YARRA YARRA AQUATIC MONITORING

ASSESSING THE EFFECT OF DEEP DRAINS ON THE ECOLOGICAL HEALTH OF THE YARRA YARRA PLAYAS AND WETLANDS

prepared for

YARRA YARRA CATCHMENT MANAGEMENT GROUP

by

Wetland Research & Management

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Disclaimer

This document has been printed on 'Reflex Green Recycled Paper'.

Frontispiece (clockwise from left): sunset at Yarra Yarra site 13 (photo: J. Lynas), *Paratemia* (photo: provided by Russ Shiel) and macroinvertebrate sampling at site 11 (photo: A. Storey).

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1 INTRODUCTION

1.1 Background

The Yarra Yarra catchment has an extensive network of ephemeral lakes (playas) and wetlands, nearly all of which are saline. There are approximately 60 sub-catchments within the catchment, with surface runoff from these areas draining into the central receiving endoreic (land-locked) chain of larger lakes (especially the 60 km long Lake Mongers). The entire lake system extends approximately 300 km from saline wetlands near Kalannie to Yarra Yarra Lake near Carnamah, with a fall of only about 40 m. The low gradient of the system, combined with blockage of many creeklines means that surface water does not drain to the lowest, central chain of wetlands, but ponds along creeklines and in lower and mid-slope depressions. Clearing of vegetation for agriculture has removed the natural pumps to transpire this water, resulting in recharge to the saline aquifer, bringing the saline groundwater table to the surface. This in turn makes arable land non-productive and kills remnant vegetation, with only species such as samphire and saltbush capable of withstanding the water-logging and salinity.

Plate 1. Deep drains constructed in the Yarra Yarra catchment.

To address this issue, the Yarra Yarra Catchment Management Group (YYCMG) are rehabilitating the streamlines through de-silting water courses and construction of deep drains (Plate 1). The drains are designed to keep the saline groundwater separate from the fresher surface flows, and generally avoid using natural streamlines.

Although there are many benefits of these management approaches, there is a disadvantage in that some of the groundwater is likely to be of poor quality, reflected in low pH, high acidity, high salinity and high concentrations of iron and aluminium. Acidic groundwater in the wheatbelt is known to contain elevated levels of metals (Halse *et al.* 2003), many of which are toxic to aquatic (and terrestrial) fauna (and flora) at high dissolved concentrations. Low pH is also toxic to aquatic fauna.

As some drains flow through or discharge into playas and wetlands there is concern over the ecological impacts of the drainage water on the ecological health of wetlands. The Yarra Yarra Catchment Management Group commissioned *Wetland Research & Management* to assess the ecological effects of deep drainage on these receiving wetlands.

1.2 Study objectives

The main objective of this project was to assess the effects of deep drainage on the ecological health of receiving playas and wetlands. This was achieved by comparing water samples and macro- and microinvertebrate samples collected from reference sites with those collected from exposed sites within the Yarra Yarra Catchment area.

2 METHODS

2.1 Study area

The Yarra Yarra catchment is one of four sub-regions within the Northern Agricultural Region (NAR) of southwestern Western Australia, approximately 250 km north of Perth (Figure 1). The catchment covers around one million hectares and comprises a chain of playas and ill-defined wetlands bounded by a series of low hills. The playas are part of an ancient natural drainage system (palaeo-drainage) that has slowly changed over the past 30,000 - 50,000 years in response to increasing aridity (Boggs 2007).

Approximately 97% of native vegetation has been cleared for agriculture and nearly 10% of the arable land is now affected by dryland salinity (secondary salinisation). While the playas are naturally saline, many of the formerly fresh wetlands have become saline due to secondary salinisation resultant of rising groundwater levels (Boggs 2007, Georges *et al.* 2008).

2.2 Sites and sampling design

A number of playas and wetlands were selected in consultation with YYCMG staff, including reference (with no drains), exposed (with drains), and future exposed sites. The sites covered six sub-catchments and a variety of physico-chemical types, including saline, brackish and naturally acidic wetlands. Sites were sampled over a 4-day period between 19th and 22nd May 2008. A list of the sites, along with their GPS location and treatment type (control, exposed, future exposed) is provided in Table 1. Maps showing the location of each site within the various sub-catchments are provided in Figures 2 through 7. Photographs of sites taken at the time of sampling are provided in Appendix 1.

Groundwater in many areas of the catchment is naturally acidic and the pH of playas in these areas will be influenced by natural discharge of acidic groundwater and recharge by near neutral rainfall. In some wetlands, the pH may also be naturally low due to humic-rich peaty soils. The pH and salinity of the Yarra Yarra system is further complicated by discharge of saline acidic waters *via* the deep drains and rising saline acidic groundwaters due to catchment clearing. The depth to groundwater is generally thought to be less than 10 m rising to 2 m in the vicinity of the playas. The general direction of groundwater flow is from Mongers Lake to Yarra Yarra Lake with “each playa acting as a discharge point” (Boggs 2007).

Table 1. Sites sampled within the Yarra Yarra catchment of Western Australia, and their GPS location (UTM WGS84).

Sub-catchment	Site No.	Treatment	GPS Location		Comments
			Easting	Northing	
Lake Hillman	1	Control (Reference)	50 515080	6647205	Within Lake Hillman
	2	Exposed	50 517922	6645252	Within Lake Hillman close to inflow from deep drain; strong sulphur smell off lake. In receiving environment of acidic hypersaline discharge from Nixon's drain.
	3	Control (Reference)	50 516515	6644722	Small basin on the edge of Lake Hillman; not inundated by flow from main lake but may be connected through the shallow groundwater (R. Nixon, pers. comm.).
Lake DeCourcy	4	Exposed	50 513349	6653367	Within Lake DeCourcy close to inflow from deep drain.
	5	Control (Reference)	50 509299	6656261	Within Lake DeCourcy - large, broad, flat playa; strongly affected by wind fetch.
Mongers 55	6	Control (Reference)	50 476926	6695158	
	7	Control (Reference)	50 477939	6693209	Tinika (Boat) Lake
	8	Exposed	50 479955	6695763	Extremely degraded; downstream end of large deep drain.
	9	Exposed	50 478748	6693995	Crystal Lake. Extremely degraded; upstream of #8; deep drain flows through wetland.
	10	Exposed	50 478797	6694561	Extremely degraded; bunds of deep drain eroded & drainage waters flow into wetland.
	11	Control (Reference)	50 478257	6691517	Lake MacPherson. Impacted by cattle; dead trees suggest increased inundation. Likely influenced by acidic groundwater.
Mongers 16	15	Control (Reference)	50 471404	6719355	Severe algal bloom.
	16	Future Exposed	50 471726	6718710	
	17	Control (Reference)	50 471903	6719202	*May be impacted by flow from #16.
	18	Control (Reference)	50 471748	6718277	
Goodlands	12	Control (Reference)	50 503487	6664779	
	13	Future Exposed	50 508992	6663990	
	19	Future Exposed	50 508629	6664863	
	20	Control (Reference)	50 508966	6664599	Surface drain from east but no deep drains; flows into #19 during high rainfall years.
	21	Exposed	50 505020	6659760	Very large playa, strongly affected by wind fetch; deep drain flows through but constitutes relatively small area of the total lake.
Xantippe	22	Control (Reference)	50 504639	6652252	
	23	Exposed	50 503349	6653220	Extremely degraded; drain bunds eroded and sheet flows bring drainage waters into eastern side of wetland.
	24	Exposed	50 503722	6653531	Extremely degraded; deep drain flows through #23 and into #24; large deposits of silt from drain.
	25	Control (Reference)	50 504016	6651490	

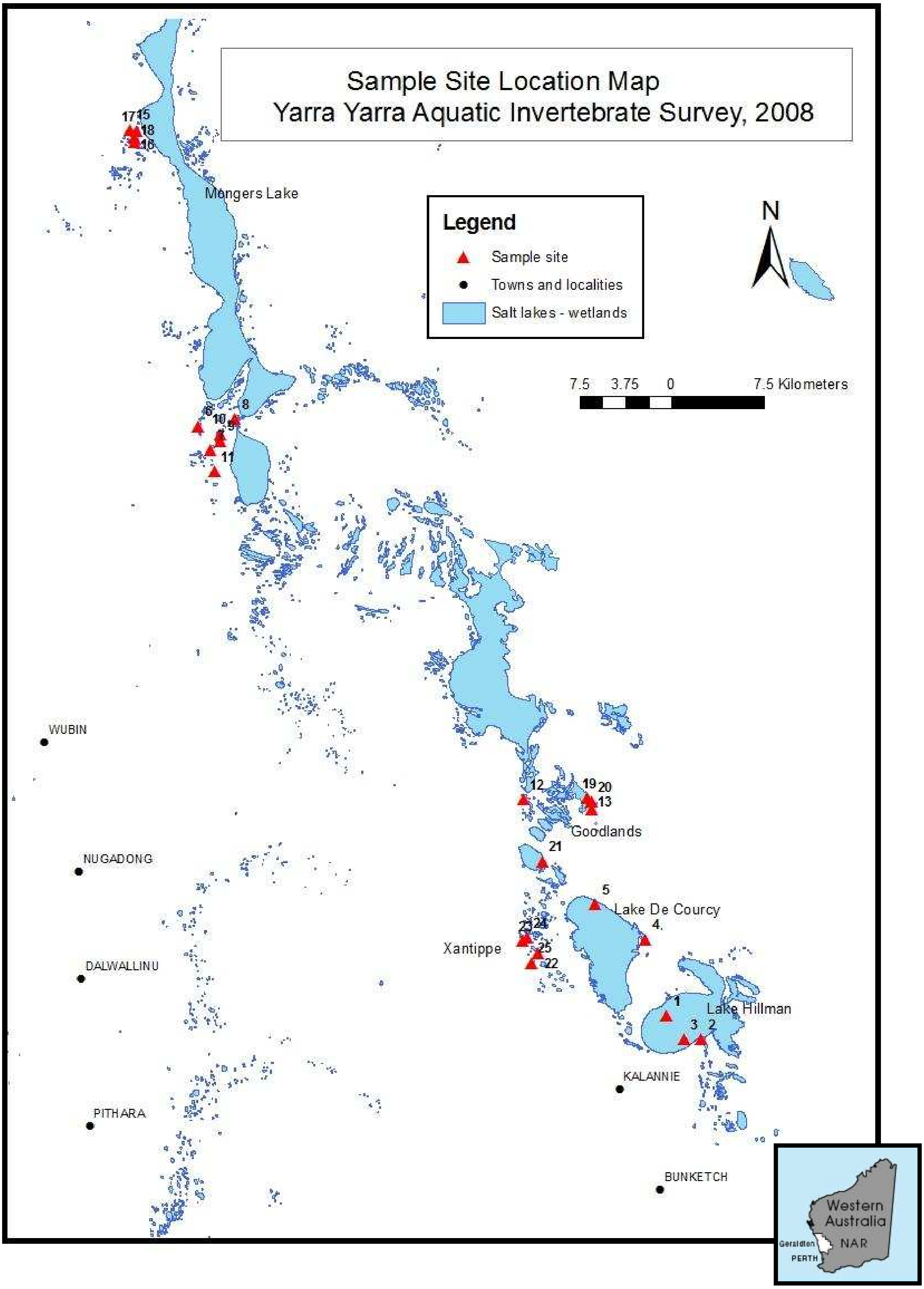
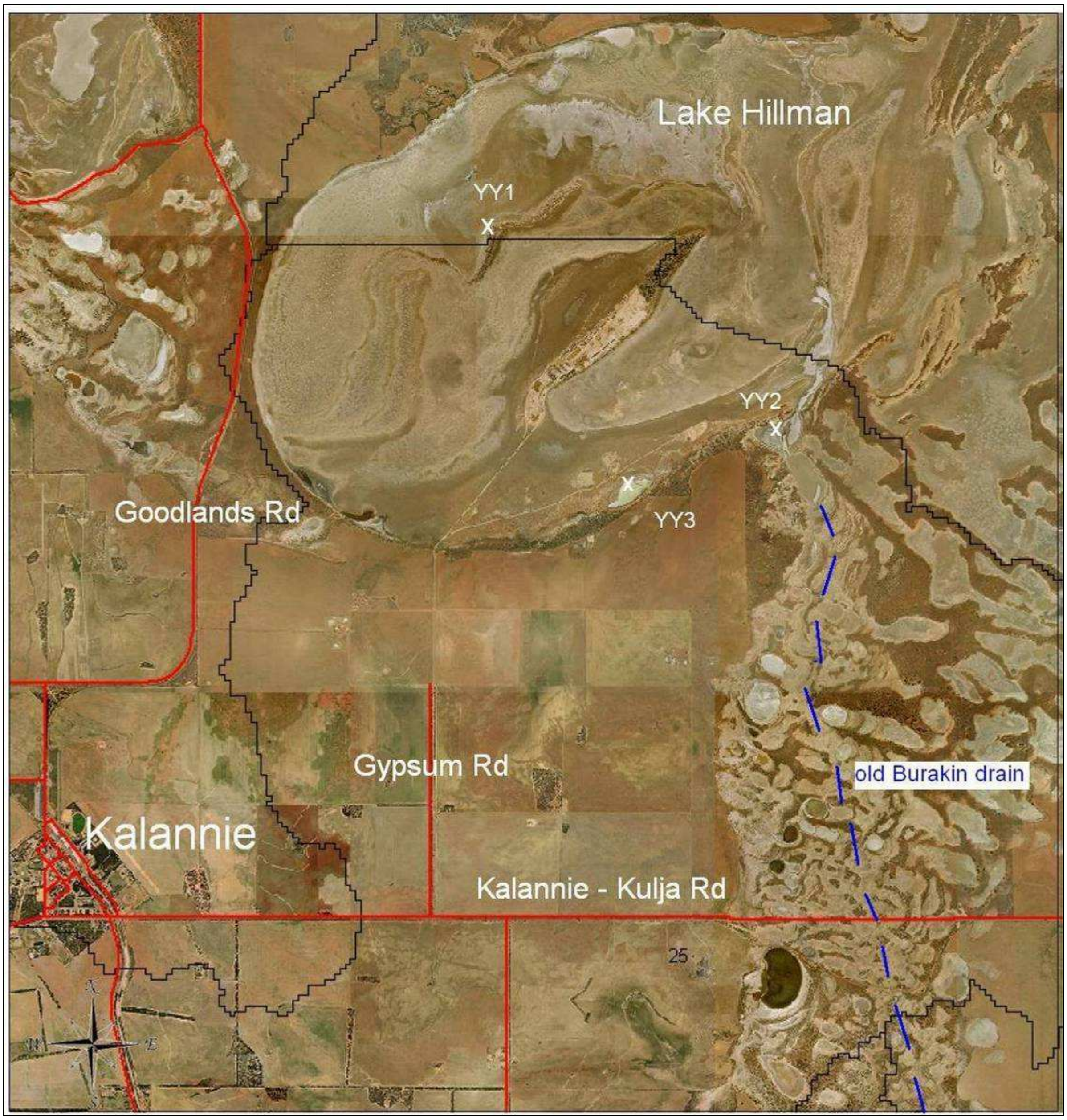


Figure 1. Overview of sites sampled within the Yarra Yarra catchment in the Northern Agricultural Region (inset) of Western Australia (map courtesy Ian Fordyce).



