total invertebrate abundance group (Group Three). Finally, W007, the highly turbid wetland, was an outlier from Group Four. Figure 28 provides a graphical representation of the influence of these physico-chemical parameters on invertebrate structure (total abundance).

In addition, vegetation and wetland characteristics influenced the invertebrate fauna communities within the BMRC. The abundance of reeds/rushes were greatest within sites from Group One (fresher water sites), percent bacterial benthic mat cover was highest within hypersaline sites (Groups Three and Four), and vegetation cover was dominant within Group One (Figure 28).

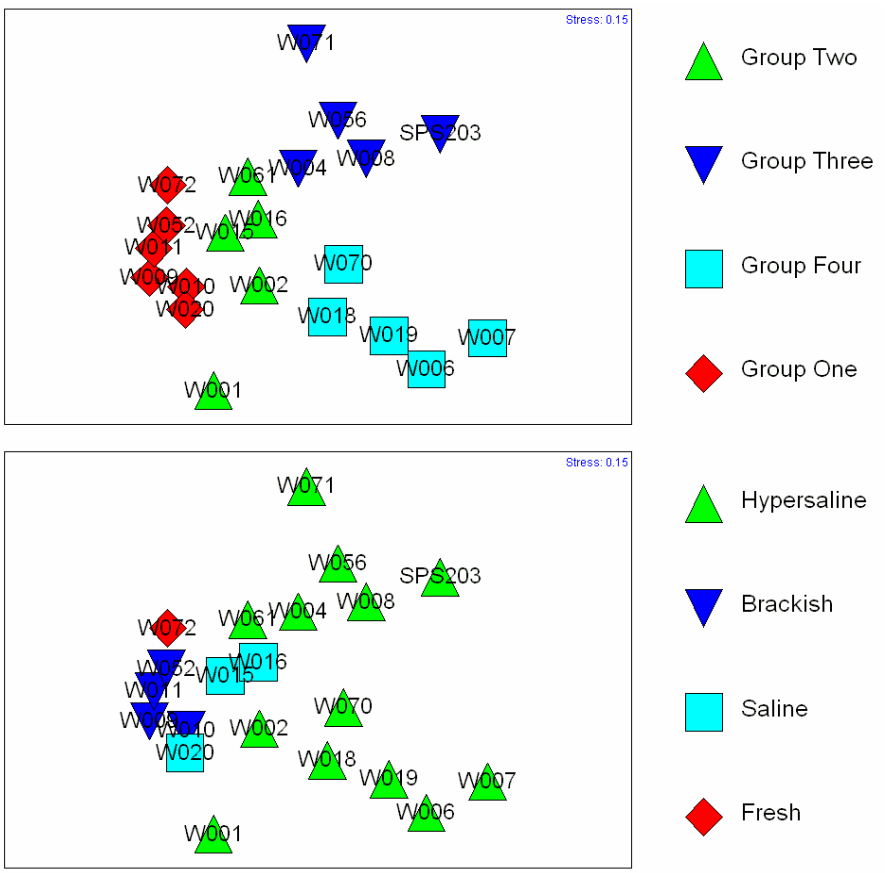

Figure 27. MDS ordination of the 21 wetlands using total fauna log(10) abundance data, with sites labelled by site codes, and coloured by *a posteriori* groupings from cluster analysis (top), and by salinity (bottom). Stress was 0.15.

Table 20. ANOSIM results showing pairwise comparisons of groups based on abundance of total fauna. * = significantly different, ns = not significantly different.

	1	2	3	4
1				
2	*			
3	*	*		
4	*	*	*	

Between-site pairwise similarity values were tabulated to illustrate levels of site similarity, and indicate pairs of sites with a high similarity as opposed to those with a high dissimilarity (Table 21). Variation in abundance of invertebrate fauna between sites was generally high, with 34 pairwise combinations having 100% dissimilarity (i.e. 0% similarity or no shared taxa). This suggests that the invertebrate structure within a high number of wetlands is distinctly different from others within the BMRC. The highest similarity was between sites W008 and W056 (57.14%).

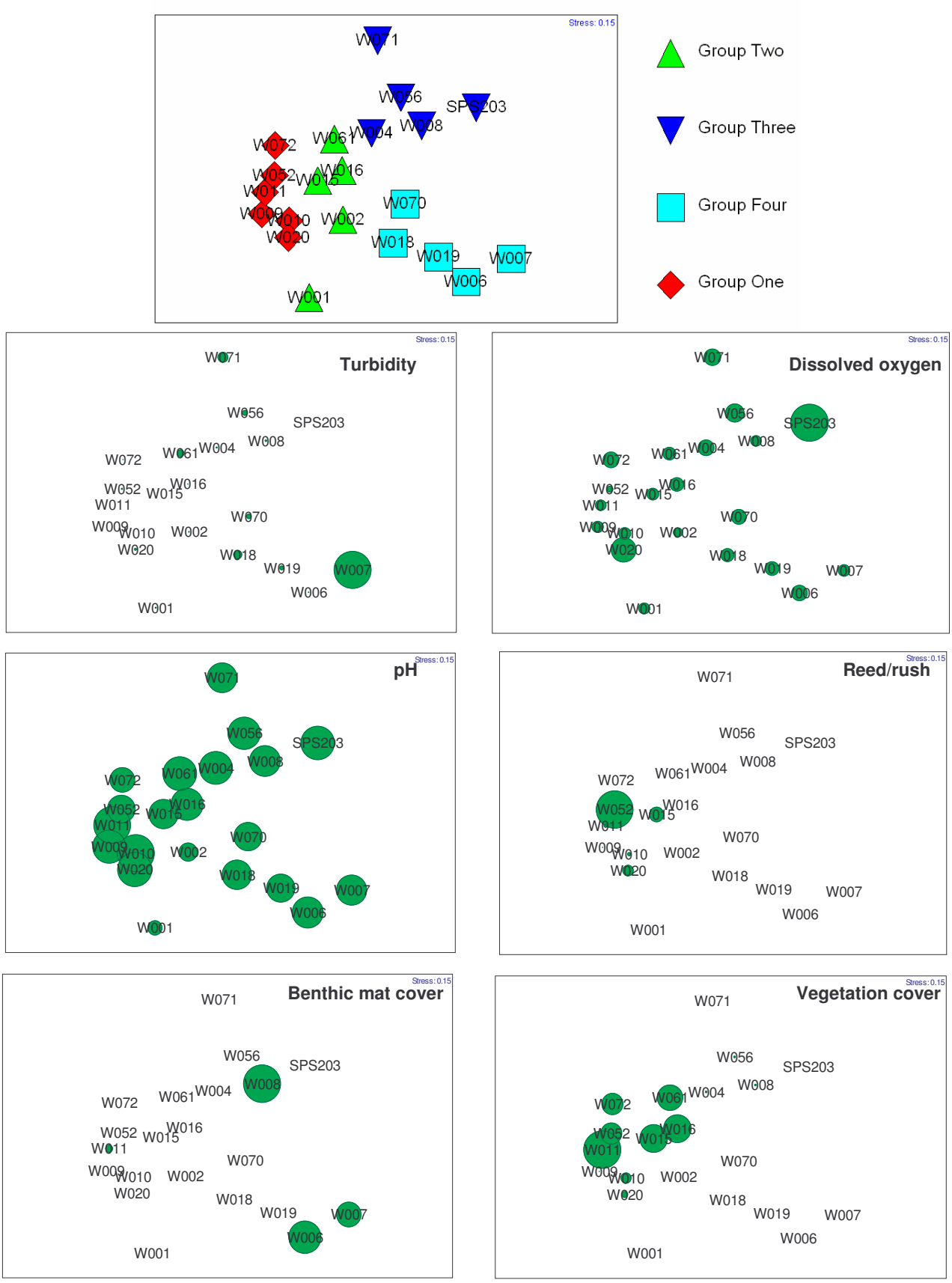

Figure 28. Bubble plots of some physico-chemical, wetland and vegetation characteristics on the total invertebrate $\log_{10}$ abundance ordination.

Table 21. Matrix of association values with each value indicating percent pairwise similarity amongst each wetland, calculated using the Bray-Curtis association measure on total fauna $\log_{(10)}$ abundance data.

	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072
W002	20.34																			
W004	8.89	18.92																		
W006	0.00	7.84	0.00																	
W007	0.00	4.44	0.00	25.00																
W008	0.00	14.55	24.39	11.11	16.67															
W009	22.50	16.51	12.63	0.00	0.00	5.26														
W010	14.00	20.16	13.91	4.35	2.33	2.08	34.67													
W011	14.29	21.28	17.32	0.00	0.00	5.56	33.33	39.56												
W015	7.32	27.03	12.37	5.41	2.94	17.95	24.24	39.47	28.05											
W016	7.89	34.29	26.37	5.88	3.23	19.44	20.63	24.66	26.58	32.81										
W018	13.79	24.14	18.18	19.05	13.33	8.00	7.59	12.12	7.21	19.75	18.67									
W019	8.70	15.38	15.79	40.00	22.22	10.53	2.74	10.75	1.90	10.67	11.59	45.45								
W020	23.08	20.56	8.60	5.71	3.13	2.70	46.88	47.30	45.00	26.15	19.35	12.99	11.27							
W052	12.05	26.79	16.33	0.00	0.00	7.59	40.60	37.91	42.42	31.11	18.60	7.32	5.26	42.75						
W056	0.00	9.84	42.55	0.00	0.00	57.14	4.88	0.00	5.26	14.29	25.64	12.90	0.00	0.00	7.06					
W061	13.33	27.03	36.67	0.00	0.00	24.39	14.74	19.13	28.35	30.93	50.55	22.73	5.26	17.20	28.57	38.30				
W070	28.57	15.63	8.00	29.63	9.52	32.26	16.47	13.33	15.38	16.09	17.28	23.53	28.57	16.87	9.09	21.62	16.00			
W071	0.00	4.26	6.06	0.00	0.00	42.86	2.94	0.00	2.00	8.57	9.38	0.00	0.00	0.00	2.82	30.00	18.18	26.09		
W072	9.09	22.22	21.36	2.50	0.00	7.14	28.99	17.72	23.53	21.43	17.91	13.79	4.94	22.06	31.21	6.67	19.42	6.45	2.63	
SPS203	0.00	4.00	22.22	0.00	0.00	23.53	2.82	4.40	3.88	2.74	2.99	0.00	14.29	5.80	5.41	26.09	0.00	0.00	0.00	2.53

Presence/absence data

Similar groupings in total invertebrate fauna were found using presence absence data to the abundance data, and were of lower salinity sites from saline/hypersaline wetlands. Cluster analysis separated the 21 sites into four main groupings, the occupants of which were the same as those determined using abundance data (see Figures 27 & 29). However, in this case there were only three outliers to the main groups; SPS203 from Group One, W072 from Group Three, and W001 from Group Four (Figure 29).

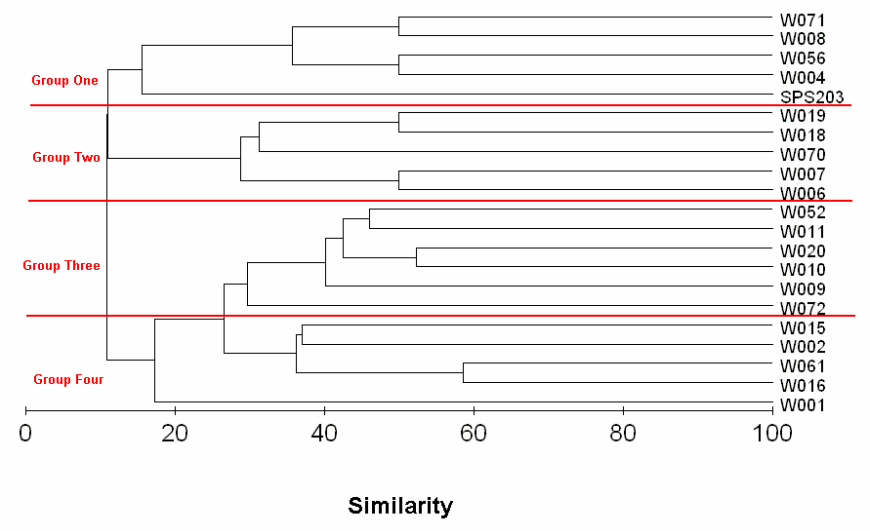

Figure 29. Cluster dendogram of the 21 sites using total fauna presence/absence data, indicating the four main groupings.

The four main site groupings from the cluster analysis, when superimposed on the MDS ordination were relatively well separated in ordination space (Figure 30). Furthermore, ANOSIM detected a significant separation between these groups (Global R = 0.758, significance level of sample statistic = 0.1%), with all groups being significantly different from each other (Table 22).

Table 22. ANOSIM results showing pairwise comparisons of groups based on presence/absence of total fauna. * = significantly different, ns = not significantly different.

	1	2	3	4
1				
2	*			
3	*	*		
4	*	*	*	

Sites were generally more similar with respect to their faunal communities, when analysed by presence/absence data, in comparison to abundance data (Tables 21 & 23).

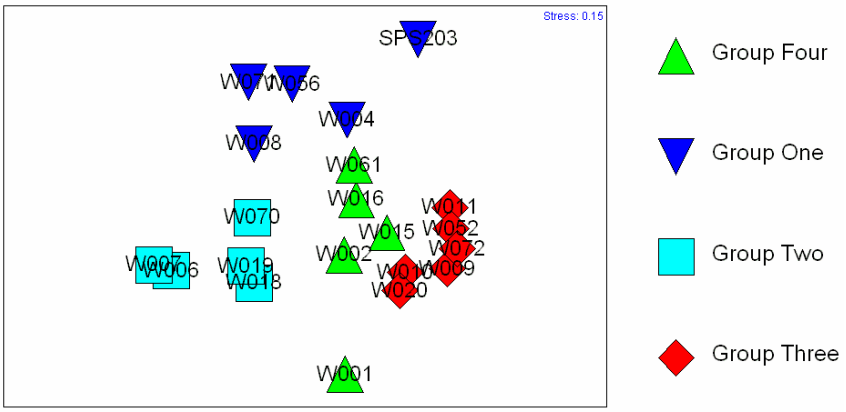

Figure 30. MDS ordination of the 21 wetlands using total fauna presence/absence data, with sites labelled by site codes, and coloured by *a posteriori* groupings from cluster analysis. Stress was 0.15.

Comparisons of 2003, 2004 & 2005 data

Biodiversity

Comparison of species richness at each of the eight wetlands sampled in November 2003, August 2004, and again in August 2005 showed no consistent pattern of either higher or lower diversity in one year versus the other year for any faunal component (Figure 31). No permanent fauna were collected from W018 in 2005. The greatest inter-annual difference was for site W011, with 2004 samples having a greater richness in all faunal components compared to 2003 and 2005. The increase in species richness recorded from W011 in 2004 likely reflects the collection of additional taxa as a result of sampling the adjacent wetland W012 as part of the W011 sample in August 2004. There was comparable between-year species richness within the permanent resident fauna. The greatest between-year variation then was recorded within the temporary faunal component (Figure 31). Across years, the fresher water wetlands (W009, W010 & W011) consistently contained more temporary fauna (and therefore greater total number of taxa) than the hypersaline wetlands (viz. W002, W004, W006, W019 & W019) (Figure 31).

Multivariate Analysis of Total Invertebrate Fauna

Abundance data

Only eight sites have been monitored yearly since 2003. Cluster analysis of these sites separated wetlands into two main groups based on the abundance of total invertebrate fauna (Figure 32). Classification of sites was based on salinity, with brackish wetlands (Group Two) forming a distinct group, separate from hypersaline sites (Group One). A number of wetlands showed little change over time, with samples from the same wetland clustering together (i.e. W004 & W002).

Table 23. Matrix of association values with each value indicating percent pairwise similarity amongst each wetland, calculated using the Bray-Curtis association measure on total fauna presence/absence data.

	W001	W002	W004	W006	W007	W008	W009	W010	W011	W015	W016	W018	W019	W020	W052	W056	W061	W070	W071	W072
W002	23.08																			
W004	10.00	17.65																		
W006	0.00	8.70	0.00																	
W007	0.00	9.52	0.00	50.00																
W008	0.00	23.08	30.00	22.22	28.57															
W009	22.86	20.41	13.95	0.00	0.00	5.71														
W010	19.51	25.45	16.33	5.26	5.56	4.88	40.63													
W011	12.24	22.22	17.54	0.00	0.00	8.16	36.11	38.46												
W015	10.00	37.04	12.50	5.41	5.71	15.00	28.57	40.58	28.57											
W016	12.12	42.55	29.27	6.67	7.14	24.24	28.57	32.26	28.57	39.34										
W018	16.67	30.77	20.00	22.22	28.57	16.67	5.71	14.63	8.16	20.00	24.24									
W019	16.67	23.08	30.00	44.44	28.57	16.67	5.71	19.51	4.08	15.00	18.18	50.00								
W020	22.22	28.00	9.09	12.12	6.45	5.56	40.68	52.31	46.58	31.25	28.07	16.67	22.22							
W052	16.22	31.37	17.78	0.00	0.00	10.81	43.33	42.42	45.95	30.77	24.14	5.41	10.81	42.62						
W056	0.00	7.69	50.00	0.00	0.00	50.00	5.71	0.00	4.08	10.00	24.24	16.67	0.00	0.00	5.41					
W061	20.00	29.41	35.71	0.00	0.00	30.00	18.60	24.49	28.07	33.33	58.54	20.00	10.00	18.18	31.11	40.00				
W070	25.00	20.00	8.33	30.77	18.18	37.50	15.38	17.78	15.09	18.18	21.62	25.00	37.50	20.00	9.76	25.00	16.67			
W071	0.00	9.09	12.50	0.00	0.00	50.00	6.45	0.00	4.44	11.11	13.79	0.00	0.00	0.00	6.06	50.00	25.00	33.33		
W072	13.95	21.05	19.61	5.00	0.00	9.30	36.36	22.22	27.50	25.35	21.88	13.95	9.30	26.87	35.29	4.65	19.61	8.51	5.13	
SPS203	0.00	8.33	22.22	0.00	0.00	20.00	6.06	10.26	8.51	5.26	6.45	0.00	20.00	11.76	11.43	20.00	0.00	0.00	0.00	4.88

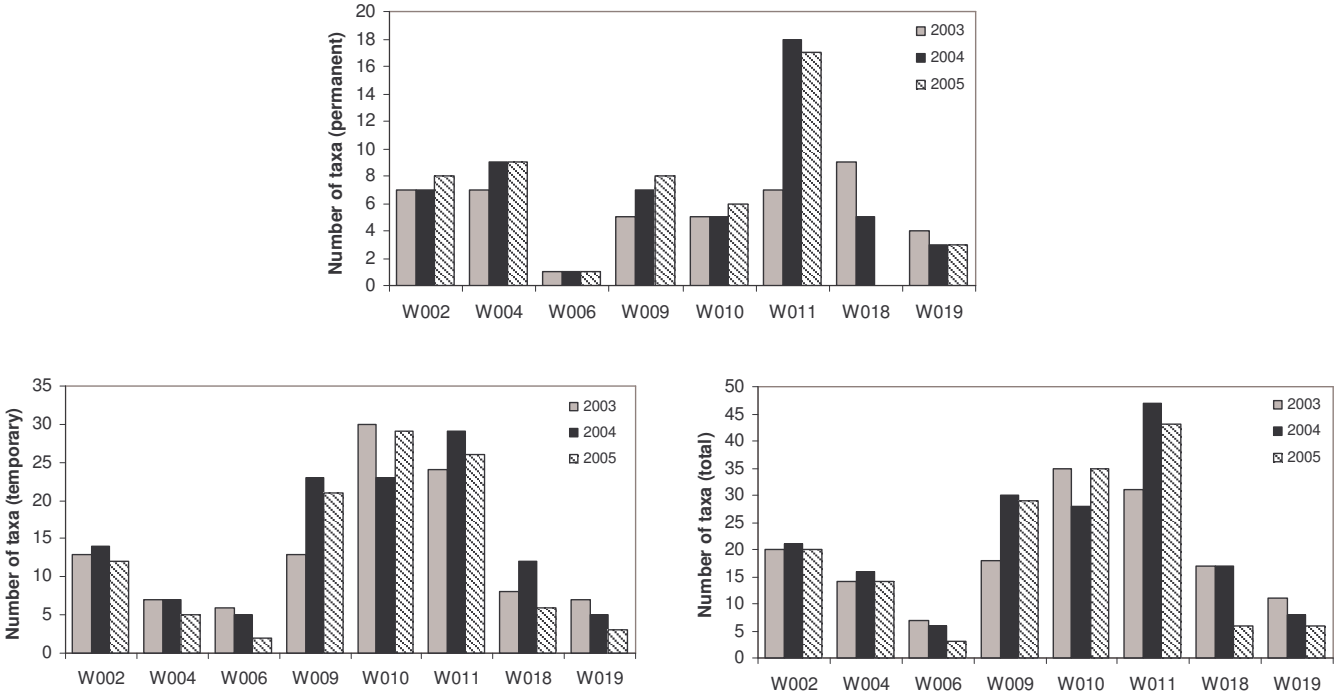

Figure 31. Species diversity at each of the eight wetlands sampled in November 2003, August 2004, and August 2005 for permanent fauna (top), temporary fauna (bottom left) and total aquatic invertebrate fauna (bottom right).

MDS ordination of the 24 samples again showed a clear separation of the lower salinity sites (brackish) from the hypersaline wetlands (Figure 33). These two groups were significantly separate in ordination space (ANOSIM, Global R = 0.709, significance level of sample statistic = 0.1%). Using salinity type & year as groups, ANOSIM also detected significant separation (Global R = 0.504, significance level of sample statistic = 0.1%). As would be expected, brackish sites were significantly separate between all years (Table 24). In addition, ANOSIM detected significant separation between hypersaline sites of 2003 and 2005 (Table 24). However, grouping sites by years for analysis, ANOSIM found no significant separation (Global R = 0.073, significance level of sample statistic = 15.4%). Therefore, in this case salinity has a greater influence over the invertebrate fauna community than time.

Table 24. ANOSIM results showing pairwise comparisons of groups based on abundance of total fauna. * = significantly different, ns = not significantly different. B = Brackish, H = Hypersaline.

	03 - H	03 - B	04 - H	04 - B	05 - H	05 - B
03 - H						
03 - B	*					
04 - H	ns	*				
04 - B	*	ns	*			
05 - H	*	*	ns	*		
05 - B	*	ns	*	ns	*	

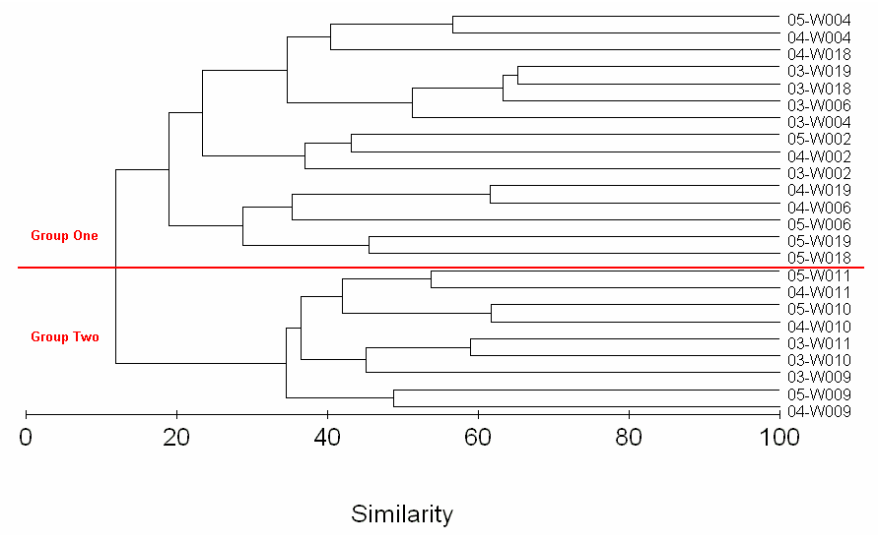

Figure 32. Cluster analysis of the eight BMRC wetlands sampled in 2003, 2004 & 2005, indicating the two main groups.

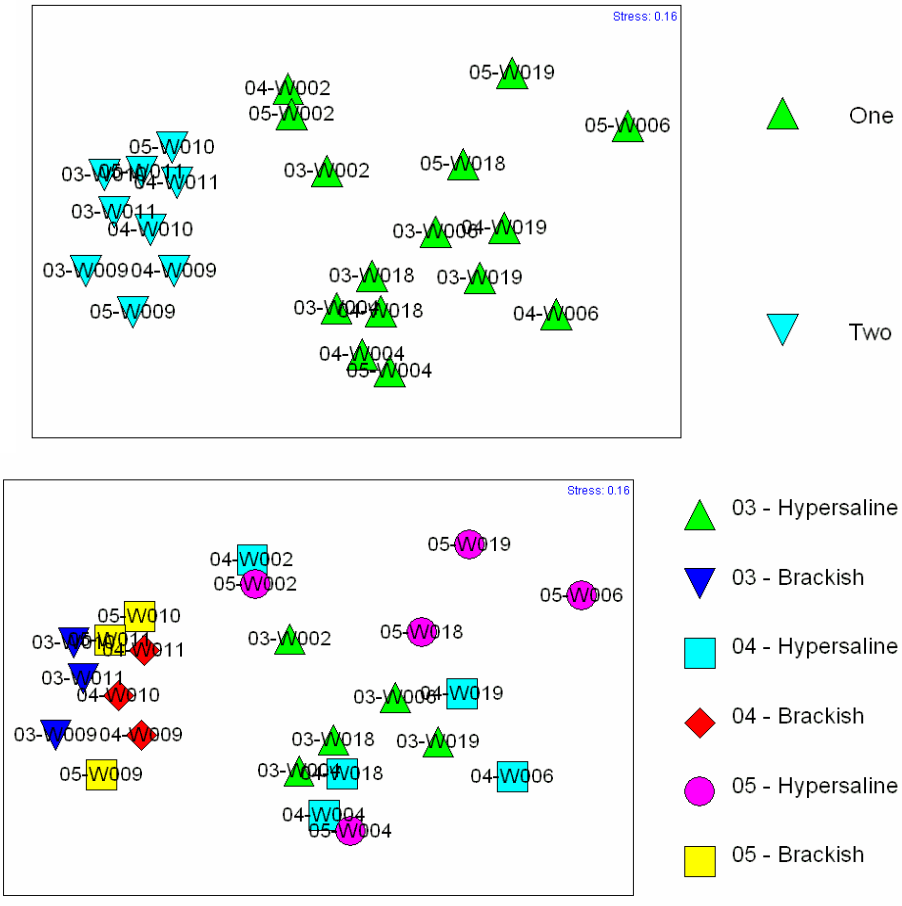

Figure 33. MDS ordination of the eight wetlands sampled in 2003, 2004 and 2005, using total fauna $\log_{10}$ abundance data, with sites labelled by site codes, and coloured by *a posteriori* groupings from cluster analysis (top), and salinity type within each year (bottom). Stress was 0.16.