—	road / track
—	stream
– –	delivery drain
X	sample location

Figure 2. Map showing the location of sample sites within the Lake Hillman sub-catchment. Site numbers are prefixed by YY.

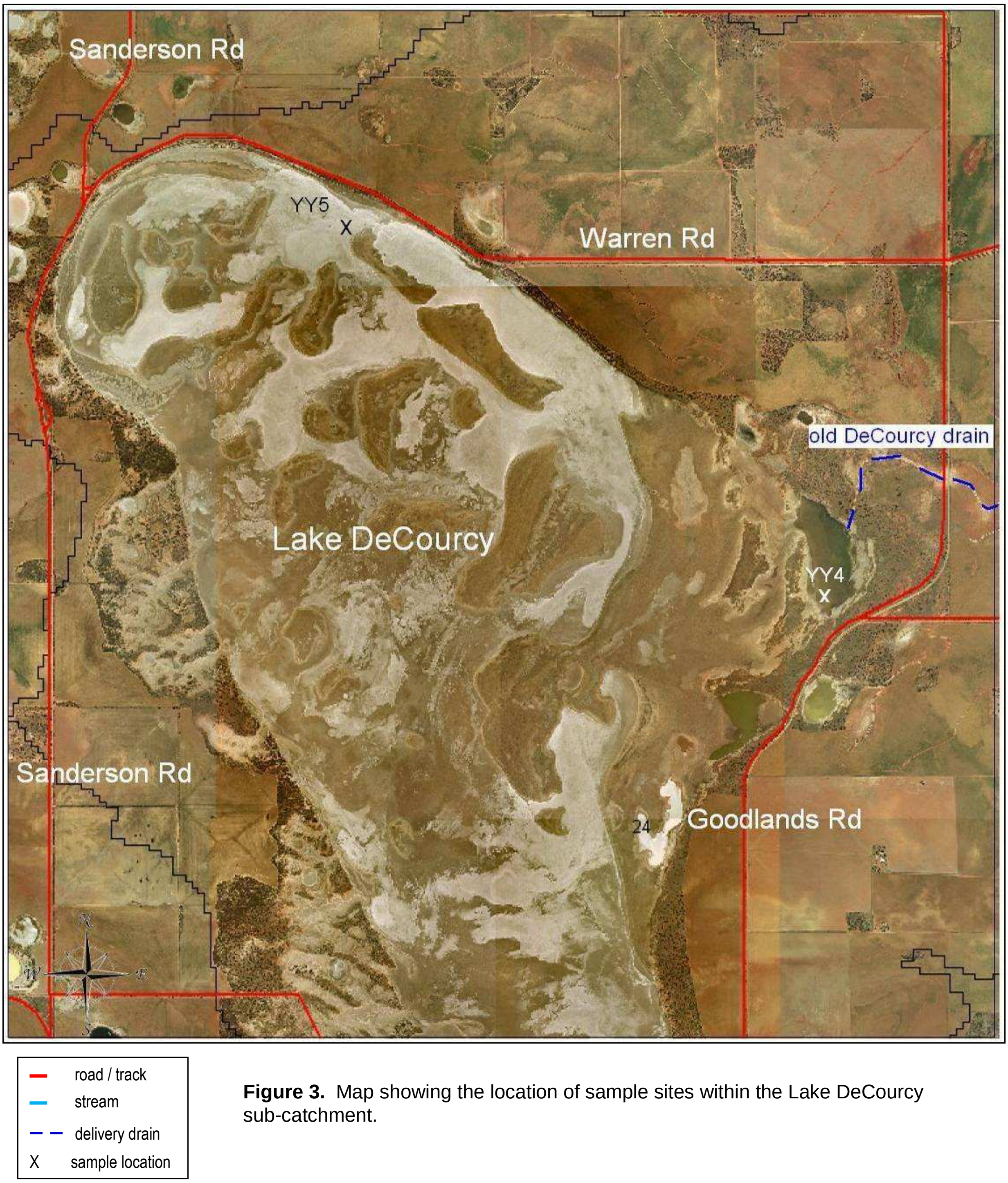


Figure 3. Map showing the location of sample sites within the Lake DeCourcy sub-catchment.

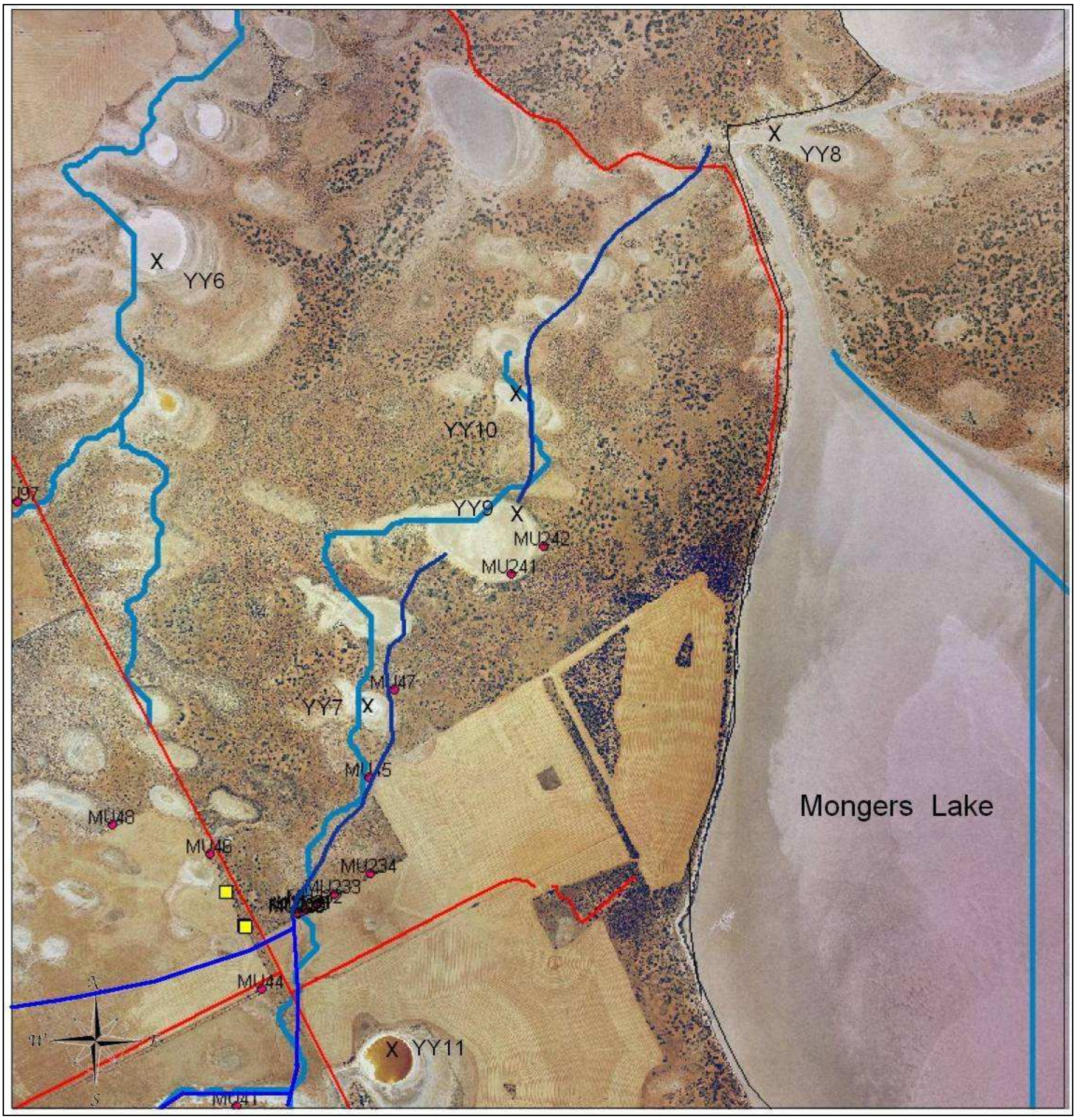
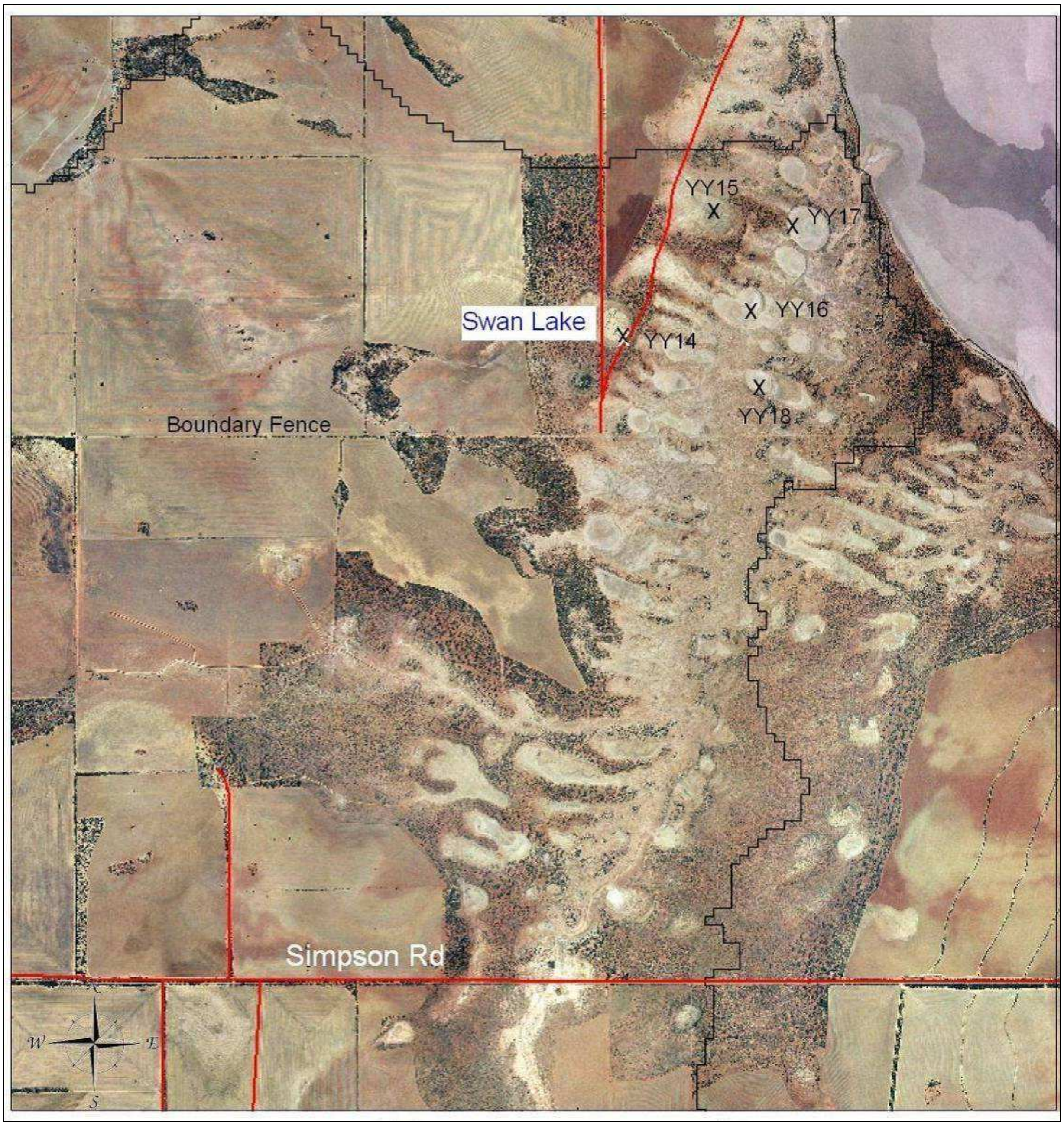


Figure 4. Map showing the location of sample sites within the Mongers 55 sub-catchment.



road / track
X sample location

Figure 5. Map showing the location of sample sites within the Mongers 16 sub-catchment.

—	road / track
X	sample location

Figure 6. Map showing the location of sample sites within the Goodlands sub-catchment.

—	road / track
X	sample location

Figure 7. Map showing the location of sample sites within the Xantippe sub-catchment.

2.3 Water Quality

At each site a number of water quality variables were recorded *in situ* using portable WTW field meters, including pH, electrical conductivity (mS/cm), dissolved oxygen (% and mg/L), redox potential (mV), and water temperature (°C). Maximum water depth (m) was measured using a graduated pole. A measure of turbidity (water transparency) was taken using a Secchi disk. Undisturbed water samples were taken for laboratory analyses of ionic composition, dissolved metals and nutrients. Samples collected for nutrients were filtered through 0.45 µm Millipore nitrocellulose filters. Samples collected for dissolved metals were filtered through 0.45 µm Millipore nitrocellulose filters and acidified in the field. All water samples were kept cool in an esky while in the field, and frozen as soon as possible for subsequent transport to the laboratory. All laboratory analyses were conducted by the Natural Resources Chemistry Laboratory, Chemistry Centre, WA (a NATA accredited laboratory). Water quality variables measured are summarised in Table 2.