Between-wetland pairwise similarity values are presented in Table 25. To illustrate change within individual wetlands over time, mean between-year pairwise similarities

were calculated. Mean pairwise similarity ranged from 26% at W019 to 47% at sites W004 & W011 (Figure 34).

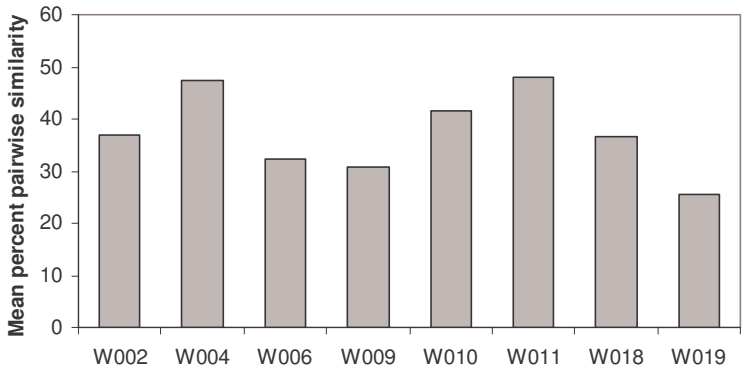

Figure 34. Mean pairwise percent similarity for each site sampled in 2003, 2004 & 2005, based on $\log_{10}$ abundance data, and similarity calculated using the Bray-Curtis Similarity Measure.

Presence/absence data

Cluster analysis on presence/absence data separated the eight sites sampled since 2003 into two main groups (Figure 35). Once again, separation was of hypersaline from brackish wetlands. In this instance, site W002 formed a distinct sub-group within Group One, and was intermediate between brackish and hypersaline sites (Figures 35 & 36). This site showed little change in the presence/absence of total invertebrate fauna over time. Within each main group, samples from the same wetland paired together for several wetlands, but there was a greater tendency for wetlands to group by year. The two major groups were significantly separate in ordination space (Figure 36; ANOSIM, Global R = 0.666, significance level of sample statistic = 0.1%).

Between-wetland pairwise similarity values are presented in Table 26. To illustrate change within individual wetlands over time, mean between-year pairwise similarities were calculated. Mean pairwise similarity ranged from 25% at site W006 to 55% at site W004 (Figure 37).

Table 25. Matrix of association values with each value indicating percent pairwise similarity amongst the eight wetlands sampled in 2003, 2004 & again in 2005, calculated using the Bray-Curtis association measure on total fauna log_{10} abundance data.

	03-2	03-4	03-6	03-9	03-10	03-11	03-18	03-19	04-2	04-4	04-6	04-9	4-10	04-11	04-18	04-19	05-2	05-4	05-6	05-9	05-10	05-11	05-18
03-4	39.29																						
03-6	36.36	42.86																					
03-9	23.73	17.54	8.89																				
03-10	22.73	13.95	13.51	51.69																			
03-11	24.39	20.00	11.76	38.55	58.93																		
03-18	32.14	62.96	61.90	14.04	16.28	17.50																	
03-19	29.17	47.83	64.71	8.16	10.26	8.33	65.22																
04-2	38.36	22.54	16.95	13.51	17.48	20.62	19.72	9.52															
04-4	23.73	52.63	31.11	6.67	8.99	12.05	52.63	32.65	16.22														
04-6	9.76	10.26	37.04	4.76	2.82	0.00	20.51	38.71	3.57	19.05													
04-9	13.79	9.41	10.96	34.09	37.61	37.84	21.18	7.79	19.61	18.18	8.57												
4-10	21.51	17.58	15.19	34.04	45.53	42.74	13.19	7.23	22.22	14.89	10.53	42.62											
04-11	25.42	20.69	13.46	23.53	37.84	49.30	18.97	11.11	27.07	16.81	0.00	34.01	45.75										
04-18	19.67	33.90	29.79	6.45	6.59	9.41	44.07	19.61	28.95	45.16	18.18	24.44	12.50	16.53									
04-19	18.60	19.51	48.28	9.09	5.48	5.97	29.27	36.36	10.34	27.27	61.54	11.11	10.26	3.88	30.43								
05-2	35.62	28.17	16.95	16.22	21.36	22.68	28.17	12.70	43.18	24.32	0.00	23.53	22.22	25.56	23.68	10.34							
05-4	20.34	42.11	17.78	6.67	4.49	7.23	38.60	20.41	24.32	56.67	19.05	13.64	8.51	10.08	35.48	31.82	18.92						
05-6	11.11	0.00	27.27	0.00	0.00	0.00	11.76	30.77	7.84	0.00	42.11	6.15	0.00	4.17	5.13	28.57	7.84						
05-9	14.89	10.87	10.00	27.37	30.65	33.90	15.22	4.76	12.84	14.74	5.19	48.78	37.21	35.06	24.74	5.06	16.51	12.63					
05-10	17.54	12.50	12.00	26.09	37.50	36.23	12.50	7.69	24.81	12.17	4.12	33.57	61.74	42.53	18.80	12.12	20.16	13.91	4.35	34.67			
05-11	19.05	17.74	10.71	23.62	34.62	46.67	16.13	6.90	17.02	18.90	3.67	30.97	39.75	53.76	7.75	7.21	21.28	17.32	0.00	33.33	39.56		
05-18	18.60	24.39	41.38	9.09	8.22	5.97	29.27	30.30	17.24	31.82	15.38	13.89	7.69	13.59	34.78	42.86	24.14	18.18	19.05	7.59	12.12	7.21	
05-19	16.22	5.71	17.39	5.26	2.99	3.28	11.43	14.81	15.38	5.26	10.00	9.09	2.78	6.19	20.00	45.45	15.38	15.79	40.00	2.74	10.75	1.90	45.45

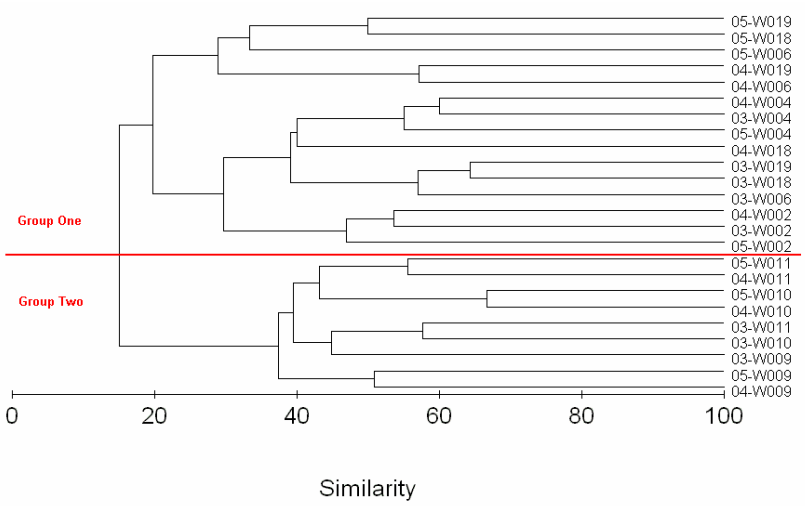

Figure 35. Cluster dendogram of the eight sites sampled in 2003, 2004 and 2005, using total fauna presence/absence data, and indicating the two main groups.

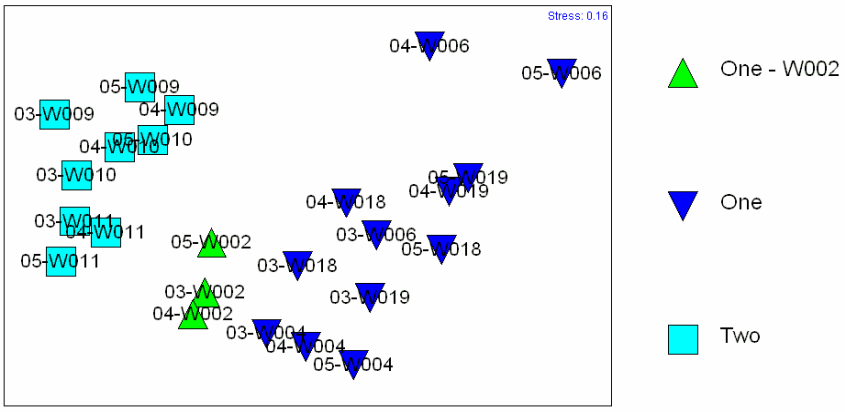

Figure 36. MDS ordination of the eight wetlands sampled in 2003, 2004 and 2005, using total fauna presence/absence data, with sites labelled by site code, and coloured by *a posteriori* groupings from cluster analysis, and showing the distinct sub-group (green triangles). Stress was 0.16.

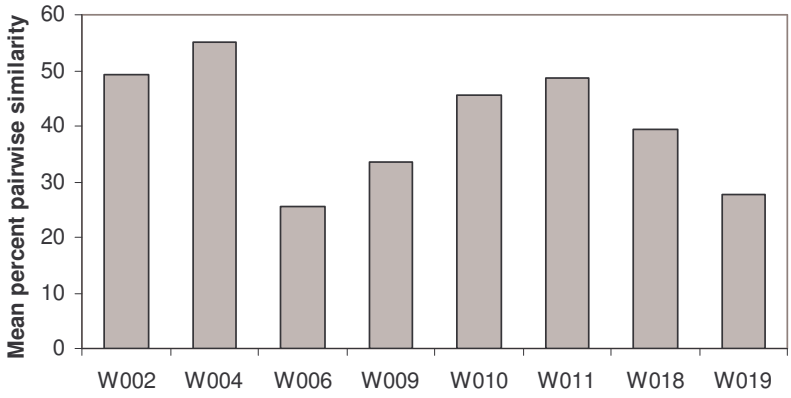

Figure 37. Pairwise percent similarity for each site sampled in November 2003, August 2004, and August 2005, based on presence/absence data, with similarity calculated using the Bray-Curtis Similarity Measure.

Table 26. Matrix of association values with each value indicating percent pairwise similarity amongst the eight wetlands sampled in 2003, 2004 and again in 2005, calculated using the Bray-Curtis association measure on total fauna presence/absence data.

	03-2	03-4	03-6	03-9	03-10	03-11	03-18	03-19	04-2	04-4	04-6	04-9	4-10	04-11	04-18	04-19	05-2	05-4	05-6	05-9	05-10	05-11	05-18
03-4	47.06																						
03-6	37.04	38.10																					
03-9	26.32	18.75	8.00																				
03-10	32.73	20.41	19.05	52.83																			
03-11	27.45	26.67	15.79	36.73	57.58																		
03-18	37.84	58.06	58.33	17.14	23.08	25.00																	
03-19	38.71	56.00	55.56	13.79	17.39	14.29	64.29																
04-2	53.66	34.29	28.57	15.38	21.43	26.92	26.32	18.75															
04-4	27.78	60.00	26.09	5.88	11.76	17.02	48.48	37.04	21.62														
04-6	7.69	10.00	30.77	8.33	4.88	0.00	17.39	23.53	7.41	18.18													
04-9	16.00	13.64	10.81	37.50	36.92	36.07	34.04	14.63	19.61	21.74	11.11												
4-10	29.17	23.81	17.14	43.48	50.79	44.07	17.78	10.26	32.65	18.18	17.65	44.83											
04-11	32.84	26.23	14.81	21.54	41.46	48.72	21.88	13.79	32.35	19.05	0.00	33.77	50.67										
04-18	21.62	38.71	33.33	5.71	7.69	12.50	52.94	28.57	36.84	42.42	26.09	29.79	17.78	15.63									
04-19	14.29	18.18	40.00	7.69	4.65	5.13	24.00	31.58	13.79	25.00	57.14	10.53	11.11	3.64	32.00								
05-2	45.00	35.29	29.63	26.32	29.09	31.37	32.43	19.35	48.78	27.78	0.00	32.00	29.17	29.85	32.43	14.29							
05-4	23.53	50.00	19.05	6.25	4.08	8.89	38.71	32.00	28.57	60.00	20.00	18.18	9.52	13.11	38.71	36.36	17.65						
05-6	8.70	0.00	20.00	0.00	0.00	0.00	10.00	14.29	8.33	0.00	22.22	6.06	0.00	4.00	10.00	18.18	8.70	0.00					
05-9	20.41	13.95	11.11	29.79	31.25	36.67	21.74	10.00	16.00	17.78	11.43	50.85	45.61	39.47	30.43	5.41	20.41	13.95	0.00				
05-10	21.82	16.33	14.29	33.96	40.00	36.36	19.23	13.04	28.57	15.69	4.88	40.00	66.67	43.90	23.08	18.60	25.45	16.33	5.26	40.63			
05-11	25.40	21.05	12.00	29.51	35.90	48.65	20.00	11.11	21.88	23.73	4.08	35.62	39.44	55.56	6.67	7.84	22.22	17.54	0.00	36.11	38.46		
05-18	15.38	30.00	46.15	8.33	9.76	5.41	26.09	35.29	14.81	27.27	16.67	11.11	5.88	11.32	34.78	42.86	30.77	20.00	22.22	5.71	14.63	8.16	
05-19	23.08	10.00	30.77	8.33	4.88	5.41	17.39	23.53	22.22	9.09	16.67	11.11	5.88	7.55	26.09	57.14	23.08	30.00	44.44	5.71	19.51	4.08	50.00

Comparisons of 2004 and 2005 data

Biodiversity

Taxa richness within BMRC wetlands was higher in 2004 than 2005, with the exception of sites W010, W016, and W070 (Table 27).