Table 2. Water quality parameters measured.

TYPE	PARAMETER	UNITS
Basic water quality	pH	pH units
	Electrical conductivity	mS/cm
	Dissolved oxygen	% saturation
	Dissolved oxygen	mg/L
	Redox potential	mV
	Water temperature	°C
	Secchi depth	m
	Maximum water depth	m
Ions	Sodium (Na)	mg/L
	Potassium (K)	mg/L
	Calcium (Ca)	mg/L
	Magnesium (Mg)	mg/L
	Chloride (Cl)	mg/L
	CO_3	mg/L
	HCO_3	mg/L
	SO_4	mg/L
Nutrients	Nitrate (N_NO_3)	mg/L
	Total Nitrogen (N_total)	mg/L
	Total Phosphorus (P_total)	mg/L
Metals	Arsenic (As)	mg/L
	Cadmium (Cd)	mg/L
	Cobalt (Co)	mg/L
	Chromium (Cr)	mg/L
	Copper (Cu)	mg/L
	Iron (Fe)	mg/L
	Manganese (Mn)	mg/L
	Molybdenum (Mo)	mg/L
	Nickel (Ni)	mg/L
	Lead (Pb)	mg/L
	Selenium (Se)	mg/L
	Vanadium (V)	mg/L
	Zinc (Zn)	mg/L

2.3.1 ANZECC/ARMCANZ water quality guidelines

Water quality was assessed against current ANZECC/ARMCANZ (2000) guidelines for the protection of aquatic ecosystems in south-west Western Australia. The guidelines specify biological, sediment and water quality 'trigger' values 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 Appendix 2. Marine trigger values were also included for comparison because the majority of sites were hypersaline with electrical conductivities in excess of seawater; *i.e.* >50mS/cm. The marine guidelines for metal concentrations tend to be more lenient allowing for the greater complexing capacity of dissolved metals by chloride in seawater (WRM 2008a).

2.4 Microinvertebrates

Microinvertebrate fauna consists of microscopic fauna including micro-crustacea (ostracods, copepods and cladocera), protists and rotifers. Microinverterbates are used as bioindicators throughout the world for many reasons. Firstly, the microinvertebrate community holds a strategic position in food webs (Bunn & Boon 1993, Zrum & Hann 1997, Bunn & Davies 1999, Jenkins & Boulton 2003). They regulate the biomass of phytoplankton in the water column and epiphyton on submersed aquatic macrophytes through grazing (Zrum & Hann 1997). They also provide a food source for other organisms, such as macroinvertebrates (Bunn and Boon 1993, Zrum & Hann 1997, Bunn & Davies 1999, Jenkins & Boulton 2003). Many waterbirds feed directly on microinvertebrate fauna (Crome 1985), and most fish species depend on them for their first feed after hatching (Geddes & Puckridge 1989). Therefore, any change in the microinvertebrate community will ultimately result in changes to the entire aquatic ecosystem. Due to their short life cycle, rapid changes occur in their populations with disturbance in the ecosystem (Kaur & Ansal 1996). Lastly, they have intimate contact with the surrounding environment. They are planktonic, and continually exposed to the ambient water quality. Hence, they are vulnerable to environmental pollutants and provide a useful biomonitoring tool (Kaur & Ansal 1996). The microinvertebrate community also plays a role in nutrient cycling within wetland systems (Baldwin & Mitchell 2000).

Previous studies have shown that for assessing the conservation value of aquatic systems in south-western Australia, and for detecting subtle impacts on wetlands, the rarer components of the aquatic invertebrate fauna tend to be in the microinvertebrate fauna (Storey *et al.* 1993, Halse & Storey 1996, Halse *et al.* 1996, ARL 2005, WRM 2005a).

Microinvertebrate samples were collected from each site by gentle sweeping over an approximate 50 m distance with a 53 μm mesh pond net. Care was taken not to disturb the benthos (bottom sediments). Samples were preserved in 70% ethanol and sent to Dr Russ Shiel of The University of Adelaide for processing. Dr Shiel is a world authority on microfauna, with extensive experience in fauna survey and impact assessment across Australasia.

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

2.5 Macroinvertebrates

Macroinvertebrates (*i.e.* fauna retained by a 250 μm aperture mesh) typically constitute the largest and most conspicuous component of aquatic invertebrate fauna in both lentic (still) and lotic (flowing) waters. Macroinvertebrates are used as a key indicator group for bioassessment of the health of Australia's streams and rivers under the National River Health Program (Schofield & Davies 1996), and have inherent value for biological monitoring of water quality (ANZECC/ARMCANZ 2000).

Sampling was conducted with a 250 μm mesh FBA pond net to selectively collect the macroinvertebrate fauna. 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. Each sample was washed through a 250 μm sieve to remove fine sediment, leaf litter and other debris. Samples were then preserved in 70% ethanol.

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

2.6 Data analysis

All data, including taxonomic lists, were entered onto Excel spreadsheets and copies lodged with YYCMG for future reference. Mean values together with 95% confidence intervals (95% CV) for water quality variables and species richness were plotted. Correlation coefficients (Pearson's r) were calculated for regressions of species richness against salinity and pH.

The main aim of data analyses was to compare the fauna and water quality of the reference wetlands to the exposed wetlands. Macroinvertebrate and microinvertebrate data were analysed separately to test for differences in patterns, biodiversity and relationships to water quality.

To help differentiate any effects of acidic drainage water on wetland health, sites were grouped by:

- Potential impact, *i.e.* control/reference sites *versus* exposed sites. For the current study, control sites (n = 15) included future exposed sites, *i.e.* sites where planned drains are yet to be built. Exposed sites were those already potentially affected by deep drains (n= 9).
- pH, *i.e.* acidic sites *versus* neutral/basic sites. From a biological viewpoint, acidification effects can occur at pH values as high as 6.5 (Psenner 1994), therefore for the current study (and taking a slightly more conservative approach) sites with pH <6 were classed as acidic (n = 9) and those with pH >6 were classed as circum-neutral/basic (n = 15).

2.6.1 Multivariate statistics

To investigate patterns in the data, water quality and invertebrate species and abundance data were analysed using multivariate procedures from the PRIMER (v5) software package (Clarke & Gorley, 2006). All data were ordinated using Multi-Dimensional Scaling (MDS) (Clarke & Warwick, 2001). MDS 'groups' sites according to how similar (or dissimilar) they are to each other.

Water quality data were standardised prior to analysis, as recommended for multivariate analysis on mix-type variables (Harch *et al.* 1996). MDS was used in preference to Principle Components Analysis (PCA) for water quality data so that the hypotheses of differences in site type (*i.e.* exposed *versus* control and acidic *versus* neutral/basic) could be tested using the ANOSIM (similar to analysis-of variance) procedure in PRIMER. Invertebrate data were untransformed, but infrequently occurring species (species occurring in <5% of samples) were omitted from the ordination analysis to avoid 'low-occurrence' taxa having a disproportionate effect on the results (Gauch 1982, Belbin 1995). Analyses were performed on microinvertebrate presence-absence data and on macroinvertebrate presence-absence and abundance data. MDS ordinations were based on Bray-Curtis similarity matrices (Bray & Curtis 1957). ANOSIM was used to test the significance (p <0.05) of the separation of site types for both water quality and invertebrate data.

The SIMPER routine within PRIMER was used to examine which invertebrate taxa were contributing to any differences between sites types. Similarity matrices generated for water quality and invertebrate data were correlated using the RELATE routine within PRIMER analysis.

Relationships between water quality and invertebrate data were further assessed using BIOENV to calculate the smallest subset of environmental variables that explained the greatest percentage of variation in the species ordination pattern, as measured by Spearman rank correlation (ρ) (Clarke & Warwick 2001). The BIOENV performs best on a relatively small environmental data set and to this end, correlated variables were omitted. Mutually correlated variables identified by Spearman rank as having a high correlation coefficient (r ≥0.93) were excluded from BIOENV analysis:

Excluded Variable	**Correlated variable(s)**
Redox	pH
DO mg/L	DO % saturation
Cl	EC, Na
Na	EC, Cl
K	Mg, SO_4
SO_4	Mg, K
Cu	As, Ni
Ni	As, Cu
Cd	Cr, Mo, Se
Mo	Cr, Cd, Se
Se	Cr, Cd, Mo

3 RESULTS AND DISCUSSION

3.1 Wetland Condition

Most sites were considered degraded due to historic pastoral practices and unrestricted livestock access to the natural waterbodies. Sites 8, 9, 10 in the Mongers 15 sub-catchment and sites 23 and 24 in the Xantippe sub-catchment were classified as extremely degraded as they have been further impacted by drain construction. A deep drain flows through site 9 and into the wetland at site 8 before emptying into Lake Monger. Both sites 8 and 9 were heavily silted with clay fines. Site 10 lies between sites 8 and 9 with the drain originally constructed to bypass most of the wetland at site 10. However drain bunds have eroded and disposal waters now flow through the east side of the site 10 wetland. A similar problem has occurred at site 23 where disposal waters have broken through the bund wall and sheet flows now carry the water through the eastern side of the wetland and back out into the drain. The drain itself is heavily sedimented. It eventually flows into the wetland at site 24 where much of its sediment load appears to be deposited.

There was a severe, dense phytoplankton bloom at site 15 in the Mongers 16 catchment. The bloom had turned the entire small, shallow wetland pea-green. Halophilic (salt-tolerant) phytoplankton, diatoms and benthic microbial communities (benthic mats) usually dominate the ecology of saline playas and wetlands. Benthic mats are composed primarily of cyanobacteria and bacteria and often appear as pink mats on the beds of shallow, clear salt lakes (DoE 2005).

A few of the sites still retained relatively healthy fringing vegetation, most notably reference sites 1, 7 and 25. Vegetation was dominated by melaleuca thickets over samphire grading into eucalypt woodlands (York and salmon gum). Typically, benthic mats and algal blooms come to dominate where salinities and nutrients are too high for aquatic plants persist (DoE 2005).

3.2 Water Quality

3.2.1 General water parameters, salinity and acidification

Raw water quality data are presented in Appendix 3. At the time of sampling, water depths were mostly shallow (≤1 m) and water temperatures were moderate to high (13.8 - 26 ^{o}C). Dissolved oxygen (DO) levels ranged from moderate (52%) to super-saturated (>100%). DO levels are often 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). In waterbodies where rates of metabolism are high (*e.g.* where high algal growth occurs), DO levels can reach super-saturation during the day, but may drop to near zero (anoxia) overnight as a result of high rates of respiration. Sustained levels of super-saturation as well as sustained anoxia are both detrimental to aquatic fauna. Super-saturation can lead to super-saturation and bubble formation in internal fluids and ultimately death.

Twenty-one of the sites sampled were hypersaline[1] with electrical conductivities greater then seawater (*i.e.* >50 mS/cm) and with a range of 60.8 - 238 mS/cm. Two sites were classified as saline (sites 2 & 11) and one brackish (site 7). The composition of major ions in the wetlands was dominated by sodium and chloride with magnesium and sulphate sub-dominant (Na^+ >>Mg^{2+} >Ca^{2+} <>K^+ : Cl^- >>SO_4^{2-} >>HCO_3^-). Sodium and chloride ions accounted for approximately 89% and 91% of total cation and anion concentrations, respectively. There was little difference in ionic dominance between control and exposed sites, nor between acidic and neutral/basic sites. The pattern of ionic dominance was generally consistent with sea water, implying a marine origin - likely relict marine deposits in groundwater (Hart & McKelvie 1986).

Nine of the sites sampled were acidic, with pH levels of 3.04 - 4.16. Four of these (sites 8, 9, 10 & 24) were exposed to acidic drainage waters, though it is not known if they were already acidic prior to the installation of the deep drains. The plot in Figure 8 provides a summary of the ranges in pH and salinity encountered at the sites. While there was no correlation between pH and salinity for the sites sampled, acidification of lakes across the wheatbelt is known to be closely coupled to dryland salinity and has been the focus of a number of recent studies by the Department of Water and CSIRO (Franzmann *et al.* 2007, Degens *et al.* 2008). The acidification of wheatbelt lakes is largely the result of rising acidic (pH <4.5) saline groundwaters (Halse *et al.* 2003). Some is also due to disposal of acidic drainage waters. Evidence from sediment mineralogy suggests that some acidic lakes were previously alkaline and some alkaline lakes may have been acidic in the past (Degens *et al.* 2008).

Most natural inland waters in Western Australia have a pH range of 6.5 - 8.5. While there are some seasonal wetlands and salt lakes that are naturally acidic (pH 3 - 5) due to seasonal wetting and drying cycles and the natural occurrence of acid groundwater, these tend to be in the minority. Even a small drop in pH can have significant deleterious effects on biota by altering ionic and osmotic balances (Dallas & Day 1993). The pH scale is logarithmic and a decline of one pH unit (*e.g.* from pH 5 to pH 4) represents a ten-fold increase in acidity (Psenner 1994). Even at higher pH, a one-unit decrease in pH from 7 to 6, may result in up to an order of magnitude change in metal toxicity (ANZECC/ARMCANZ 2000).

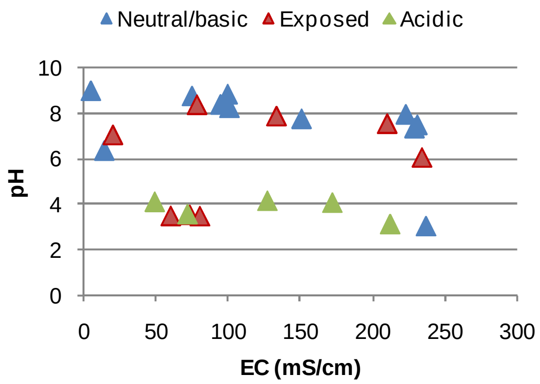


Figure 8. Salinity *versus* pH for sampled sites within the Yarra Yarra catchment. Exposed = all sites receiving disposal waters from deep drains; neutral/basic = control sites with circum-neutral or basic pH ≥6; acidic = control site with pH <6.

3.2.2 Metals

Summary plots of metal levels are given in Figure 9. Acidic groundwaters in the wheatbelt often contain elevated concentrations of metal contaminants such as aluminium, iron, zinc, lead, copper, chromium and uranium (Franzmann *et al.* 2007). Irrespective of pH, most sites in the Yarra Yarra catchment had greatly enriched metal concentrations compared to ANZECC/ARMCANZ (2000) guidelines for protection of aquatic ecosystems (Figure 9). Levels of Cd, Cr, Co, Cu, Ni, Se and Zn were particularly high. Co, Fe, Pb and Mn concentrations were also appreciably higher at acidic sites, regardless of exposure to deep drains. Fe concentrations were much greater at acidic exposed sites compared to acidic control sites (Figure 9).

[1] Hypersaline >50 mS/cm; saline 8.8 - 50 mS/cm; brackish 2 - 8.8 mS/cm; using a conversion of TDS mg/L = ~ 680 x electrical conductivity mS/cm (ANZECC/ARMCANZ 2000).

In the plots in Figure 9, the higher mean concentrations of As and Cu shown for neutral/basic sites are due primarily to highly enriched levels at one site only; exposed site 21. Concentrations of As (0.35 mg/L) at site 21 were at least 14x greater than at all other sites, and Cu (0.83 mg/L) concentrations were at least 27x greater. The source of these enriched metals is not known. The pH was somewhat acidic at 6.06 though it was expected that in-flow from the deep drain would contribute only a relatively small proportion to the total volume of the large saline playa at site 21. Total discharge from the drain and total loads of contaminants are unknown. Concentrations of metals stored in playa sediments are also unknown.

At pH values >7, many metals will precipitate out of solution (*i.e.* the water column) and thereby their availability, and hence toxicity, to aquatic biota is reduced. The pH value at which metals precipitate varies depending on the metal. Many may be bound to suspended particulates or sediment and may not be biologically 'available'. The bioavailability of the elevated metals at the Yarra Yarra wetlands is not known. It is possible that while dissolved metals may be quite high, they remain unavailable through complexing with dissolved organic carbon and iron-rich colloids. Thus analysis of total concentration may be misleading if the form of the metal is unknown. Even so, concentrations of some metals at the study sites were so elevated as to likely exceed the complexing capacity of receiving waters, and so were likely to be at levels toxic to aquatic fauna (*viz.* Cu concentration of 0.83 mg/L at site 21).

Speciation measurements to quantify which forms (or species) are present would be needed to provide a better estimate of the bio-available metal concentration where the total and dissolved metal concentrations exceed the guideline trigger values. Re-sampling for dissolved concentrations using a smaller filter size is also recommended to confirm high ambient concentrations of Cu, Fe, Mn, Pb and Zn. These metals readily form or sorb to colloids, some of which may be small enough to pass through the standard 45 µm filter used to define dissolved concentrations, thereby leading to overestimates of the metal levels present (Kimball 2007).

It should also be noted, that spot measurements of metals (or of nutrients or salts) are not necessarily indicative of total loads or of ambient conditions at other times of year. Summer-dry wetlands and lakes have less capacity for dilution of contaminants, than do permanent waterbodies. Contaminants may be transported many kilometres along natural and artificial drainage lines or overland during flood flows, only to be concentrated by evaporation as waters recede. This is particularly relevant in systems that are actively eroding and in endorheic systems such as Yarra Yarra which terminates in playas. The dry sediments and interstitial waters of playas and wetlands in receiving environments may act as sinks for many pollutants and accumulate them over time, leading to greater potential for toxicological effects on both the surface water and sediment biota (Smith *et al.* 2004, WRM 2005b).

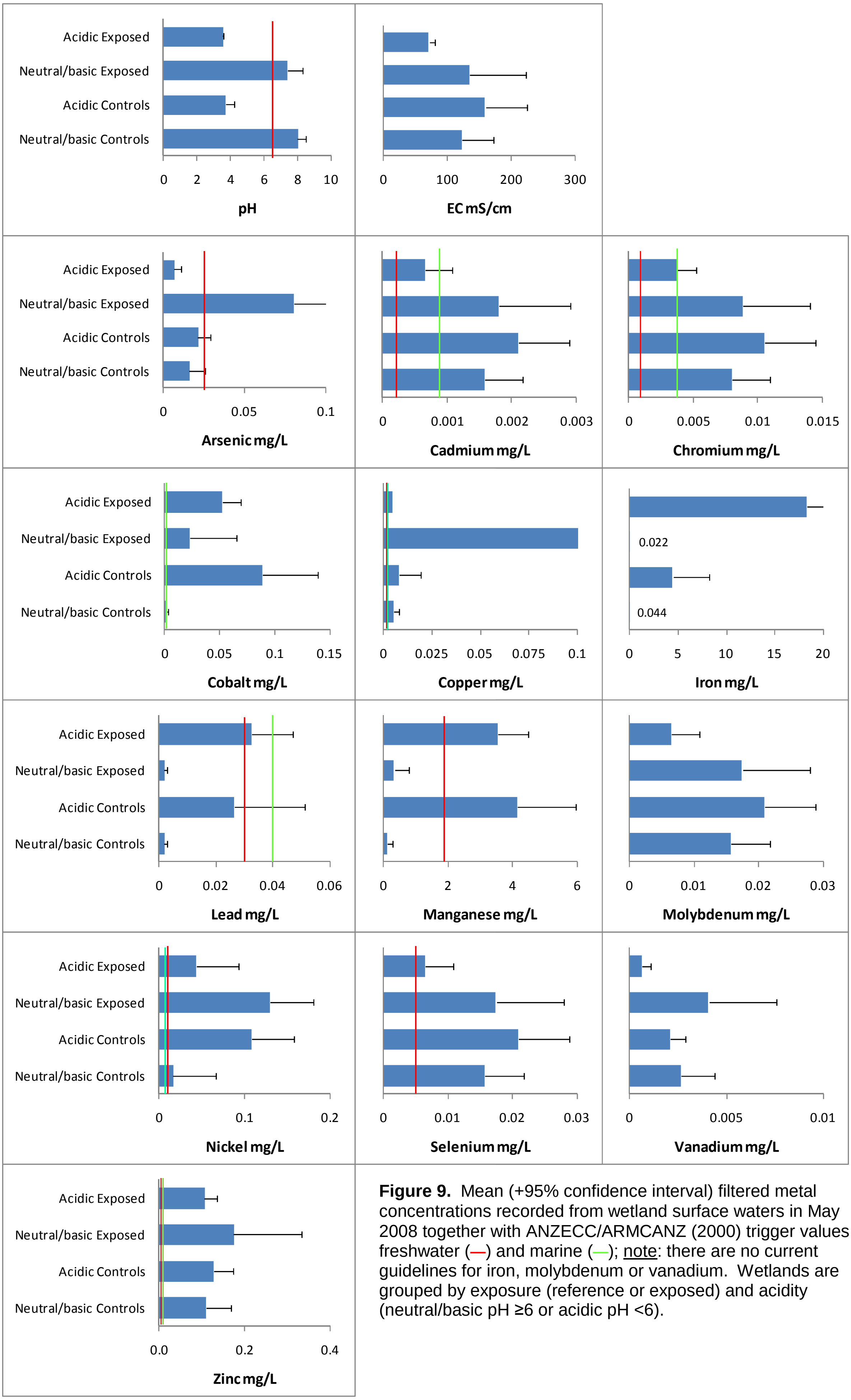


Figure 9. Mean (+95% confidence interval) filtered metal concentrations recorded from wetland surface waters in May 2008 together with ANZECC/ARMCANZ (2000) trigger values for freshwater (—) and marine (—); note: there are no current guidelines for iron, molybdenum or vanadium. Wetlands are grouped by exposure (reference or exposed) and acidity (neutral/basic pH ≥6 or acidic pH <6).

3.2.3 Nutrients

Nutrient levels at most sites were high and well above ANZECC/ARMCANZ guidelines for the protection of aquatic ecosystems (Figure 10). The range for TN was 0.61 - 36 mg/L, 0.005 - 7.1 mg/L for NO_3 and 0.005 - 0.75 mg/L for TP. Maximum TN and TP levels were recorded from reference site 15 in Mongers 16 sub-catchment. This site was experiencing a severe algal bloom at the time of sampling, undoubtedly due to high nutrient concentrations and low water levels. High levels of TN (& NO_3) were also recorded at site 3 in Lake Hillman and slightly lower levels at sites 13 and 19 in Goodlands sub-catchment. High levels of TP (0.24 mg/L) were also recorded at site 16, again in Mongers 16. There was no major difference in nutrient concentration between exposed and control sites.

Like metals, spot measurements of nutrients are unlikely to reflect total loads or sediment stores. High nutrient concentrations were not unexpected given the past land management practices and unrestricted access of livestock to the wetlands and natural drainage lines. Nitrogen in the form of ammonia (NH_3) and ammonium (NH_4^+) were not measured during the current study but are expected to be high, given the high levels of TN. The relative concentration of each in water is determined by pH and temperature. As pH shifts from alkaline (>7.0) to acid (<7.0) NH_3 is converted to ammonium and *vice versa*. While ammonium is not considered harmful, ammonia is acutely toxic at relatively low concentrations (ANZECC/ARMCANZ 2000).

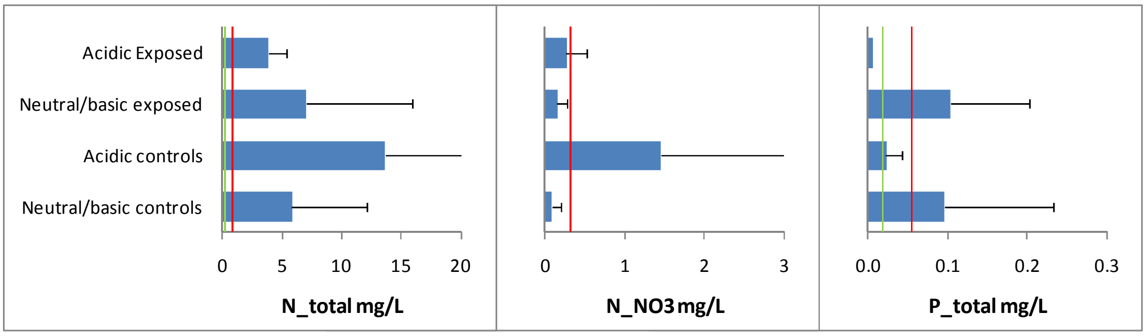


Figure 10. Mean (+95% confidence interval) nutrient concentrations recorded from wetland surface waters in May 2008 together with ANZECC/ARMCANZ (2000) trigger values for freshwater wetlands (—) and marine inshore waters (—). Wetlands are grouped by exposure (reference or exposed) and acidity (circum-neutral/basic pH ≥6 or acidic pH <6).

3.2.4 Patterns in water quality

MDS ordination was used to search for spatial patterns in water quality amongst sites. Figure 11 shows the 'clustering' of sites based on overall similarities/dissimilarities in the total suite of water quality variables. The over-riding influence appeared to be salinity with a significant separation of hypersaline sites from brackish-saline sites (ANOSIM, Global R-statistic 0.636, p = 0.002). There was no significant (ANOSIM) separation of sites on the basis of exposure or acidity (pH), though acidic exposed sites 8, 9, 10 and 24 tended to group together within the broader grouping of hypersaline sites (Figure 11). These sites had particularly low pH (<4) coupled with higher levels of both Co and Fe and salinity between 50 and 100 mS/cm.

Ordination on metals only, rather than the full suite of water quality variables, revealed a quite different pattern. Once the masking effects of salinity were removed, analyses of metals alone showed a much stronger separation of sites on the basis of pH. Sites broadly separated into two groups: acidic sites and neutral/basic sites (Figure 11). The separation was primarily influenced by higher levels of Co, Fe, Pb and Mn at acidic (pH <6) sites. Within these acidic sites, exposed sites 8, 9, 10 and 24 tended to 'cluster' separately from control sites.