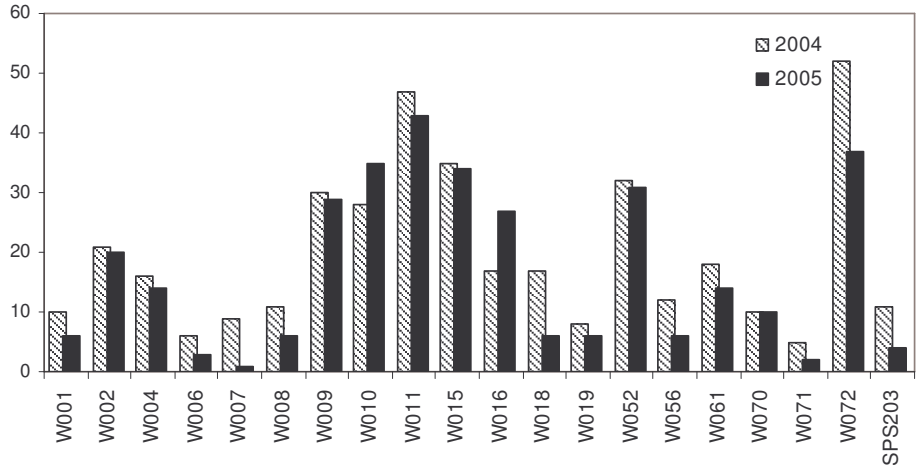

Table 27. Taxa richness from BMRC wetlands in 2004 and 2005.

Multivariate Analysis of Total Invertebrate Fauna

Abundance data

The additional 2005 site (W020) was excluded from comparisons, leaving 20 sites for multivariate statistics. PRIMER cluster analysis separated these sites into five main groups based on the abundance of total invertebrates (Figure 38). As with all other analyses, hypersaline sites (Groups One, Three, Four and Five) were separate from the fresher water brackish wetlands (Group Two). In addition, 2004 and 2005 samples from the acidic gypsum wetland (W001) paired together and formed a distinct group (Group Three). Generally, individual wetlands from both years clustered within the same group, with the exception of sites W018 (2004 = group one, 2005 = group four), W071 (2004 = group four, 2005 = group one), and SPS203 (2004 = group one, 2005 = group five). SPS203 in August 2005 formed a group of its own (Figure 38). Groups showed some separation in ordination space (Figure 39).

There was significant separation between groups classified by cluster analysis (ANOSIM, Global R = 0.746, significance level of sample statistic = 0.1%). Separation between all groups was significant, with the exception of Group Five (Table 28).

Table 28. ANOSIM results showing pairwise comparisons of groups based on abundance of total fauna from both 2004 and 2005. * = significantly different, ns = not significantly different.

	1	2	3	4	5
1					
2	*				
3	*	*			
4	*	*	*		
5	ns	ns	ns	ns	

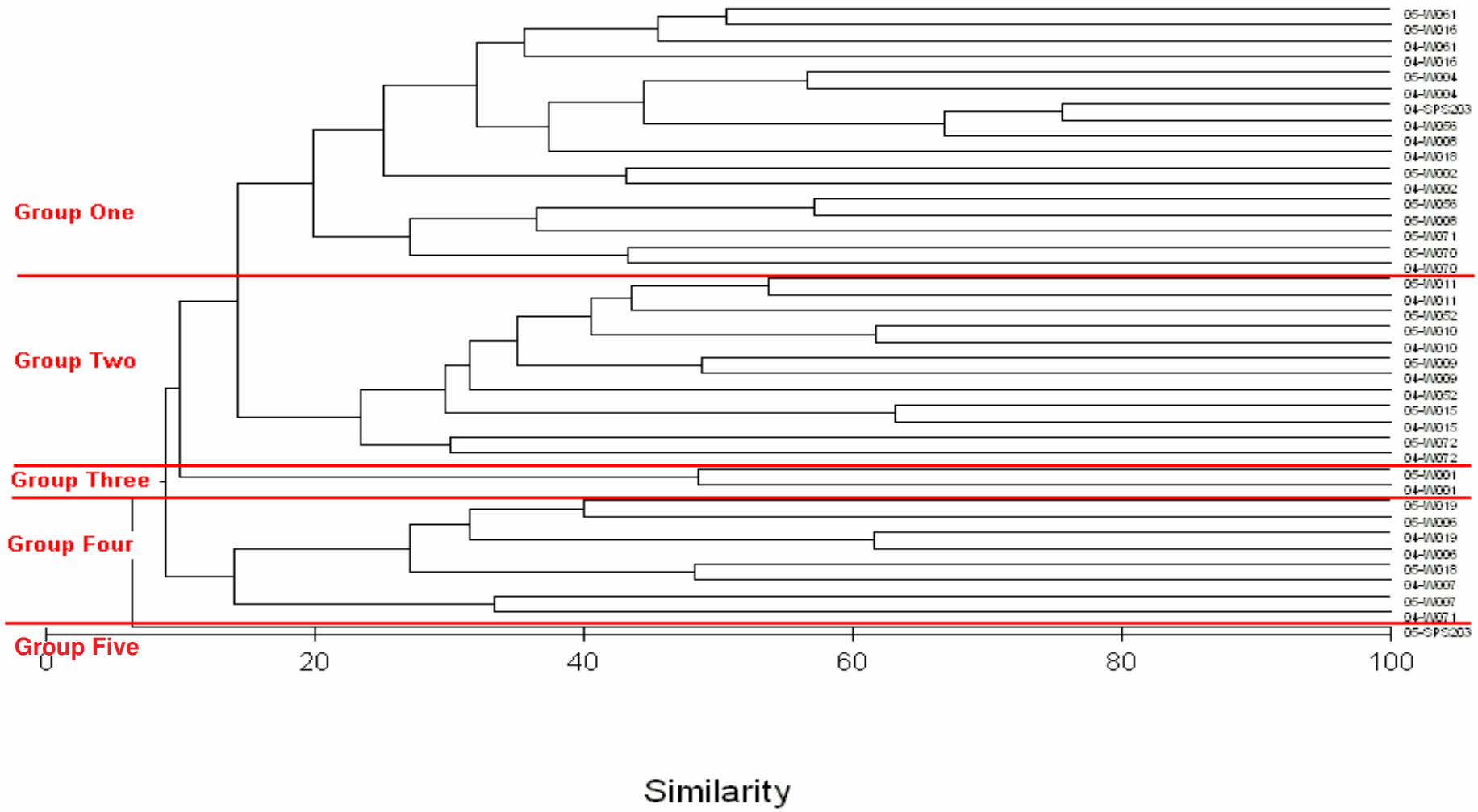

Figure 38. Cluster dendrogram of the 20 sites sampled in 2004 and 2005, using total fauna abundance data, and indicating the five main groups

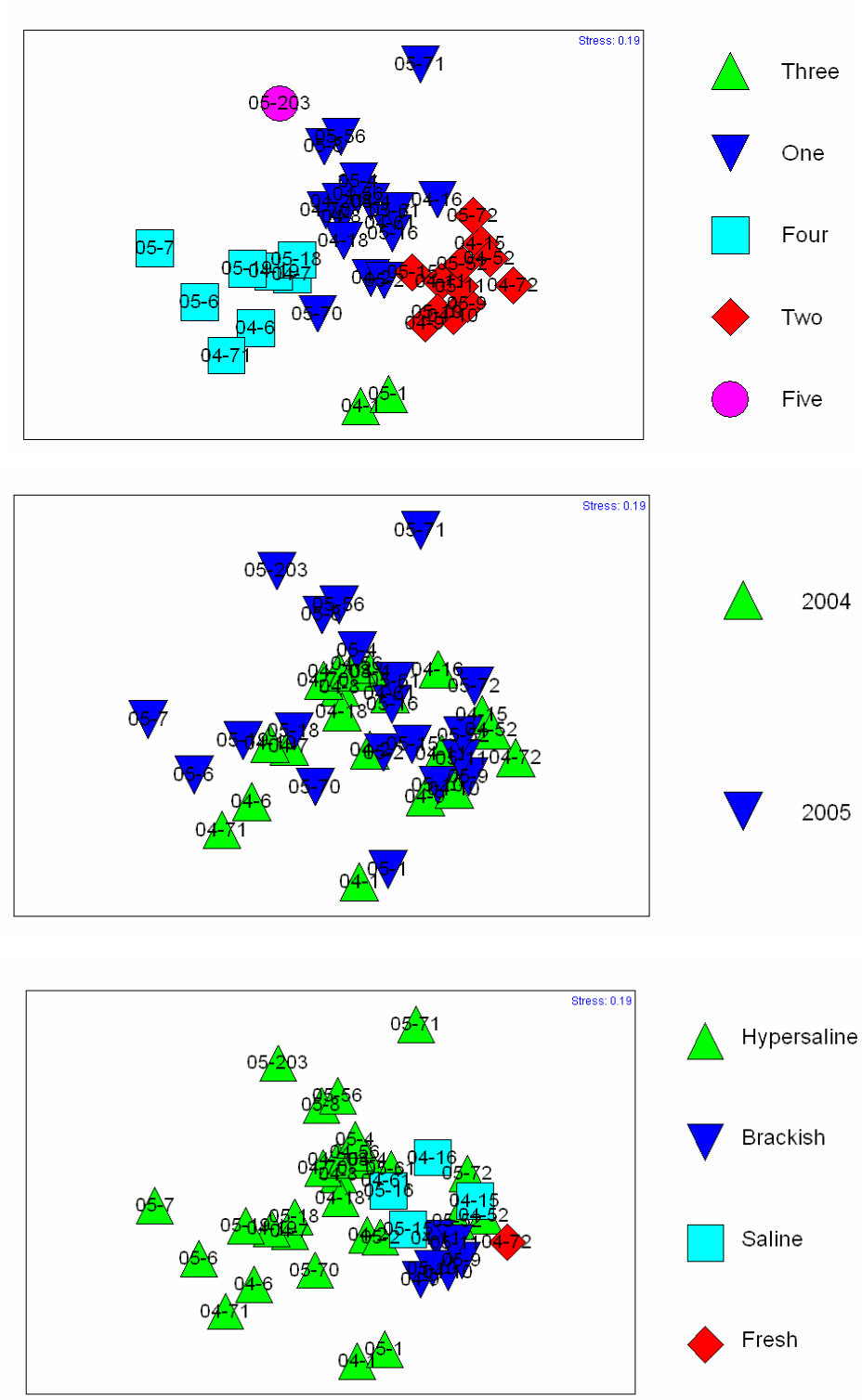

Figure 39. MDS ordination of the 20 wetlands sampled in 2004 and 2005, using total fauna $\log_{10}$ abundance data, with sites labelled by site code, and coloured by *a posteriori* groupings from cluster analysis (top), year (middle) and salinity (bottom). Stress was 0.19

SIMPER analysis was used to determine which species were typical of a group by providing a list of taxa which were found at consistently high abundances within most samples from a particular group. Group Two (brackish/low salinity sites) were typified by ceratopogoniinae spp. (larvae), *Austrochiltonia subtenius*, *Tanytarsus fuscithorax*, *Micronecta*

robusta, *Procladius paludicola*, cyclopoid copepodites, *Anisops* spp., *Chironomus aff. alternans*, chironomid spp. (pupae), *Allodessus bistrigatus*, *Boeckella triarticulata*, *Orthetrum caledonicum*, *Limnophyes pullulus*, and *Austrolestes annulosus*. These species are all considered to be good bioindicators and are known to be sensitive to high salinities.

Fauna dominant within Group One (hypersaline sites) included; cyclopoid copepodites, cyclopoid nauplii, ceratopogoniinae spp. (larvae), *Tanytarsus barbitarsus*, *Meridiecyclops baylyi*, *Diacypris* sp., muscidae spp (pupae), *Australocypris cf. insularis*, and ephydridae spp (larvae). Samples within Group Four (also hypersaline sites) were typified by Diptera including muscidae spp (larvae and pupae), *Tanytarsus barbitarsus*, and Ceratopogoniinae spp. (larvae). Other taxa characteristic of this group were *Artemia parthogenetica* and *Mesovelia* sp. Over 94% of the within-group similarity was explained by these six taxa.

The hypersaline acidic site (W001) within Group Three was characterised by *Reticypris* sp., calanoid copepodites, ceratopogonid spp. (larvae and pupae), and calanoid nauplii, with these five taxa explaining 100% of the within-group similarity.

SIMPER can also be used to compare fauna communities between the lower salinity brackish wetlands and the hypersaline ones, by providing a measure of dissimilarity. The average dissimilarity between groups one (hypersaline sites) and two (brackish/low salinity sites) was over 85%. Generally, variation between these groups was largely explained by higher abundances of microcrustacea (permanent taxa) and diptera species such as *Tanytarsus barbitarsus*, ephydrid larvae and muscid pupae within group one, and more sensitive indicator taxa such as; the amphipod *Austrochiltonia subtenius*, the coleopterans *Sternopriscus sp.* (larvae)*, Necterosoma sp.* (larvae), and *Allodessus bistrigatus,* the hemipterans *Micronecta robusta* and *Agraptocorixa eurynome*, the odonates *Austrolestes annulosus*, *Orthetrum caledonicum*, and *Hemicordulia tau*, and the chironomids *Procladius paludicola*, *Chironomus aff. alternans*, and *Procladius villosimanus* (Table 29).

The relationships between patterns in wetland fauna and environmental variables were investigated using BIOENV procedures. Environmental variables most likely to be influencing community structure within BMRC wetlands were percent cover of vegetation, flooded riparian vegetation, samphire, and reedrushes. These wetland characteristics were found to be influenced by conductivity, with hypersaline sites comprising less percent vegetation cover, flooded riparian vegetation and reed/rushes, and more samphire than fresher sites.