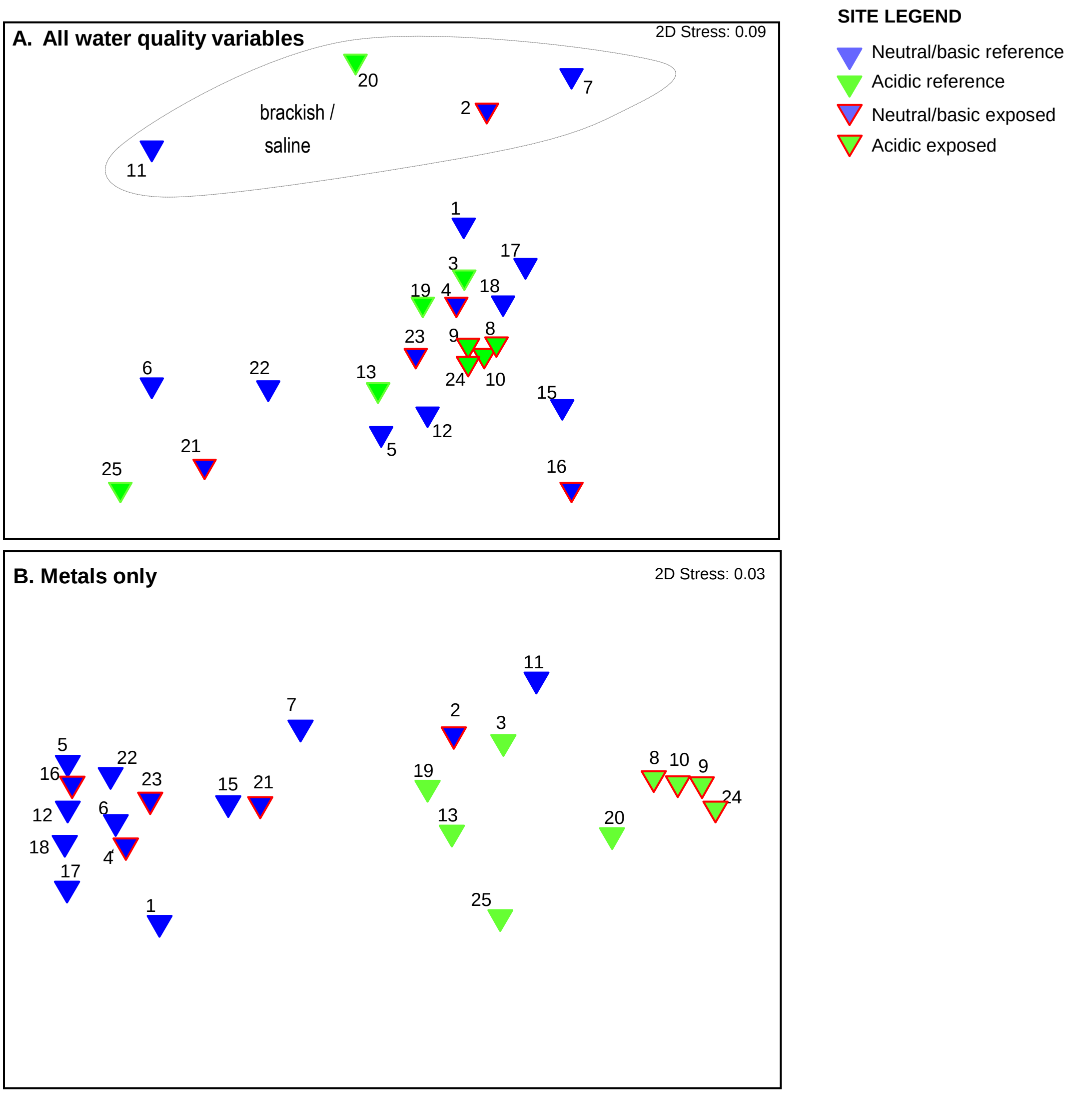


Figure 11. MDS ordinations on (A) the full suite of water quality variables and (B) on metal concentrations only. Wetlands are labelled by site codes and coloured by exposure (reference or exposed) and acidity (circum-neutral/basic pH ≥6 or acidic pH <6).

Two circum-neutral basic sites (pH >6) also grouped with the more acidic sites - exposed site 2 in Lake Hillman, with a pH ~7, and control site 11 in Lake MacPherson, with a pH of 6.35. Both these sites had higher levels of Co, Fe and Mn than most other neutral-basic sites. As a general 'rule-of-thumb', metals begin to dissolve into solution as soon as pH falls below 7, depending on the complexing capacity of the water and soils. This may be why sites 2 and 11 had relatively elevated metal concentrations even though their pH was not particularly low. Acidic groundwater is the likely source of the elevated metals at control site 11. Groundwater at pH ~4 has been recorded ca. 40 cm below the surface in the centre of Lake MacPherson (I. Fordyce, pers. comm.). A pH of 6.35 at site 11 also suggests the presence of acidic groundwater interacting with more neutral surface sources. Site 2 is in the receiving environment for acidic hypersaline discharge from Nixon's drain. Elevated concentrations of dissolved Mn have previously been recorded from this drain (Ian Fordyce, pers. comm.).

Figure 12 provides a graphic illustration of the relationship between ordination groupings and selected metal concentrations. Further discussion on the water quality of these sites is presented in section 3.4.3 in relation to possible effects on macroinvertebrate communities.

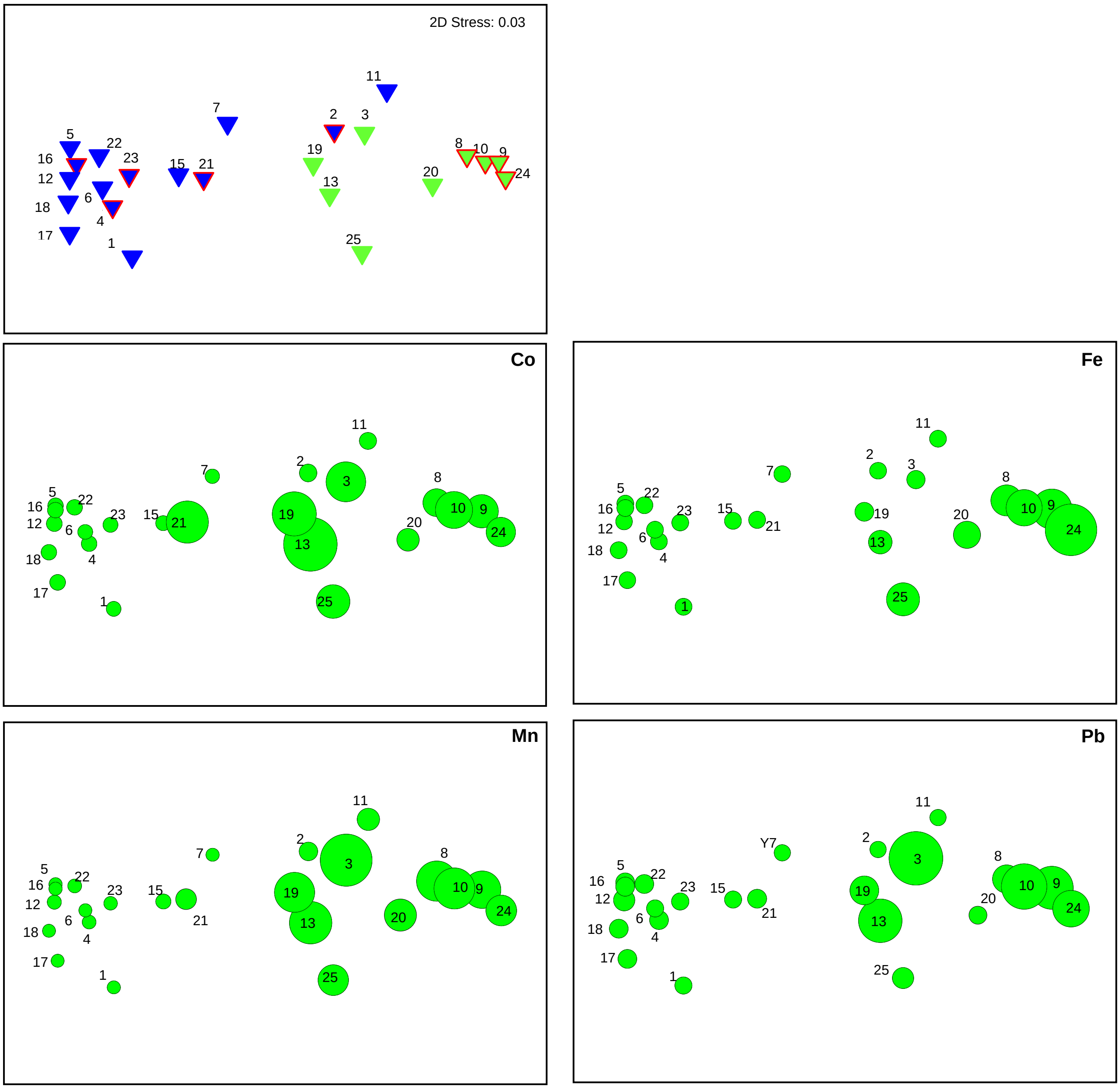


Figure 12. 'Bubble' plots of selected metal concentrations (Co, Cr, Fe, Mn & Pb) superimposed on metals ordination (top left). The larger the 'bubble', the greater the metal concentration. Refer Figure 11 for site codes.

3.3 Microinvertebrates

3.3.1 Taxonomic composition

A systematic list of microinvertebrate fauna recorded is provided in Appendix 4. A total of 23 taxa ('species') were collected together with a number of specimens that could not be positively identified owing to immaturity of life stage. Taxa included 9 rotifers, 5 ostracods, 3 cladocerans, 3 copepods, and one Protista. Examples of the types of taxa collected are shown in Plate 2. All microinvertebrate fauna collected were considered 'permanent' residents of the wetlands that is, they have desiccation-resistant life stages that allow them to survive within the wetland and lake sediments once surface waters have evaporated. Typically, 'permanent' fauna emerge within hours once surface waters return and develop quickly over a period of about two weeks, before more predatory colonisers (*e.g.* many macroinvertebrates) appear.

In the Yarra Yarra catchment, as in many saline inland systems, micro-crustacea (seed shrimps, copepods & water fleas) were the dominant microinvertebrate. Micro-crustacea constituted 58% of all microinvertebrates collected, Rotifera accounted for nearly 42% and Protista the remainder with only one species (*Stentor* sp.). Cyclopoid copepods were the most common microinvertebrate, in particular *Apocyclops* and *Metacyclops* species, occurring at 11 of the 24 sites sampled. Of the rotifers, *Brachionus* species were the most common, occurring at four wetlands.

3.3.2 Conservation significance of microinvertebrates

Endemicity of the fauna is indicated in Appendix 4. At least 50% were considered cosmopolitan species with an Australia-wide and/or world-wide distribution. None of the species collected were considered rare or restricted in distribution. However the endemicity of many remains unknown. There is a paucity of research on microinvertebrates of Australia, and Western Australia in particular, and the extent of distributions within the southwest have not been adequately surveyed. The lack of relevant published taxonomic keys for many species is also problematic. In general, copepods, cladocera, ostracods and rotifers are believed to have high levels of endemicity (Williams 2002, Segers & Shiel 2003, Halse *et al.* 2003). This is at partly due to the fact that they have only passive means of dispersal. Translocations between catchments are usually attributed to the resting eggs (ephippia) of rotifers, copepods and cladocerans being caught in feathers of migratory birds, thus making long distance dispersal possible for at least some species.

3.3.3 Species richness

Spatial variation in species richness was high and there were many (58%) singletons, *i.e.* species occurring at only one site. Abundances were generally low. The number of taxa at individual sites ranged from zero (*e.g.* all acidic sites) to 13 at control site 7 with pH 8.97 and salinity 5.58 mS/cm (Figure 13). Maximum richness was typically found at the brackish-saline sites (2, 7 & 11) with neutral-basic pH. Acidity exerted a strong influence on species richness and abundance even at relatively low salinity (Figure 14). The only species recorded from the acidic sites was a single immature copepod (copepodite) from exposed site 8. Taxa richness increased markedly at pH >6, but declined again at salinity >200 mS/cm.

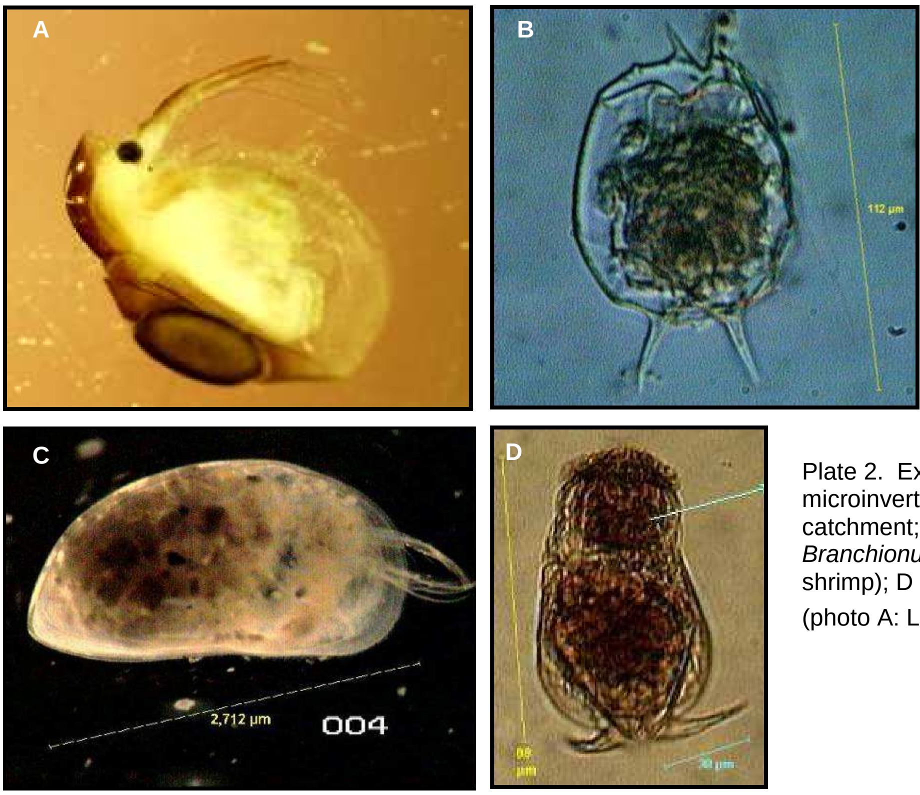


Plate 2. Examples of some of the types of microinvertebrates found in the Yarra Yarra catchment; A cladoceran (water flea); B *Branchionus* (rotifer); C ostracod (seed shrimp); D *Cephalodella* (rotifer).
(photo A: L. Chandler; photo B-D: R. Shiel).

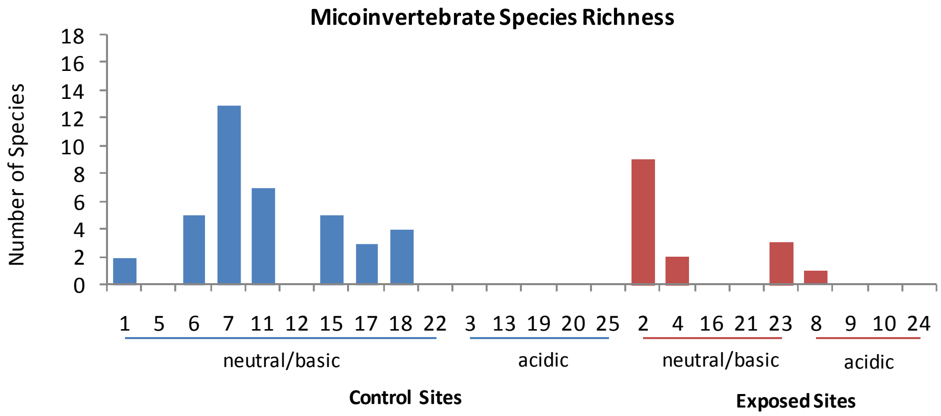


Figure 13. Comparison of microinvertebrate species richness between sites. Neutral/ basic = sites with pH ≥6; acidic = sites with pH <6.