To illustrate change within individual wetlands over time, between-year pairwise similarities were calculated using the Bray-Curtis Association Measure. Pairwise similarity ranged from 0% at site W071 to 63% at site W015. In 2004, 4 temporary taxa were recorded from W071, while in 2005 two permanent taxa were collected. W007 also showed considerable change in invertebrate structure between 2004 and 2005, and this was reflected in the low pairwise similarity (12%). This site comprised primarily temporary taxa. Temporal change in community structure at SPS203 (15% similarity) likely supports the contention that this wetland dried prior to sampling in 2005, resulting in a distinctly different assemblage.

Table 29. Between-group SIMPER results for log_{10} total invertebrates, showing species contributing to the variation between groups one (hypersaline) and two (brackish).

Species	Group One Av. Abund.	Group Two Av. Abund.	Av. Diss	Cumulative %
Austrochiltonia subtenius	0.41	3.00	2.93	3.42
Tanytarsus fuscithorax	0.0	2.5	2.51	6.35
Micronecta robusta	0.0	2.08	2.15	8.86
Procladius paludicola	0.35	2.08	2.01	11.21
Chironomus aff. alternans	0.	1.67	1.78	13.29
Ceratopogoniinae spp. (L)	1.53	2.75	1.64	15.2
Tanytarsus barbitarsus	1.65	0.0	1.63	17.1
Anisops spp	0	1.5	1.49	18.84
Ceratopogoniinae spp. (P)	0.65	1.5	1.42	20.49
Boeckella triarticulata	0.29	1.33	1.37	22.10
calanoid copepodites	0.18	1.42	1.34	23.66
cyclopoid copepodites	2.47	1.67	1.32	25.2
Meridiecyclops baylyi	1.24	0	1.31	26.73
Diacypris sp.	1.0	0.42	1.29	28.23
Necterosoma sp. (L)	0.65	1.25	1.29	29.74
Allodessus bistrigatus	0	1.17	1.26	31.21
calanoid nauplii	0.24	1.17	1.23	32.64
Ephydridae spp (L)	1.12	0.75	1.22	34.06
cyclopoid nauplii	1.47	1.08	1.20	35.47
Oligochaetes	0.29	1.08	1.19	36.86
Culicinae spp. (L)	0.06	1.17	1.19	38.25
Dolichopodiae spp	0.65	0.83	1.16	39.60
Chironomid spp. (P)	0.71	1.25	1.14	40.93
Muscidae spp (P)	0.94	0.67	1.12	42.24
Daphnia carinata	0.12	1.08	1.10	43.52
Procladius villosimanus	0	1.17	1.06	44.76
?Limnophyes pullulus	0	1.00	1.04	45.98
Tabanidae spp.	0.53	0.75	0.93	47.07
Austrolestes annulosus	0	1.00	0.92	48.14
Orthetrum caledonicum	0	0.92	0.88	49.17
Australocypris cf. insularis	0.88	0.00	0.86	50.18
Hemicordulia tau	0.06	0.83	0.85	51.17
Polypedilum nubifer	0	0.92	0.85	52.16
Sternopriscus sp. (L)	0	0.83	0.79	53.08
Agraptocorixa eurynome	0	0.75	0.79	54.01
Culicinae spp. (P)	0.06	0.75	0.79	54.93

Temporal variability in aquatic invertebrate fauna is common, even when samples are taken in the same manner from the same habitat and location (see Bunn *et al.* 1986, McElravy *et al.* 1989). Seasonal variation in community structure can be correlated with hydrological cycle, seasonal changes in riparian and aquatic vegetation (viz. habitat change) and the ecology/life cycle characteristics of the invertebrates themselves, particularly aspects of breeding and recruitment. In general, changes in invertebrate composition between years may also be correlated with hydrology (i.e. drought or flood), as well as disturbance such as fire. In temporary habitats, drying results in the initial loss of all species except those which can burrow or remain in resistant egg stages (diapause). While recolonisation from ovipositing aerial adults immigrating from nearby habitats may be fairly rapid (McElravy *et al.* 1989), resultant changes to community composition are highly likely, especially within the temporary fauna.

Between-year variation in permanent fauna may also be high depending on rates of succession and time since inundation. This is because only a proportion of any particular

species' 'hatchable' resting egg bank will be cued to hatch at any one time in response to inundation (Shiel *et al.* 2001). Such sequential hatching is likely a survival strategy in highly unpredictable ephemeral environments and defence against rapid drought (Tan & Shiel 1993, Shiel *et al.* 2001). In addition, there is high variation in hatching rates between species, with protists emerging within hours, rotifers within a day, and microcrustacea within days following the initial flood event (Tan & Shiel 1993). In turn, successional changes become evident over time as competitive and predatory interactions establish (Shiel *et al.* 2001).

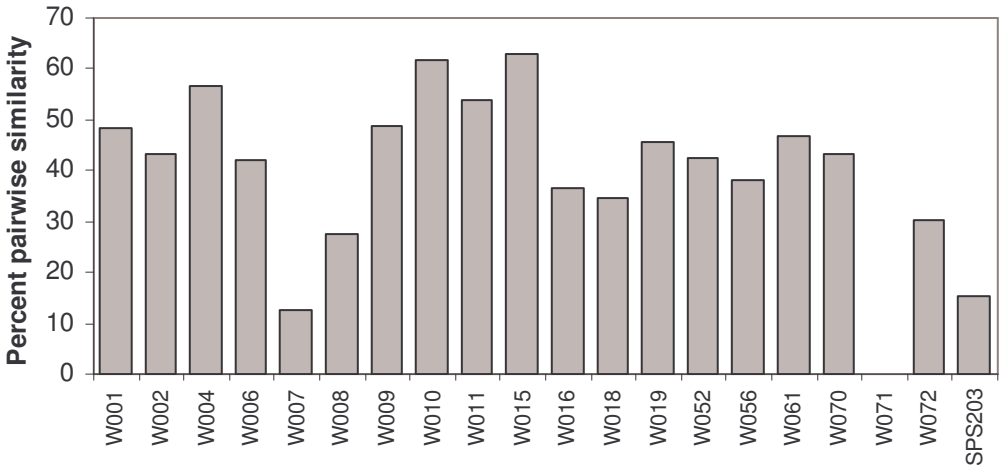

Figure 40. Between-year percent similarity for the 20 wetlands sampled in August 2004 and August 2005, using $\log_{10}$ abundance of total invertebrate fauna.

Presence/absence data

Cluster analysis on presence/absence of total fauna again separated the 20 common sites from 2004 and 2005 into five main groups. Group members were the same as those classified by $\log_{10}$ abundance data, with sites separating on the bases of salinity, rather than year (see Figures 39 & 41).

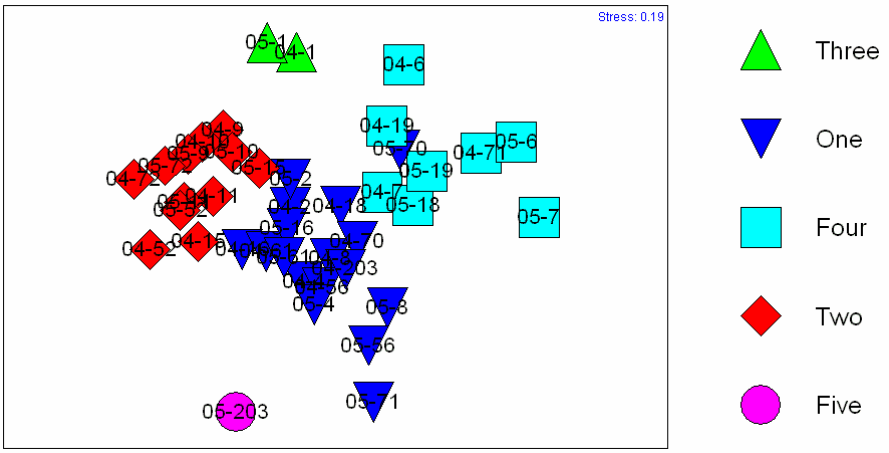

Figure 41. MDS ordination of the 20 wetlands sampled in 2004 and 2005, using presence/absence of total fauna, with sites labelled by site code, and coloured by *a posteriori* groupings from cluster analysis. Stress was 0.19.

Since results were the same as abundance data, ANOSIM, SIMPER and BIOENV results will not be repeated.

Between-year pairwise similarities were calculated using the Bray-Curtis Association Measure to illustrate change within individual wetlands over time (Figure 42).

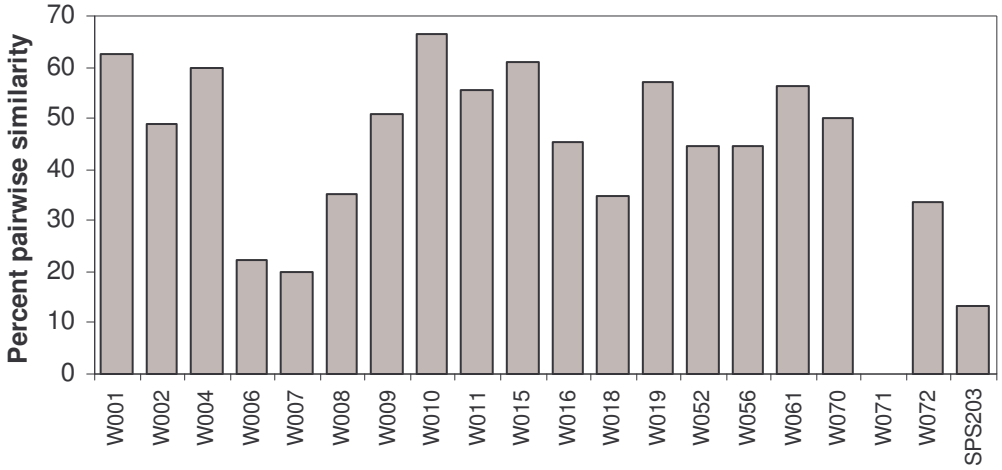

Figure 42. Between-year percent similarity for the 20 wetlands sampled in August 2004 and August 2005, using presence/absence of total invertebrate fauna.

Comparison with SAP Samples

Biodiversity

The Salinity Action Plan (SAP) Wheatbelt survey in Sept 1999 sampled four wetlands in the BMRC (SPS157 = W008, SPS158 = W007, SPS201 & SPS203). Three of these sites were sampled again in 2004 and 2005 (SPS201 was dry). Prior to statistical analysis, all data were transformed to presence/absence to reduce effects due to differences in sampling approaches and seasons, and taxonomy was standardised as best as possible to minimise apparent differences due to level of resolution. For example, some Chironomidae reported as species complexes under SAP (i.e. *Tanytarsus fuscithorax, Tanytarsus ?semibarbitarsus* and *Tanytarsus barbitarsus)*, but taken to individual species level for BMRC, were amalgamated to the same level. The *Diacypris* ostracod was also amalgamated.

In the first instance, broad comparison in species richness across sites was made by determining total species richness for each site (Figure 43). Analysis showed that species richness consistently decreased over time. Taxa richness was greater in samples collected for SAP than in August 2004 or 2005, with site SPS203 supporting 6 times as many taxa (54) in 1999 than 2004 (9). Overall, the three SAP sites contained 74 taxa, whilst the same three sites sampled in August contained 16 and nine taxa (after re-standardisation) in 2004 and 2005, respectively. The greater biodiversity recorded in 1999 is likely due to the increased inundation of wetlands in the BMRC as a result of flooding and high rainfall in that year. The greater water levels not only reduced salinity within SPS203 as a result of dilution effects (see Figure 43), but also allowed inundation of riparian vegetation, effectively increasing habitat diversity for aquatic fauna.

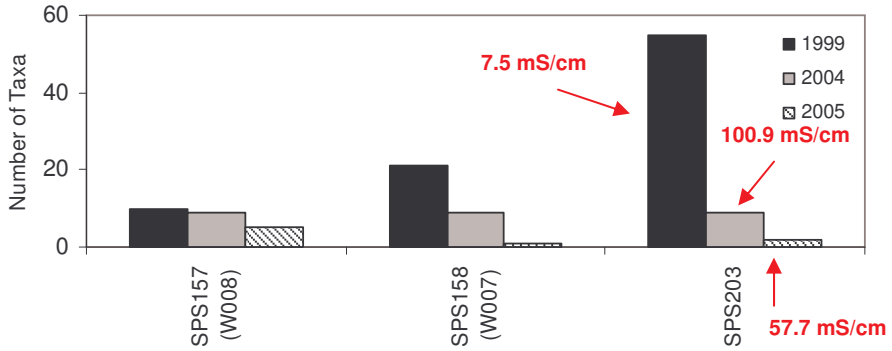

Figure 43. Species richness at the three sites in the BMRC sampled in the SAP in September 1999 and again in August 2004 and 2005.

Multivariate Analysis of Total Invertebrate Fauna

Classification of the nine samples separated sites into four main groups (Figure 44). SPS203 was highly dissimilar from other wetlands and formed its own group in 1999 and 2005. The BMRC 2004 wetlands tended to cluster together. MDS showed sites sampled in 2005 generally separated from 2004 and 1999 samples (Figure 45).