Studies suggest that even a slightly low pH (*e.g.* 6.5) can have detrimental effects on sensitive organisms and that few survive in waters of pH <5.5 (Psenner 1994). There is often an abrupt decline in microinvertebrate richness due to the loss of acid-intolerant micro-crustacea. However not all microinvertebrates are acid-intolerant. Species of the copepod genus *Calamoecia* are commonly present in hypersaline (75 mS/cm) acidic (pH<4) lakes in the wheatbelt (Blinn *et. al.* 2004). In the northern hemisphere, rotifer species of the genus *Branchionus* and *Cephalodella* have been recorded at pH close to 3 (Denke 2000, Walseng *et al.* 2003). While species of *Branchionus* and *Cephalodella* were recorded during the current study, none were collected from the acidic wetlands.

At neutral-basic sites there was a strong negative correlation (r = -0.881, p <0.001) between micro-invertebrate species richness and salinity (Figure 14). Cladocerans and most rotifers were absent from sites with salinities >50 mS/cm. The exception was the branchionid rotifer *Branchionus plicatilis* which was present at salinities up to 75 mS/cm. Micro-invertebrates were not present in hypersaline wetlands with salinities >200 mS/cm. This is in accord with the findings of Blinn *et al.* (2004) who surveyed 56 wetlands across the wheatbelt and found no microinvertebrates in wetlands with salinities >202 mS/cm.

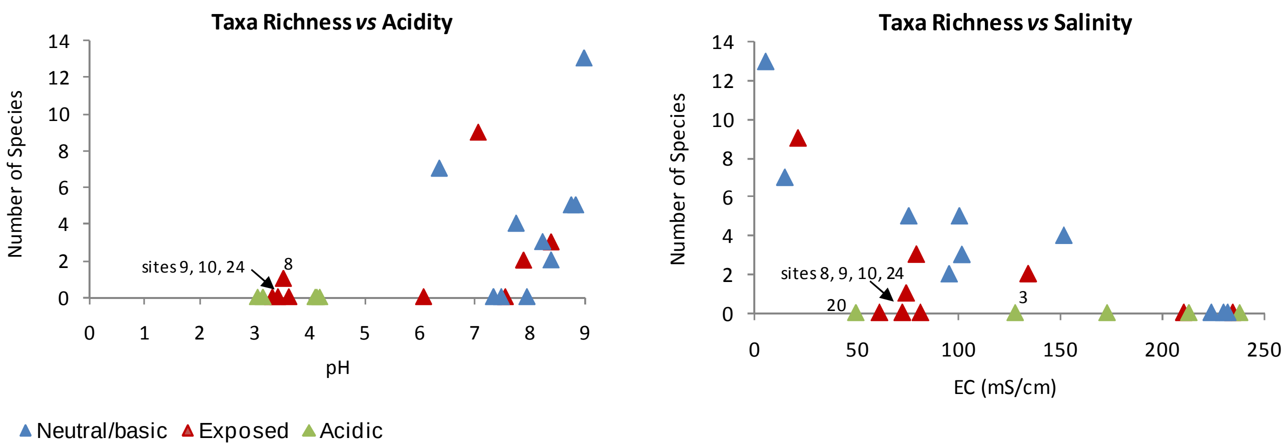


Figure 14. Plots of microinvertebrate species richness *versus* salinity (mS/cm EC) and acidity (pH). Exposed = all sites receiving disposal waters from deep drains; neutral/basic = control sites with circum-neutral or basic pH ≥6; acidic = control site with pH <6.

Figure 15 shows a comparison of average species richness at control sites and exposed sites with neutral-basic pH. Although species richness appeared lower at exposed sites this result was complicated by the fact that a relatively greater proportion of the neutral-basic exposed sites (2 out of 5; 40%) had salinities >200 mS/cm compared to control sites (30%).

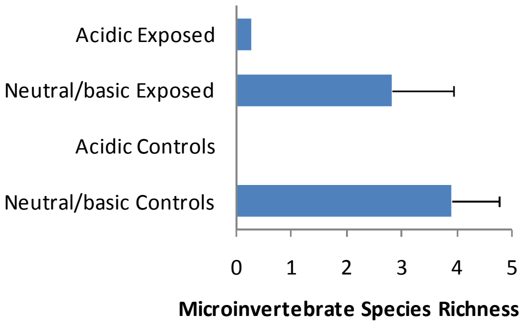


Figure 15. Mean (+95% confidence interval) microinvertebrate species richness. Wetlands are grouped by exposure (reference or exposed) and acidity (circum-neutral/basic pH ≥6 or acidic pH <6).

3.3.4 Patterns in microinvertebrate assemblage structure

Differences in microinvertebrate community structure between wetlands were investigated using MDS ordination analysis (PRIMER). Analyses indicated that after acidity, salinity was the most strongly influencing factor on community assemblages. Plots of ordinated data in Figure 16 show the clear separation of brackish-saline (EC ≤50mS/cm) sites 2, 7 and 11, from the hyper-saline (>50mS/cm) sites. The outlier from the brackish-saline group was acidic site 20 from which no microinvertebrates were collected. The separation of brackish-saline from hypersaline sites was statistically significant (ANOSIM, Global R-statistic 0.851, $p = 0.001$).

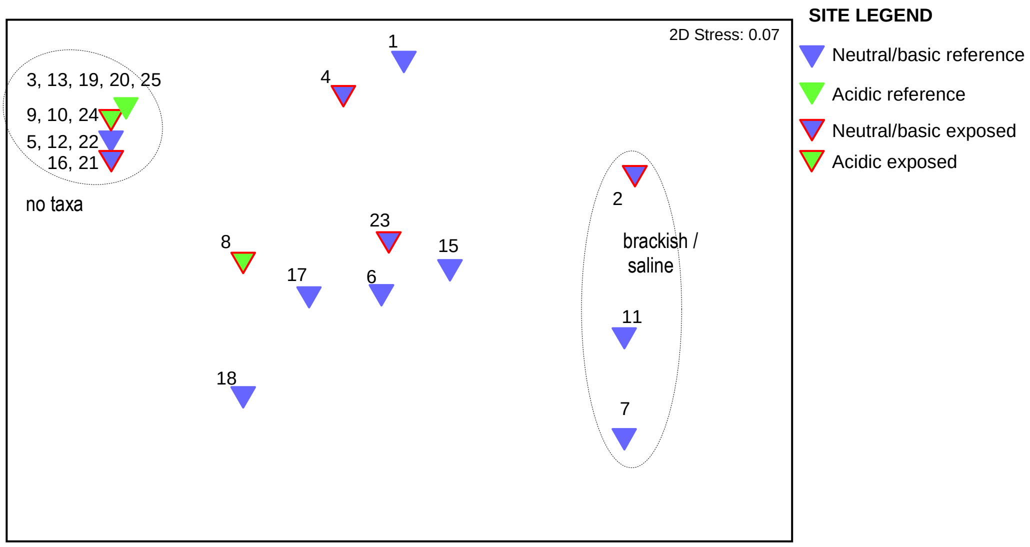


Figure 16. MDS ordination on microinvertebrate presence/absence data data. Wetlands are labelled by site codes and coloured by exposure (reference or exposed) and acidity (neutral/basic pH ≥6 or acidic pH <6). Optimum solution for the ordinations was three dimensions with a stress of 0.01, but for visualisation dimensions 1 and 2 are shown.

Groupings of sites were largely attributable to the loss of species with increasing salinity, in particular the absence of rotifers and cladocerans at salinities >75 mS/cm. Despite the influence of salinity evidenced by ordination analyses, there were no statistically significant correlations (RELATE, $\rho = 0.5$, $p = 0.06$) between measured water quality variables and patterns in micro-invertebrate fauna assemblages. This was not unexpected because communities as a whole are unlikely to respond to changes in environmental parameters in a strictly linear fashion due to the different tolerance thresholds of the various species. Of measured water quality variables, salinity

(EC) did explain the greatest percentage (50%) of the overall variation in microinvertebrate assemblages between sites (BIOENV). 'Bubble' plots are provided in Figure 17 to illustrate the relationship between salinity, pH and microinvertebrate assemblages.

Blinn *et al.* (2004) did find salinity to be significantly correlated with microinvertebrate community structure. The difference between this and the current study may be explained by the larger number of wetlands sampled (56) by Blinn *et al.* (2204) and likely reduced spatial variation in the data.

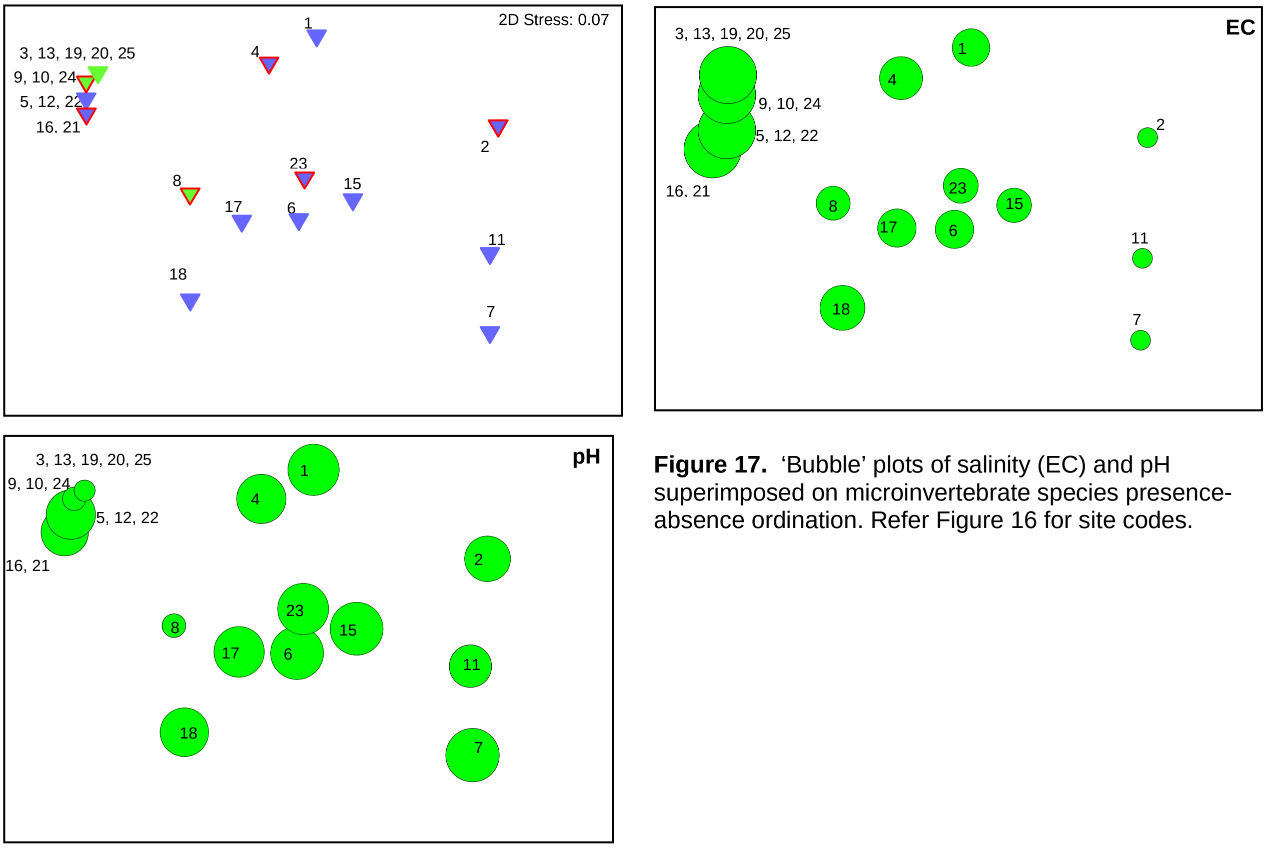


Figure 17. 'Bubble' plots of salinity (EC) and pH superimposed on microinvertebrate species presence-absence ordination. Refer Figure 16 for site codes.

Between-site pairwise similarity values were averaged to determine the level of similarity in microinvertebrate faunal assemblages between neutral-basic exposed and control sites (Table 3). Pairwise similarity can be used to compare changes in faunal assemblages relative to baseline conditions and also across years. The expectation was that faunal assemblages would be more similar between individual exposed than between individual control sites because of the loss of less resilient taxa from exposed sites. Results indicated this to be the case, although between-site similarities were very low for both control (16%) and exposed groups (10%) and difference were not statistically significant (ANOSIM, Global R-statistic -0.067, $p = 0.776$). The low between-site similarities were considered largely due to generally low species richness and high number of singletons.

Table 3. Average percent pairwise similarity amongst sites, calculated using the Bray-Curtis association measure on microinvertebrate presence-absence data.

PRESENCE-ABSENCE DATA	PAIRWISE SIMILARITY (%)
WITHIN GROUP COMPARISON	
Neutral-basic (pH >6) Reference (n = 10)	16
Neutral-basic (pH >6) Exposed (n = 5)	10
BETWEEN GROUP COMPARISON	
Neutral-basic Reference *vs* Neutral-basic Exposed	15

3.4 Macroinvertebrates

3.4.1 Taxonomic composition

A systematic list of macroinvertebrate fauna recorded is provided in Appendix 5. A total of 39 taxa ('species') were recorded together with a number of specimens that could not be identified to species-level owing to immaturity of life stage (*e.g.* Corixidae) or absence of male specimens required for positive identification (*e.g.* Notonectidae, Dytiscidae). A summary of the types of taxa collected is given in Table 4 and examples are shown in Plate 3 and cover photographs. The macroinvertebrate fauna was dominated by Insecta (87%). Of the Insecta, Diptera (two-winged flies) and in particular Chironomidae (non-biting midge), were the most common, followed by Coleoptera (aquatic beetles). The most common and abundant Chironomidae were the salt-tolerant freshwater *Procladius paludicola* and the halophile *Tanytarsus barbitarsus*. Halophiles (or halophilous species) typically occur in saline water up to ca. 70 mS/cm, but may also occur in freshwater (Halse *et al.* 1998). *Necterosoma* and *Berosus* were the most commonly occurring aquatic beetle species, but only at salinity <134 mS/cm. The adults of some species of these genera are known halophiles (Pinder *et al.* 2005), but larvae can rarely be identified to species. Salinity tolerances are known to vary between adults and larvae of the same species as well as between species.