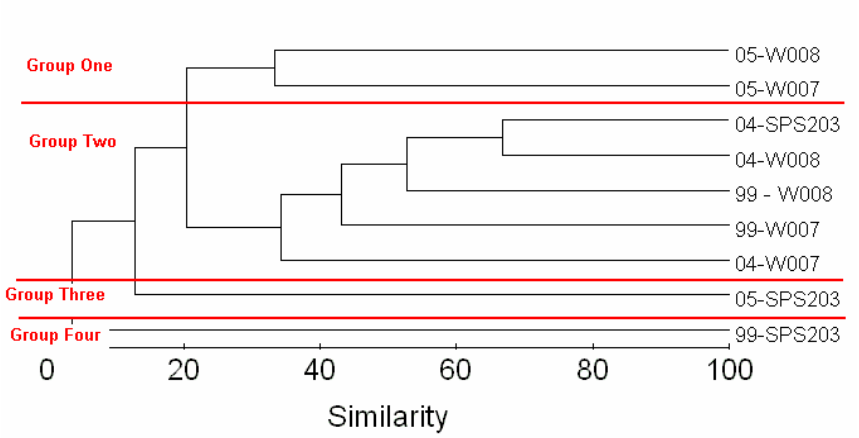

Figure 44. Cluster dendrogram of the three SAP sites sampled in 1999, 2004 and 2005, using total fauna presence/absence data, and indicating the four main groups

ANOSIM detected significant separation between the four cluster groups (Global R = 0.905, significance level of sample statistic = 0.1%). However, pairwise comparisons revealed significant separation was only between groups one and two (Table 30). There was no significant separation between years (ANOSIM, Global R = 0.284, significance level of sample statistic = 1.8%).

Table 30. ANOSIM results showing pairwise comparisons of years based on presence/absence of total fauna from SAP wetlands sampled in 1999, 2004 and 2005. * = significantly different, ns = not significantly different.

	1	2	3	4
1				
2	*			
3	ns	ns		
4	ns	ns	ns	

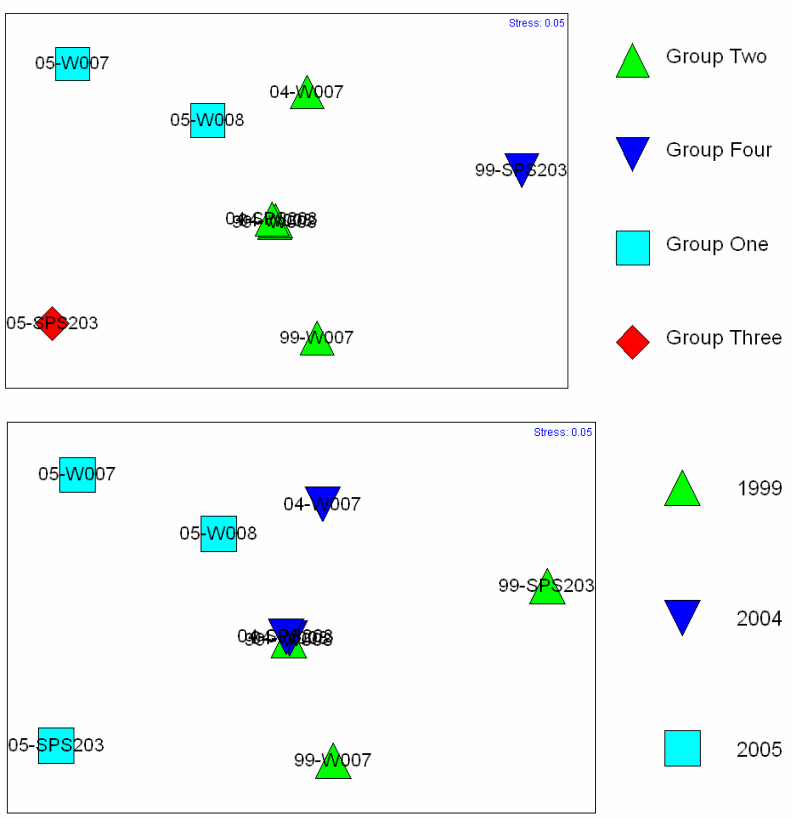

Figure 45. MDS ordination of the three wetlands sampled in 1999, 2004 and 2005, using presence/absence of total fauna, with sites labelled by site code, and coloured by *a posteriori* groupings from cluster analysis (top) and year (bottom). Stress was 0.05.

Between-site pairwise similarity values are provided in Table 31. In addition, mean between-year pairwise similarities were calculated using the Bray-Curtis Association Measure to illustrate change within individual wetlands over time (Figure 46). Site W008 showed the greatest between-year similarity whilst SPS203 varied greatly over time.

Table 31. Matrix of association values with each value indicating percent pairwise similarity amongst the three wetlands in the BMRC sampled in the SAP in September 1999 and again in August 2004, and 2005, calculated using the Bray-Curtis association measure on total fauna presence/absence data.

	99-W007	99 - W008	99-203	04-W007	04-W008	04-203	05-W007	05-W008
99 - W008	46.67							
99-203	13.33	3.08						
04-W007	27.59	31.58	3.13					
04-W008	34.48	52.63	3.13	44.44				
04-203	48.28	52.63	3.13	33.33	66.67			
05-W007	0.00	0.00	0.00	20.00	0.00	20.00		
05-W008	24.00	40.00	3.33	28.57	28.57	42.86	33.33	
05-203	9.09	16.67	0.00	0.00	18.18	18.18	0.00	28.57

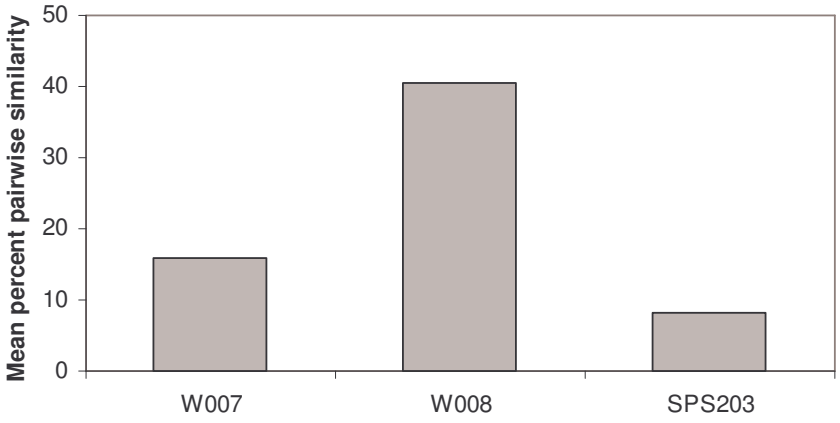

Figure 46. Mean percent pairwise similarity of the three SAP wetlands between 1999, 2004 and 2005, using presence/absence total invertebrate fauna data.

Wetland Characterisation

To determine whether biodiversity values of BMRC wetlands can be characterised using other attributes, linear regression was used on data from both 2004 and 2005 surveys. Only the strongest relationships are reported here.

Taxa richness and conductivity provided the strongest correlation, with the number of taxa decreasing as conductivity increased (Figure 47). The best predictive relationship was between conductivity (log(x+1)) and total taxa richness ($r^2 = 0.836$). This suggests that over 83% of the between-wetland variation in total taxa richness can be explained by measuring conductivity. Permanent fauna showed the weakest relationship with conductivity ($r^2 = 0.543$).

A positive relationship was recorded between taxa richness (permanent, temporary and total number of taxa) and percent cover of vegetation (Figure 48). High cover of vegetation within a wetland provides habitat for aquatic fauna and increased habitat heterogeneity, ultimately leading to greater biodiversity. Over 50% of the between-wetland variation in total taxa richness can be explained by percent vegetation cover.

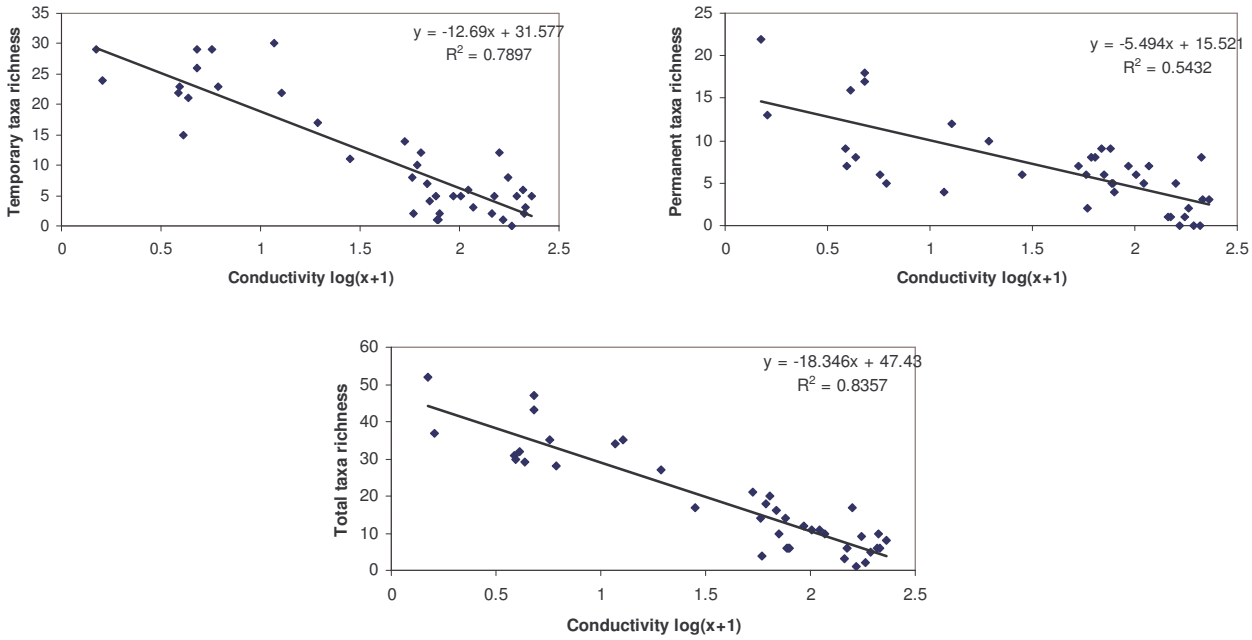

Figure 47. Linear regressions between wetland conductivity log(x+1) and taxa richness for temporary fauna (top left), permanent fauna (log(x+1) (top right) and total invertebrate taxa richness (log(x+1) (centre), giving regression equations and r^2 values.

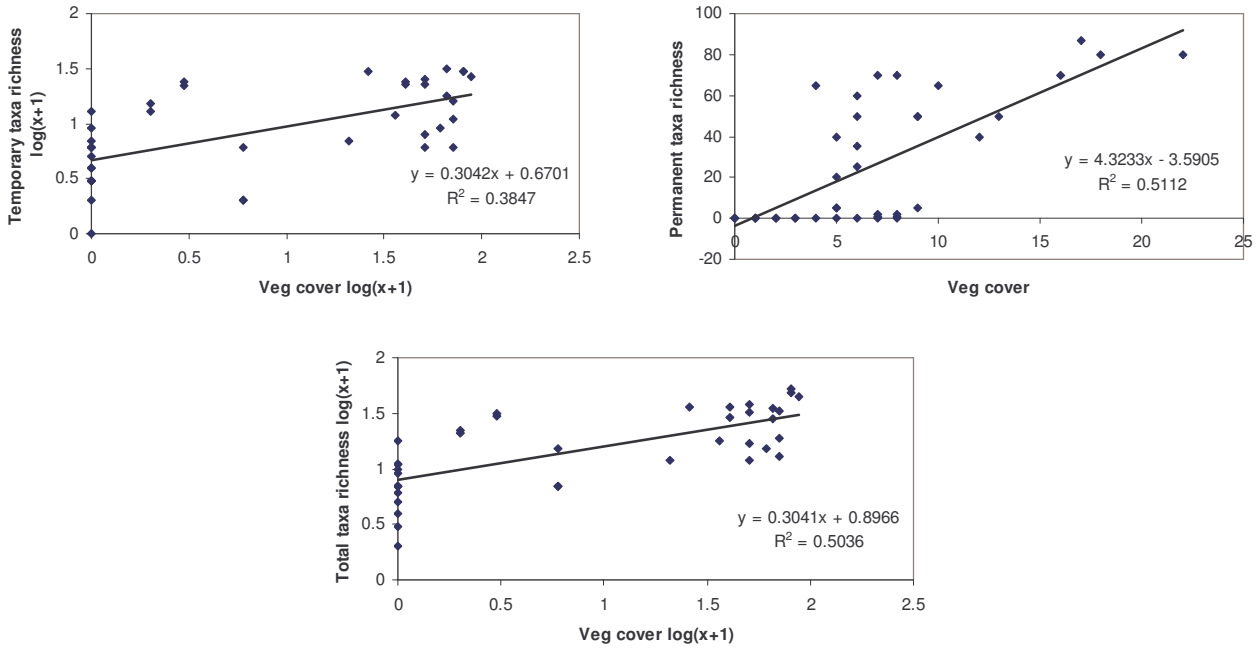

Figure 48. Linear regressions between vegetation cover and taxa richness for temporary fauna log(x+1) (top left), permanent fauna (top right) and total invertebrate taxa richness (log(x+1) (centre), giving regression equations and r^2 values.

Vertebrate Fauna

Plate 28. The motorbike frog, *Litoria moorei* (Davis 2003).

A number of vertebrate fauna were recorded from wetlands within the BMRC, including frogs, fish and birds (Table 32). A total of three frog species were identified by their mating call, all of which were found from the fresher water and brackish sites (Table 32). The bleating frog, *Crinia pseudinsignifiera,* is found throughout much of the south-west of Western Australia and is common to the drier wheatbelt area (Davis 2003). The banjo or pobblebonk frog, *Limnodynastes dorsalis*, is also common and widespread throughout W.A., with a distribution from Shark Bay to near Esperance. This species can be found within vegetation adjacent to wetlands during winter, and shelters in burrows to avoid drought in summer (Davis 2003). The motorbike or western green tree frog, *Litoria moorei* (Plate 28), is endemic to Western Australia. Its distribution extends from the lower Murchison River in the north to Pallinup River in the southwest (Davis 2003).