Table 4. Summary of macroinvertebrate fauna recorded from the Yarra Yarra study area.

MACROINVERTEBRATES	NO. OF 'SPECIES'
Mollusca	
Gastropoda (*Coxiella*)	1
Arachnida	
Acarina (water mites)	1
Crustacea	
Anostraca (brine-shrimps)	3+
Notostraca (shield shrimp)	1
Insecta	
Odonata (dragonflies & damselflies)	2
Hemiptera (true bugs)	2
Coleoptera (aquatic beetles)	7
Diptera (two-winged flies)	21
Trichoptera (caddis-flies)	1
Total number of 'species'	**39**

All Insecta were considered to be 'temporary' (*cf* 'permanent') residents, that is, they have highly mobile adult phases that allow them to avoid adverse environmental conditions and reinvade from nearby habitats, once conditions improve. Though 'temporary' residents are typically considered at lower risk from perturbations than are 'permanent' residents, this assumes adequate habitat is maintained close enough to afford refuge and/or enable re-colonisation (WRM 2005b).

'Permanent' taxa constituted only 13% of total fauna and included one species of snail (*Coxiella* sp.), one water mite (Acarina) and three species of brine shrimp (*Paratemia longicaudata*, *P. contracta*, *P.serventyi*). The snails were present along the margins of Lake Hillman at site 1. In July 2007, Dr Shirley Slack-Smith (Western Australian Museum) identified specimens of *Coxiella* from Lake Hillman as *Coxiella (Coxiella) pyrrhostoma* (Ian Fordyce, pers. comm.) and it is assumed specimens observed during the current study were also *C. (C) pyrrhostoma*. *Coxiella* species often occur in large populations on inland saline and hypersaline lakes. In the western wheatbelt, sand dunes impregnated with spiral *Coxiella* shells are the legacy of the long history of fluctuating aridity and salinity in the region (George *et al.* 2008). Entire 'dunes' of *Coxiella* shells have also been found in some Victorian saline lakes. The snails survive drought (and likely extreme salinity) by tightly closing their operculum (shell 'door') and lying dormant till re-flooded (Hammer 1986, Williams 2006). *Coxiella* are known to occur in both naturally and secondarily saline lakes at 4 - 185 mS/cm (Pinder *et al.* 2005).

Of the other 'permanent' taxa, water mites were represented by only a single individual, at site 19. Brine shrimp were recorded from 8 of the 24 sites at 20.9 - 172 mS/cm. *Paratemia* and *Coxiella* are often referred to as halobionts, that is, restricted to salinities of 70 - 430 mS/cm (Halse *et al.* 1998). Blinn *et al.* (2005) found *Coxiella* and *Parartemia* restricted to >30 mS/cm and more common in naturally saline playas of the wheatbelt than in secondarily salinised wetlands. In the current study, only *P. contracta* was recorded at <30 mS/cm. It occurred over a wide range of salinity 20.9 - 172 mS/cm and pH 4.08 - 7.88. Other studies have also recorded *P. contracta* as common in acidic saline waters (Timms 2004, ARL 2006). *P. serventyi* on the other hand, appears to prefer neutral to basic conditions (Timms 2004), and was only recorded from site 23 at pH 8.38 during the current survey.

Another 'permanent' species, shield shrimp, also occur in the catchment. The local landholder reports shield shrimp in large numbers at site 7 when the lake first filled for the season. During the current study, desiccated shield shrimp were observed above the water line at site 15 which was experiencing a severe algal bloom. Current taxonomy recognises only one species of shield shrimp, *Triops australiensis australiensis*, and it occurs across Australia. There are however, a number of subspecies/varieties dependent on geographic location and habitat (B. Timms, pers. comm.).

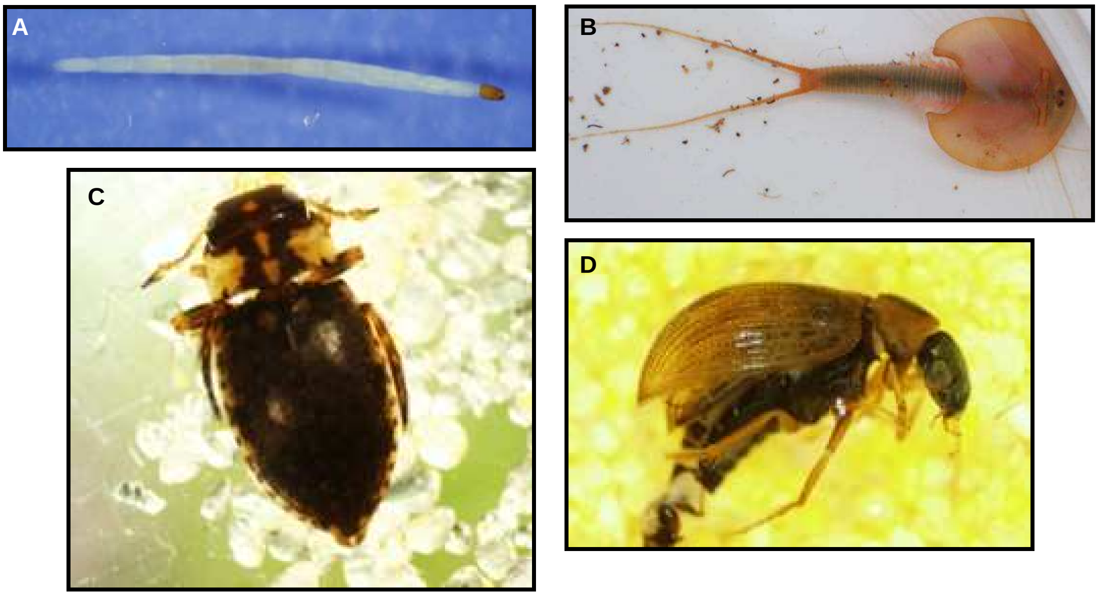


Plate 3. Examples of some of the types of macroinvertebrates found in the Yarra Yarra catchment; A dipteran larva - Ceratopogonidae (biting midge); B shield shrimp *Triops australiensis australiensis*; C *Sternopriscus* species (diving beetle); D *Berosus* species (water scavenger beetle) (photos: L. Chandler).

3.4.2 Conservation significance of macroinvertebrates

A conservation category was assigned to each of the taxa (Appendix 5). Most taxa recorded are considered tolerant of a wide range of environmental conditions and are common and frequently encountered in saline lake systems and wetlands within Western Australia. None were considered rare. Four species were Western Australian endemics. These included the three *Paratemia* species of which *P. contracta* is restricted to inland saline systems of the south-west, *P. longicaudata* occurs in the north-west and south-west of the state, and *P. serventyi* occurs in the north-west, south-west and across the western plateau. All three are common in wheatbelt areas particularly in large saline lakes dominated by benthic mats (B. Timms, pers. comm.).

The fourth endemic species was the aquatic beetle *Necterosoma darwini*. This beetle is widespread and common in both fresh and saline wetlands throughout the south-west and north-west of the state.

Owing to taxonomic uncertainties, the conservation status of a great many taxa could not be determined. This includes the saline snail *Coxiella (C) pyrrhostoma* and the shield shrimp *Triops (a) australiensis*. *Coxiella (C) pyrrhostoma* has been recorded from a number of inland and coastal salt lakes in south western Australia (Smith 1992). *Triops (a) australiensis* is typically described as an Australia-wide species however, the taxonomy is not developed enough to allow differentiation of possible species or sub-species from different regions (Pinder *et al.* 2005). *Triops (a) australiensis* is believed to have different forms (varieties/subspecies/possibly species) in different types of waters. Forms that inhabit clear inland saline lakes are likely different from those that occur in turbid waters such as claypans, and different again from those of clear vegetated waters and gnammas such as occur in the

Murchinson area (B. Timms, pers. comm.). The external morphology of *Triops* has remained relatively unchanged for ca. 200 million years and the genus is therefore believed to contain the oldest living animal species on earth. The uniformity of external morphology can make differentiation of some forms difficult. For these, genetic analysis may be the only way of distinguishing species and sub-species.

3.4.3 Species richness

Similar to the microinvertebrate fauna, spatial variation in macroinvertebrate species richness was high and there were many (61%) singletons. Abundances were again generally low. The number of taxa at individual sites ranged from zero at sites 3, 12 and 13 to 16 taxa at site 11 (Figure 18).

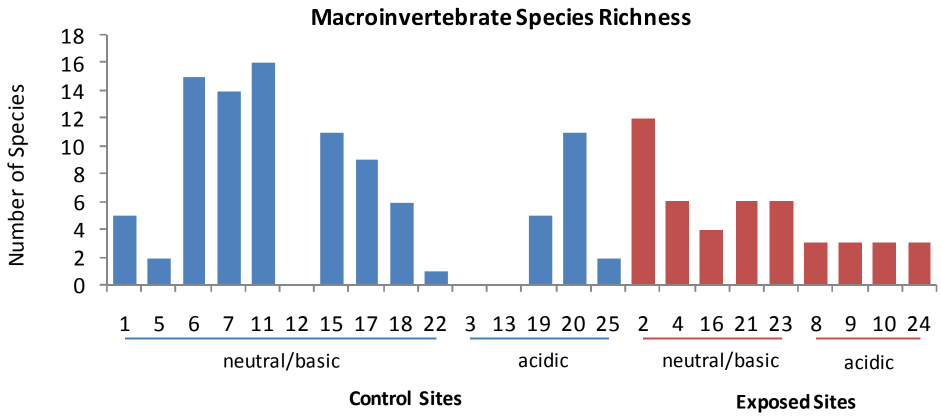


Figure 18. Comparison of macroinvertebrate species richness between sites. Neutral/ basic = sites with pH ≥6; acidic = sites with pH <6.

Salinity appeared to exert greater influence on species richness than did acidity (pH) (Figure 19). There was a strong negative correlation (r^2 = -0.806, p <0.001) between macroinvertebrate species richness and salinity. Similar relationships have been documented by Cale *et al.* (2004) and Pinder *et al.* (2005) during more extensive surveys of wheatbelt wetlands.

Exposed sites 8, 9, 10 and 24 had lower than expected macroinvertebrate species richness for the given salinity (<100 mS/cm). These sites also had relatively low pH, though the taxa richness was not considered unduly low for the given pH. The suspicion is that drainage waters coupled with low pH may be having at least a marginal effect on species richness (Figure 20). However, as only one acidic control site (site 20) with similar salinity was sampled, the evidence is far from conclusive.

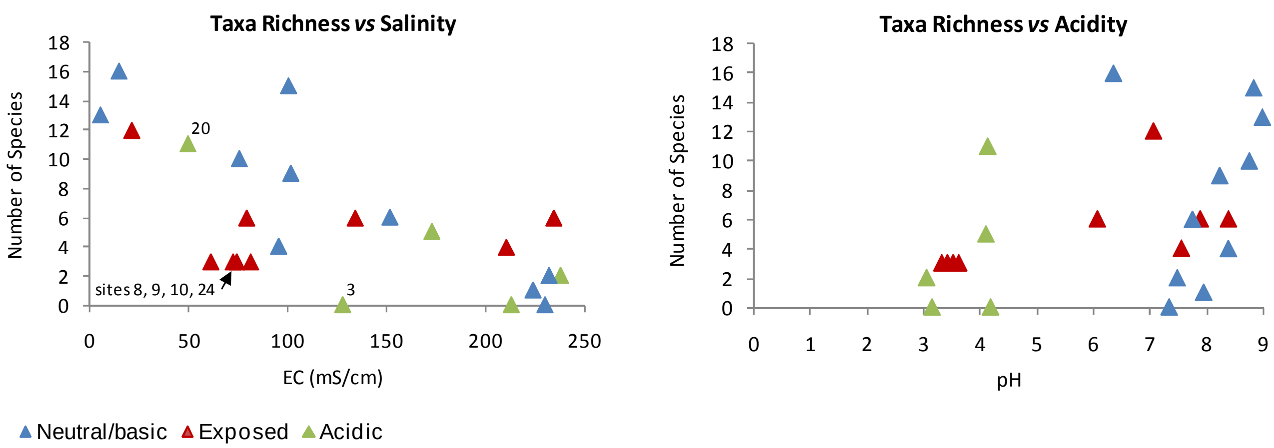


Figure 19. Plots of macroinvertebrate species richness *versus* salinity (mS/cm EC) and acidity (pH). Exposed = all sites receiving disposal waters from deep drains; neutral/basic = control sites with circum-neutral or basic pH ≥6; acidic = control site with pH <6.

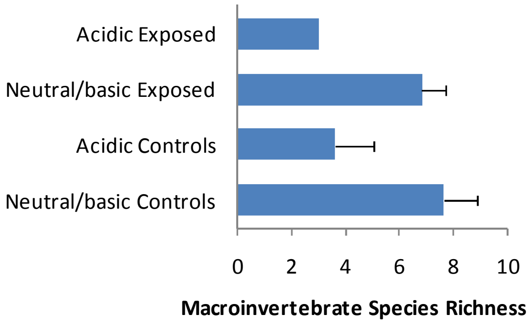


Figure 20. Mean (+95% confidence interval) macroinvertebrate species richness. Wetlands are grouped by exposure (reference or exposed) and acidity (circum-neutral/basic pH ≥6 or acidic pH <6).