The Swan River goby, *Pseugobius olorum*, was collected from W009 during the current study (Table 32). No fish had previously been recorded from wetlands within the BMRC. 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. It occurs in estuaries, rivers, and both freshwater and hypersaline lakes (Morgan *et al.* 1998). While the swan river goby is generally associated with coastal water bodies, it does penetrate long distances inland (i.e. Blackwood, Warren, Hay and Kalgan river systems), and occurs in some isolated lakes (e.g. lakes Jasper, Maringup, Towerrinning, Saide, Powell, Moates, Gardner and Angove). It is usually found over mud bottom, and sometimes amongst weeds or adjacent to rocky areas.

In the Swan River, *P. olorum* consumes algae and mats of fungi and bacteria, ingesting invertebrates in winter only, although Fairhurst (1993; cited Morgan *et al.* 1998) noted that fish in Swan Coastal Plain lakes consumed invertebrates in all seasons. The species life cycle is less than a year, with spawning during spring and autumn, and to a limited extent summer. Progeny of the spring spawning will reproduce in the following autumn when only five months old, and *vice versa* for progeny of the autumn. Some individuals will survive to spawn a second time. The female lays approximately 150 eggs on the underside of a solid object (rock, log etc), and the male guards and fans the eggs during the incubation period, which lasts about four days. Little is known of their breeding biology with respect to migratory behaviour.

Of the 12 bird species recorded from the 21 wetlands during August 2005 (Table 32), 11 are common and widespread throughout Australia.

The blue-billed duck *Oxyura australis* (Plate 29), however, is listed as 'Near Threatened' on the IUCN Redlist of Threatened Species (2004). This means the species is likely to qualify for a threatened category in the near future. Its major threats are considered from competition with invasive alien species, hunting, pollution, and habitat loss/degradation as a result of introduced fish, peripheral cattle grazing, salinisation and lowering of ground water (IUCN 2004). This duck, while not recorded during the current study, was seen by AWS beside the road causeway in site W020 during 2004 surveys.

Plate 29. Blue-billed duck ('Near Threatened' on the IUCN Redlist). Photo by Stuart Harris (photogallery.canberrabirds.org.au/swan_ducks.htm)

CONCLUSIONS

Physico-chemistry patterns

Multivariate analysis of the 21 wetlands sampled in the BMRC in August 2005 identified spatial variation in physico-chemical conditions between sites. The primary source of variation was salinity, with hypersaline sites separating from fresh/brackish sites. A range of parameters also related to these differences, including percent cover of vegetation, reeds/rushes and exposed/open sediment. Vegetative cover decreased with increasing salinity, and concomitantly the cover of exposed sediment increased. SPS203 showed considerable separation from other wetlands on the basis its considerably high dissolved oxygen levels.

On the basis of nutrients, ten of the 21 wetlands had elevated total nitrogen concentrations which exceeded the ANZECC/ARMCANZ water quality guidelines for the protection of aquatic ecosystems, and these wetlands classified as eutrophic. Total phosphorus concentrations were elevated in only two wetlands (W007 and W016), and as such, phosphorus is likely the limiting nutrient in BMRC wetlands. Increased phosphorus levels in these wetlands, particularly those holding water into summer will likely result in problem algal or macrophyte growth.

Faunal patterns

Patterns were found within aquatic invertebrate assemblages (permanent, temporary and total fauna), whereby wetlands formed distinct groups. Invertebrate community structure was primarily influenced by salinity, with the fresh/brackish wetlands consistently separating from the hypersaline sites. A number of species were found to typify the hypersaline sites, including microcrustacea (permanent taxa) and diptera species such as *Tanytarsus barbitarsus*, ephydrid larvae and muscid pupae. High abundances of such species perhaps provide a good indication of elevated historical salinities within wetlands.

Table 32. Vertebrate species from BMRC wetlands sampled in August 2004 and 2005. Values are abundances. NB: * = observed but no counts taken, + = tadpoles seen, but no adult frogs heard calling.

		1	2	4	6	7	8	9	10	11	15	16	18	19	20	52	56	61	70	71	72	203
FROGS																					+	
Bleating frog	*Crinia pseudinsignifiera*							*			*											
Motorbike frog	*Litoria moorei*							*		*												
Banjo frog	*Limnodynastes dorsalis*														*							
FISH																						
Gobiidae																						
Swan River Goby	*Pseudogobius olorum*							1														
BIRDS																						
ANATIDAE																						
Tadorninae																						
Shelduck	*Tadorna tadornoides*		2											2	*			1				
Anatinae																						
Chestnut teal	*Anas castanea*							10				3										
Pink-eared duck	*Malacorhynchus membranaceus*														*							
Oxyurinae																						
Blue-billed duck	*Oxyura australis*														#							
Musk duck	*Biziura lobata*														*							
Podicipedidae																						
Little grebe	*Podiceps ruficollis*							10							*							
Rallidae																						
Coot	*Fulica atra*														*							
Bush-hen	*Gallinula olivacea*							*														
Charadriidae																						
Black-fronted dotterel	*Charadrius melanops*	4																				
Red-kneed dotterel	*Erythrogonys cinctus*																					
Banded plover	*Vanellus tricolor*									4												
Recurvirostridae																						
Pied stilt	*Himantopus himantopus*		4							10		2										

observed in 2004

Analysis of species richness across wetlands reflected a strong decline in diversity with increasing salinity, particularly with the loss of the macroinvertebrate fauna, and within this component, the Insecta tended to be the most adversely affected by increasing salinity.

Species Conservation Significance

In general terms, the aquatic invertebrate fauna of the BMRC was characterised by commonly occurring, widely distributed, ubiquitous, salt tolerant species, with the majority of rarer, less commonly encountered species recorded from the few fresher water sites. Site W072, a Gnamma hole located on Miamoon granite rock outcrop, supported several of these less commonly encountered, endemic species, as is common for granite outcrops in the Wheatbelt Region.

Very few species endemic to the southwest of the State were collected (6 commonly encountered endemics and 3 rarer endemics), with half the recorded species being cosmopolitan in distribution. Generally, endemic taxa occur in less disturbed, higher quality conditions than those characteristic of wetlands within the BMRC. The majority of endemic taxa occurred in the fresh/brackish wetlands, with the exception of the anostracans *Parartemia contracta* and *P. ?longicaudata*, and the chironomid *?Cladopelma sp*. The hypersaline sites tended to support predominantly cosmopolitan and indeterminate species.

Of particular note within the permanent fauna were four species of rotifer. Of these species, one represents the first record in Australia (*H. propinqua*), one is the first record from Western Australia (*Proales daphnicola*), one is new to science (*Hexarthra* sp. nov), and the other has not been formally recorded from Australia (*Trichocerca obtusidens*).

Within the macroinvertebrate fauna there were also noteworthy records, including a number of Chironomid species. For example, ?*Cladopelma* sp. nov., appears to be a new species to science. An additional species collected during the current study, Orthocladiinae sp. BM2, was not recognised as any of the previously recorded Orthocladiinae species.

Storey *et al.* (2004a) reported the introduced anostracan *Artemia parthenogenetica* from the saline to hypersaline wetlands. In August 2004 *A. parthenogenetica* was again recorded from W006 and W019 (Storey *et al.* 2004b). In addition, three native species of *Parartemia*, *Parartemia serventyi Parartemia contracta*, and *P. longicaudata* endemic to south-western Australia have been recorded from several sites. Generally, *Parartemia* occur under less saline conditions, whilst *Artemia* prefer saline to hypersaline conditions.

Finally, three exotic, introduced species have been recorded from the BMRC; the brine shrimp *Artemia parthenogenetica*, the freshwater crayfish *Cherax destructor* (not recorded from the present study), and the aquatic snail *Physa acuta*.

Wetland Conservation Significance & Priority Wetlands for Future Monitoring

Wetlands were dominated by cosmopolitan species, having pan-continental or southern Australian distributions, and in general terms, the number of taxa of special interest were no greater, and possibly lower than would be expected for a survey of this kind of less disturbed wetlands in other parts of the south-west of the State. Species endemic to the south-west of Western Australian were few and mainly recorded from the fresher water sites (viz. W072, W009, W052, W011, W010, W015). As such, these sites inherently have higher conservation values. It must be noted however, that the values of these wetlands may vary from year to year, depending upon the water regime and recent past history. It is likely that following good winter rains, and especially after a series of wet years, especially if wetlands do not dry and remain fresh, they will support a greater diversity of species, as seen in site SPS203 in 1999 versus 2004/2005.

Priority wetlands for future monitoring were determined on the basis of both biodiversity and percent temporal pairwise similarity. 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. Wetlands were then ranked according to their mean rank (Table 33 and 34). A total of ten wetlands were chosen, with five from each salinity type (hypersaline and fresher water sites).

Hypersaline wetlands recording the greatest number of fauna were W002, W061, W001, W004, and W019 (Figure 49). These sites recorded high species diversity and generally showed little between-year variation. Thus, they provide a good basis for future monitoring and comparisons. The rotifer, *Hexarthra propinqua*, was found at W002 and is the first record of this species in Australia.

Table 33. Rank of hypersaline wetlands based on number of total invertebrate fauna, number of total vertebrate fauna, percent temporal similarity, and the number of conservation significant fauna. Wetlands are presented in ascending order based on their mean rank.

	Total Invertebrate Fauna Rank	Total Vertebrate Fauna Rank	% Temporal Pairwise Similarity Rank	Conservation Significant Fauna Rank	Mean Rank
W002	1	1	6	1	2.25
W061	2	2	4	4	3
W001	5	2	1	4	3
W004	2	5	2	4	3.25
W019	5	2	3	4	3.5
W070	4	5	5	4	4.5
W008	5	5	8	2	5
W056	5	5	7	4	5.25
W018	5	5	9	4	5.75
SPS203	10	5	12	2	7.25
W006	11	5	10	4	7.5
W007	13	5	11	4	8.25
W071	12	5	13	4	8.5

Table 34. Rank of fresher water wetlands based on number of total invertebrate fauna, number of total vertebrate fauna, percent temporal similarity, and the number of conservation significant fauna. Wetlands are presented in ascending order based on their mean rank.

	Total Invertebrate Fauna Rank	Total Vertebrate Fauna Rank	% Temporal Pairwise Similarity Rank	Conservation Significant Fauna Rank	Mean Rank
W011	1	3	3	1	2
W020	3	1	NA	3	2.33
W010	4	5	1	2	3
W009	5	2	4	3	3.5
W072	2	5	7	5	4.75
W015	6	5	2	6	4.75
W016	8	4	5	6	5.75
W052	7	5	6	6	6

The highest taxa richness from fresher water wetlands within the BMRC were recorded from W011, W020, W010, W009, and W072 (Figure 49). Of particular conservation importance is the new *Cladopelma* species from W011, new species of *Hexarthra* (rotifer) and Orthocladiinae (chironomid) from W072, the 'Near Threatened' blue-billed duck, *Oxyura australis* seen at W020 in 2004, the collection of *Proales daphnicola* (rotifer) from W009 which constitutes a new record for Western Australia, and the presence of the Swan River goby from W009. These wetlands require ongoing monitoring and management.

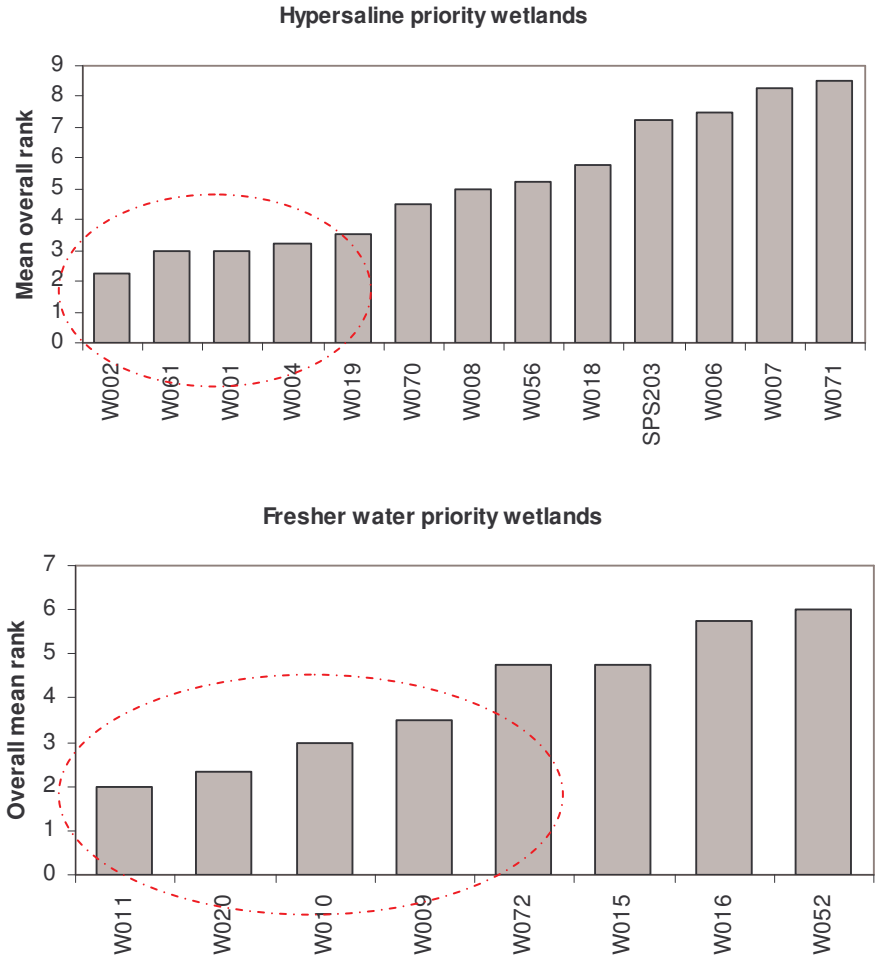

Figure 49. Priority wetlands for the hypersaline sites (above) and fresher water sites (below).

Regional Conservation Significance

When compared with other studies of this type, the wetlands from the BMRC showed low species richness. However, comparisons in taxa richness between this and other studies must be treated with some caution because of differences in aspects such as sampling method, level of taxonomic resolution, inclusion/exclusion of micro-fauna/micro-crustacea, number of times sites have been sampled, and types of wetlands (fresh versus saline). Bearing these limitations in mind, comparisons are possible with studies of wetlands in Two Peoples Bay Nature Reserve (Storey *et al*., 1993), wetlands on the Swan Coastal Plain (Davis *et al*., 1993), South Coast wetlands (Edward *et al*., 1994), wetlands in the Perth Airport (Halse & Storey, 1996), the wetlands in the Buntine-Marchagee catchment sampled under the SAP in September 1999 (Stuart Halse, Dept CALM, unpub. dat.), wetlands in the Marchagee district, immediately to the west of the study area (Halse, 1981), the 223 wetlands sampled across the Wheatbelt region under the SAP (Pinder *et al.* 2004), and Lakes Toolibin and Walbyring, east of Narrogin (Halse *et al*., 2000).

In the present study, average number of invertebrate taxa per site was 17.33, but with maximum counts at the fresher wetlands of 43 species at W011 (cond. 3.78 mS/m), 37 at W072 (cond. 0.6 mS/m), 35 at W010 (cond. 4.7 mS/m), 34 at W015 (cond. 10.7 mS/m), and 31 at W052 (cond. 2.85 mS/cm). Storey *et al* (1993) sampled three wetlands in the Two Peoples Bay Nature Reserve (Lakes Angove, Moates and Gardner Lakes) in winter 1990 and summer 1991, and recorded a total of 170 taxa, which included 47 taxa of Protozoa and Rotifera, 52 taxa of microcrustacea (Cladocera, Copepoda and Ostracoda), and 71 taxa of macroinvertebrates. The average number of macroinvertebrate taxa recorded in each season at the three lakes were 22.3 (winter) and 20.6 (summer), with respective maxima of 26 and 31 taxa from any one site.

Davis *et al.* (1993) studied the physico-chemistry and invertebrate fauna of 41 wetlands on the Swan Coastal Plain in summer of 1989 and spring of 1989 and 1990. A total of 253 taxa were recorded, which included 73 taxa of micro-invertebrates (37 species of Cladocera, 26 species of Ostracoda, and 10 species of Copepoda). Totals of 140, 203 and 187 taxa were recorded in summer 1989, spring 1989 and spring 1990, respectively. The average (and maximum) number of macroinvertebrate taxa per wetland were 25.8 (50), 35.1 (65), and 34.6 (66) in summer 1989, spring 1989 and spring 1990 respectively, with an average total (and maximum) per site of 52.8 (95) taxa for the three sampling occasions combined.

Edward *et al.* (1994) sampled 15 permanent wetlands in winter and 12 wetlands in summer 1991 along the south coast of WA between Cape Naturalist and Albany. A total of 209 taxa were recorded, including 33 taxa of microcrustacea. Mean number of taxa (including microfauna) recorded in winter and summer were 32.4 and 39.0, with respective maxima of 51 and 56 taxa.

Halse & Storey (1996) sampled nine swamps around Perth Airport in September and November 1995 and recorded a total of approximately 125 taxa, including 42 taxa of micro-crustacea. A maximum of 56 taxa (including 12 taxa of microcrustacea) was recorded at a wetland on one occasion, with an average per wetland of 30 taxa (including microcrustacea).

Halse (1981) recorded 18 species of aquatic invertebrate from five wetlands in the Marchagee area, with some sites sampled on five occasions. Overall diversity was lower than the present study, likely indicating differences in sampling methodology and levels of taxonomic resolution (i.e. rotifers were not identified). As for the present study, Halse (1981) noted that as salinity increased the number of species in a lake decreased. This would apply to biodiversity within a lake over time, but also amongst lakes of differing salinity. Pinder *et al.* (2004) also discussed the implications of salinity on aquatic invertebrate composition, suggesting that species richness is reduced as salinity increases, with replacements by salt-tolerant species. Halse (op. cit.) also noted that the fauna of the saline lakes was dominated by crustacea and microcrustacea, with insects more prevalent in the fresher lakes. The same was apparent from the BMRC samples, with insects most prevalent in the fresher wetlands. Halse *et al.* (2000) suggested however, that the invertebrate fauna of the Wheatbelt Region was comparatively salt-tolerant, and that substantial changes in community composition would only be seen when salinities exceeded 10 000 mg L^{-1} (approx 1900 mS/m).

Generally, invertebrate taxa richness from wetlands within the BMRC appears to be lower than that recorded from similar studies in the south-west of Western Australia, with the exception of the fresher water sites (mean richness of 33.25 species).

Comparisons with earlier data sets

Comparisons with the earlier BMRC sampling results showed marked differences in species assemblages over time. Taxa richness was generally lower in 2005 than all previous surveys of the BMRC wetlands. Invertebrate community change appeared to be influenced greatly by changes in salinity, for example at SPS203; salinity at this site was 4.2 ppt in 1999 and approx 70 ppt in 2004, with taxa richness declining from 54 taxa in 1999 to 9 in 2004. Differences may also be attributable to differing intensity of field sampling by personnel with varying levels of experience, seasonal differences in composition reflecting different successional stages in each wetland, or inter-annual variation in water regime reflecting differing winter rainfall. Some wetlands showed little change over time (i.e. W002 & W004).

Wetland Characterisation

Analysis of the August 2005 data set established strong predictive relationships between taxa richness and wetland salinity and vegetative cover. Essentially, fresher wetlands comprise greater cover of vegetation and ultimately record higher taxa richness. Since these parameters provide good ability to predict biodiversity, they may prove useful as efficient and inexpensive parameters to measure in preference to the more time consuming and technically challenging invertebrate fauna monitoring.

Evaluation of Analysis

The 21 samples collected from the BMRC in August 2005 constitute a small but robust data set, with sites covering a broad range of wetland types. This has provided valuable information on the range of conditions that exist in the BMRC. Interestingly, as for the August 2004 data set, a high number of singleton species (52% of taxa occurred at only one site) were recorded, and this likely contributes to the high level of variability and separation between sites. The November 2003 samples from the BMRC also contained a high proportion of singletons (41% of species), and in a study encompassing 223

wetlands across the wheatbelt, Pinder *et al.* (2004) similarly found a high proportion of singletons.

The analyses indicate wetlands of differing conservation value based on levels of endemicity and overall biodiversity, with fresh-brackish water wetlands having the highest conservation significance in terms of highest species diversity and occurrence of rare/endemic taxa. Additional samples from these and adjacent wetlands in future years, standardising as much as possible for sampling method and season will provide greater insights into their conservation significance and inter-annual variation in response to varying water regimes. Such a data set will provide a firm basis for ongoing monitoring, against which future changes may be assessed.

Temporal variability/succession needs to be examined over an annual cycle (early, mid and late wet season) to characterise changes in aquatic fauna assemblages due to wetting/drying cycles and successional change.

RECOMMENDATIONS

- The 10 selected priority wetlands should be sampled in early, mid and late winter/spring to examine seasonal succession in relation to wetting/drying and increasing salt concentrations. Standardised sampling procedures for collecting invertebrates and water quality parameters must be adhered to so that operator differences are minimised.

- Since salinity affects assemblage composition, salt load needs to be determined for each of the 21 BMRC wetlands to establish a relationship between salinity and depth. This would allow detection of changes in salt load over time, making correlations between community change and salt more tangible.

- On-going monitoring using the same protocols should occur on an infrequent basis, with sampling initiated by either changes in water quality or in response to catchment management activities that have been shown to have a perceptible influence on catchment condition and therefore likely to influence wetland condition.

- In future surveys, W011 and W012 should be sampled separately to determine whether each site in isolation supports high diversity in relation to other wetlands in the BMRC.

- Salinity and extent of vegetative cover/exposed sediments were shown to have a good ability to predict biodiversity. It is recommended that these parameters are measured on a more frequent basis than invertebrate monitoring to assess changes to wetland condition.

ACKNOWLEDGEMENTS

The authors would like to thank the following for assistance with taxonomy; Don Edward, University of W.A. (chironomids), Dr Mark Harvey, Western Australian

Museum (mites), and Willem De Smet, Antwerp (*Proales daphnicola*). Glenn Shiell is thanked for assistance with sample processing. The map of the study catchment was provided by CALM. Data from the adjacent wetlands sampled under the SAP were provided by Stuart Halse. Constructive comments on a draft were provided by Glen Daniel, Jodie Watts and Gavan Mullan. Glen Daniel is thanked for his efficient overall management of this project on behalf of CALM. Landowners are thanked for access to wetlands within property boundaries.

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APPENDICES

Appendix 1. Physico-chemical data from each wetland.

Appendix 1. Physico-chemical parameters measured from each of the 21 wetlands sampled in August 2005

	DO (%)	Water temp (ºc)	Cond (mS/cm)	pH	Depth (m)	Colour (TCU)	Tot_N (mg/L)	Tot_P (mg/L)	Turb (NTU)	Chl a (mg/L)
W001	23.6	9.12	78.7	3.96	0.15	2.5	2.4	0.005	3.6	0.045
W002	19.6	11.95	62.9	5	0.24	2.5	4.5	0.01	2.5	0.05
W004	33.5	14.1	74.7	8.87	0.6	8	1	0.01	3.5	0.052
W006	32.7	15.08	144	8.41	0.24	8	1.3	0.03	2.4	0.069
W007	24.9	12.47	164	8.16	0.16	69	2	0.09	81	0.33
W008	22.9	13.87	77.3	8.35	0.11	28	0.51	0.02	4.5	0.073
W009	24.2	12.35	3.31	8.95	0.42	23	2.9	0.02	0.9	0.065
W010	25.5	11.79	4.7	10	0.27	15	0.71	0.02	0.5	0.069
W011	22.6	11	3.78	9.97	0.24	63	0.5	0.02	0.9	0.062
W015	25.2	11.86	10.7	7.95	0.15	680	3.5	0.04	0.7	0.061
W016	29	11.83	18.4	8.68	0.2	250	1.4	0.13	1.5	0.061
W018	27.8	12.96	206	7.96	0.1	16	5	0.05	19	0.22
W019	29.4	12.91	214	7.63	0.2	10	0.97	0.04	9.4	0.21
W020	51.3	15.07	8.81	9.24	0.36	19	2	0.04	5.4	0.27
W052	13.4	11.14	2.85	7.54	0.47	12	9.8	0.02	3.9	0.057
W056	38.6	15.58	75.7	8.74	0.11	13	1.3	0.02	12	0.11
W061	27.1	10.76	56.6	9.12	0.02	29	2	0.01	16	0.071
W070	31.6	13.39	210	7.69	0.27	37	3.9	0.04	11	0.22
W071	34.9	15.22	181	8.05	0.13	60	1.5	0.03	23	0.022
W072	33.4	13.53	0.6	6.74	0.7	89	0.43	0.02	1.7	0.052
SPS203	77.3	20.86	57.7	9.05	0.1	19	0.75	0.01	0.9	0.021

Appendix 1. (cont.)

	Salt Crust (mm)	Benthic mat (mm)	Veg (% cover)	Sediment (% cover)	Riparian (% cover)	Samphire (% cover)	Macrophytes (% cover)	Reed/rushes (% cover)	Benthic mat (% cover)
W001	0	0	0	100	0	0	0	0	0
W002	0	0	1	80	0	0	35	0	0
W004	0	0	5	95	0	0	5	0	0
W006	2	2	0	100	0	0	0	0	65
W007	0	2	0	100	0	0	0	0	50
W008	0	2	5	95	0	0	5	0	75
W009	0	0	2	98	1	0	0	1	0
W010	0	0	25	75	0	0	20	5	0
W011	0	2	87	25	2	0	80	5	15
W015	0	0	65	30	0	10	35	20	0
W016	0	0	65	35	0	50	15	0	0
W018	4	0	0	100	0	0	0	0	0
W019	1	0	0	100	0	0	0	0	0
W020	0	0	15	85	0	0	0	15	0
W052	0	0	50	50	0	0	0	50	0
W056	0	0	5	95	0	0	5	0	0
W061	0	0	60	40	1	1	90	0	0
W070	3	0	0	99	0	1	0	0	0
W071	0	0	0	100	0	0	0	0	0
W072	0	0	50	50	0	0	50	0	0
SPS203	2	0	0	100	0	0	0	0	0

Appendix 2. List of voucher specimens

Appendix 2. Additional voucher specimens, indicating voucher code (continued from Storey *et al*. 2004b), family name, species name and site details.

Voucher #.	Family	Species	Site details
Coleo 23	Dytiscidae	*Antiporus gilberti*	W072 24/8/05
Coleo 24	Hydrophilidae	*Berosus macumbensis*	W016 23/8/05
Coleo 25	Hydrophilidae	*Berosus nutans*	W072 24/8/05
Coleo 26	Hydrophilidae	*Helochares tenuistriatus*	W009 23/8/05
Coleo 27	Brentidae	Brentidae spp	W072 24/8/05
Hemi 5	Saldidae	Saldidae spp	W072 24/8/05
Odo 9	Lestidae	*Austrolestes pysche*	W020 22/8/05