It maybe that acidic drainage waters deliver higher loads of dissolved metals to the wetlands than would accumulate due to rising acidic groundwaters alone. Thus, wetlands exposed to acidic drainage waters might be expected to have a larger suite of metals with elevated concentrations and/or particularly high concentrations of individual metals, than acidic wetlands without deep drains. Co (0.035 - 0.58 mg/L) and Fe (9.4 - 32 mg/L) were both particularly high at exposed sites 8, 9, 10 and 24. Co and Fe were also high at acidic control site 3 which similarly had a much lower than expected taxa richness (*i.e.* zero), given the salinity (~128 mS/cm). Mn and Pb were also both high at these sites compared to most (but not all) others. The synergistic toxicity of multiple metals is often greater than toxicity effects from single metals (Parsons 1957, Altenburger *et al.* 1996, Gardner *et al.* 1998). The extent to which these metals are bioavailable is not known and a direct causal relationship with reduced taxa richness cannot be assumed. Levels of sedimentation also appeared to be relatively high at these sites and it may be that large quantities of mobile sediments are smothering fauna, rather than increased toxicity effects of labile metals.

3.4.4 Patterns in macroinvertebrate assemblage structure

MDS ordination analyses of macroinvertebrate data indicated community assemblages were most strongly influenced by salinity. Plots of ordinated data in Figure 21 show brackish-saline (EC ≤50mS/cm) sites 2, 7 and 11 tending to cluster away from the hyper-saline (>50mS/cm) sites. The outlier from the brackish-saline group was site 20, which was the only acidic brackish-saline site. The separation of brackish-saline from hypersaline sites was still statistically significant for both presence-absence data (ANOSIM, Global R-statistic 0.524, p = 0.001) and for log-abundance data (ANOSIM, Global R-statistic 0.426, p =0.01). Reference site 25 and exposed site 10 were also separate from other sites. Site 25 was both hypersaline (>200 mS/cm) and strongly acidic (pH 3.04) with depauperate species richness (only 2 taxa) and low abundances. The only other site with similarly high salinity and low pH was site 13 which supported no macroinvertebrate fauna. Taxa contributing most to the differences in faunal assemblages were the dipterans, in particular chironomid species *Chironomus tepperi*, *Paralimnophes ?pullulus*, *Procladius paludicola* and *Tanytarsus barbitarsus* all of which were more common at ≤50mS/cm. At site 21 which had very high levels of As and Cu (refer section 3.2.2), the only aquatic fauna recorded were larval chironomids (non-biting midge).

There was no significant (ANOSIM) separation of community assemblages on the basis of exposure or acidity (pH).

Despite the influence of salinity evidenced by ordination analyses, there were no significant correlations between measured water quality variables and patterns in macroinvertebrate community structure; neither for presence-absence data (RELATE, ρ = 0.134, p = 0.130) nor abundance data (RELATE, ρ = 0.172, p = 0.07). This may be explained by the fact that invertebrate communities often respond to change in environmental conditions in a step-wise rather than a linear manner. Of measured water quality variables, both salinity and Pb concentration explained the greatest percentage of variation in macroinvertebrate community assemblages between wetlands. Salinity (EC) and Pb concentration both accounted for approximately 45% of the observed variation in species abundance and presence-absence data (BIOENV). Figure 22 shows 'bubble' plots as graphical representations of the relationship between salinity, pH, selected metals and macroinvertebrate community structure (presence-absence).

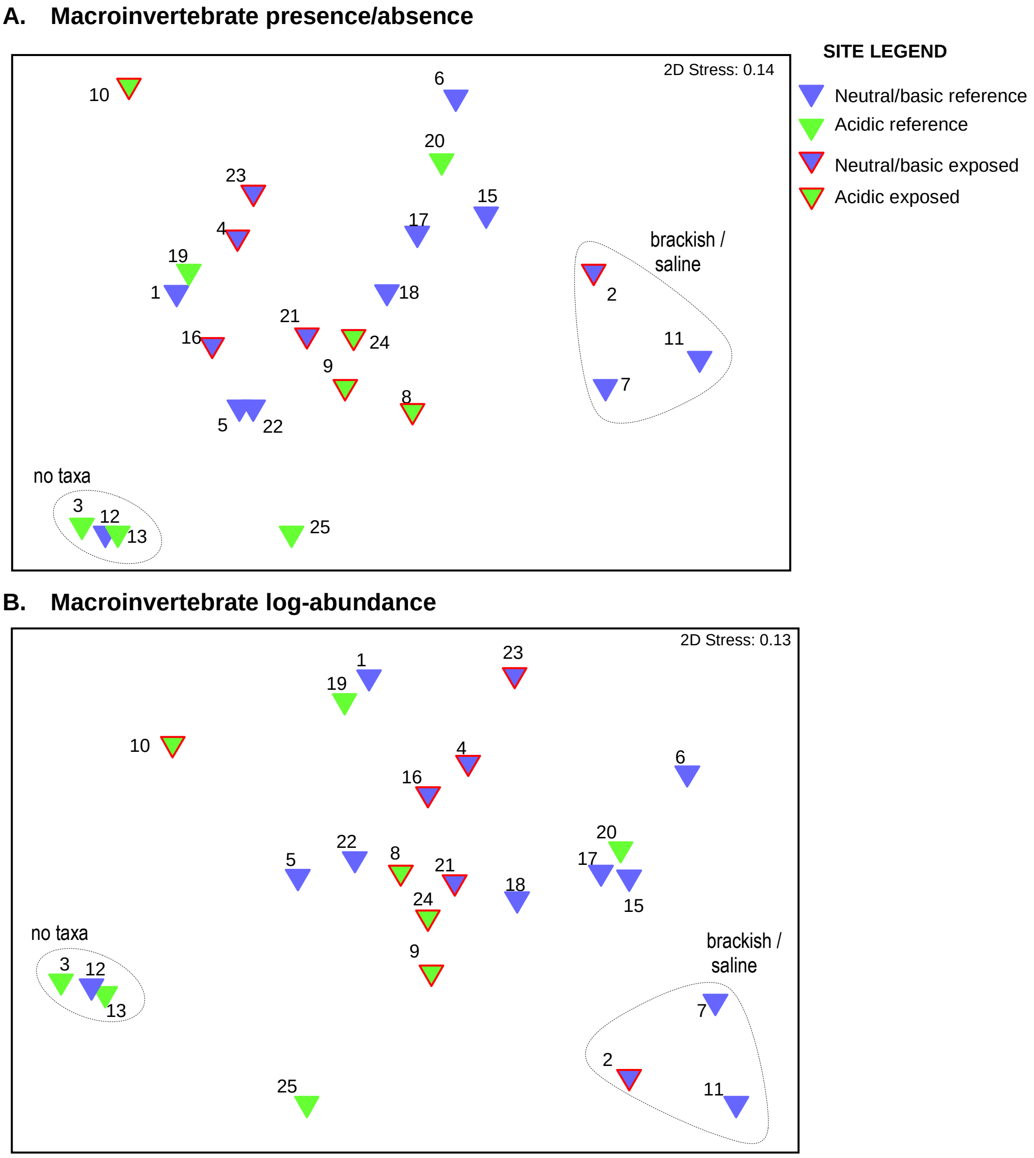


Figure 21. MDS ordination on (A) macroinvertebrate presence/absence data and (B) log-abundance data. Wetlands are labelled by site codes and coloured by exposure (reference or exposed) and acidity (circum-neutral/basic pH ≥6 or acidic pH <6). Optimum solution for both ordinations was three dimensions with a stress of 0.08, but for visualisation dimensions 1 and 2 are shown.

Between-site pairwise similarity values were averaged to determine the level of similarity between macroinvertebrate faunal assemblages of the various wetlands (Table 5). Results were essentially the same for presence-absence and log-abundance data. All average between-site pairwise similarities were low (<50%) reflective of high spatial variability in the fauna and large number of singletons. Similarity between exposed sites (34%) was higher than between reference sites (20%). Exposed sites with acidic pH (<6) were also more similar (28%) than were reference sites with acidic pH (4.3%). Of the four exposed acidic sites, sites 8, 9 and 10 were located in individual wetlands along the same drain within Mongers 55 sub-catchment. As separate wetlands they would be expected to support differing faunal assemblages but with greater between-site similarity than wetlands from different sub-catchments, such as the fourth exposed acidic site, site 24 within Xantippe sub-catchment. Greater between-site pairwise similarity in exposed groups compared to reference groups is typically taken to infer exposure has lead to loss of more sensitive species and resulted in a more uniform, cosmopolitan fauna. Though the greater between-site pairwise similarity for exposed acidic sites may point to the influence of the drains, salinity and small sample size must also be considered as complicating factors; the majority of acidic reference sites sampled (n = 5) had much higher salinities than the acidic exposed sites (n = 4). Pairwise similarity for exposed sites with neutral-basic pH (>6) was also higher than references sites, with an average 43% for exposed sites compared to 28% for the neutral-basic reference sites.

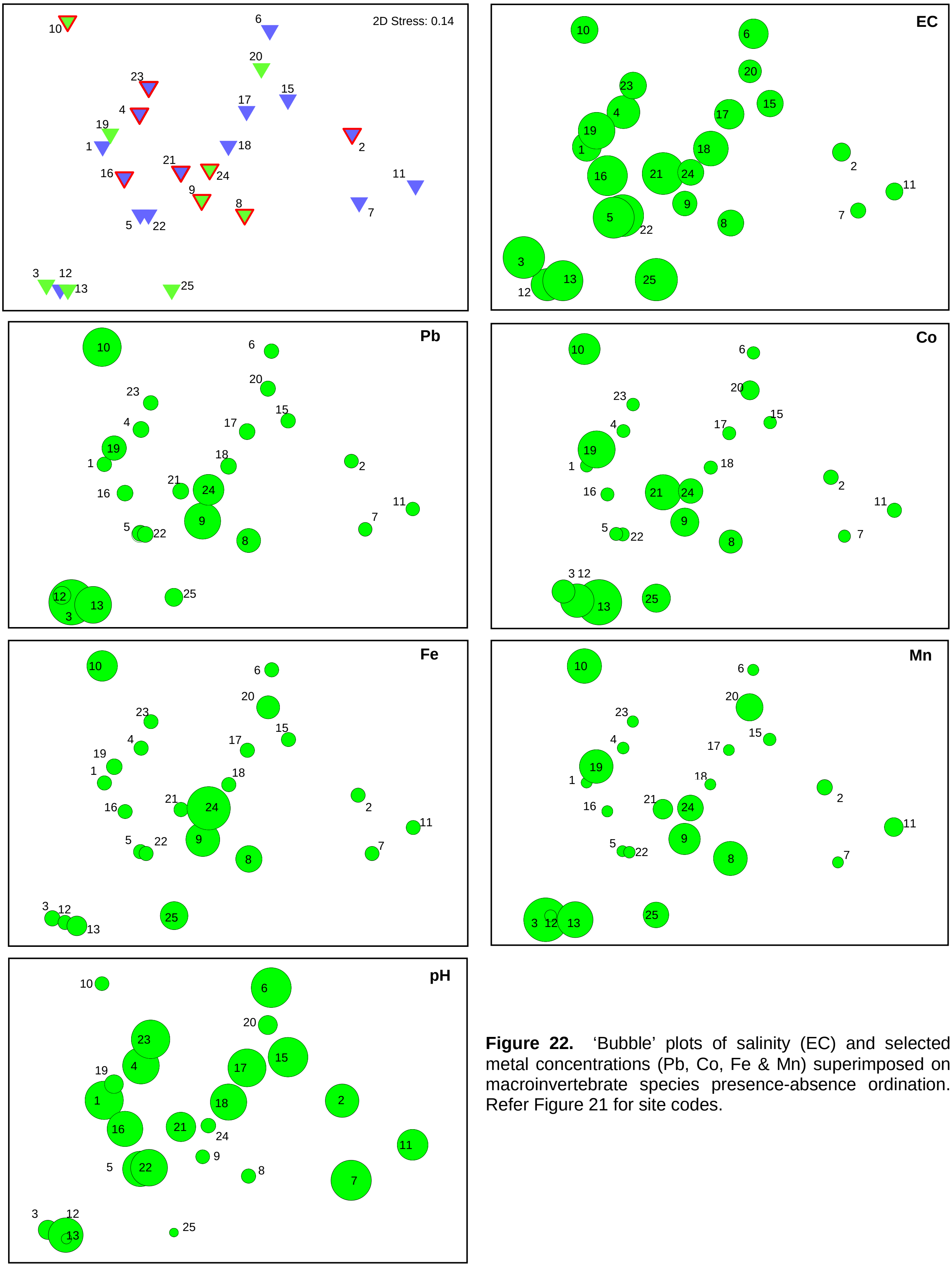


Figure 22. 'Bubble' plots of salinity (EC) and selected metal concentrations (Pb, Co, Fe & Mn) superimposed on macroinvertebrate species presence-absence ordination. Refer Figure 21 for site codes.

Table 5. Average percent pairwise similarity amongst sites, calculated using the Bray-Curtis association measure on macroinvertebrate presence-absence and abundance data.

WITHIN GROUP COMPARISON		PAIRWISE SIMILARITY (%)	
		Presence-absence	Log-abundance
All sites	Reference (n = 15)	20	21
	Exposed (n = 9)	34	35
Neutral-basic (pH >6)	Reference (n = 10)	28	29
	Exposed (n = 5)	41	43
Acidic (pH <6)	Reference (n = 5)	4.3	4.2
	Exposed (n = 4)	28	30

BETWEEN GROUP COMPARISON	PAIRWISE SIMILARITY (%)	
	Presence-absence	Log-abundance
Neutral-basic Reference *vs*:		
Neutral-basic Exposed	32	34
Acidic Reference	15	16
Acidic Exposed	30	32
Neutral-basic Exposed *vs*:		
Acidic Exposed	33	34
Acidic Reference	20	21
Acidic Exposed *vs*:		
Acidic Reference	16	18

4 CONCLUSIONS

4.1 Regional Comparisons

The Yarra Yarra catchment continues to support a moderately rich aquatic invertebrate fauna, despite secondary salinisation and acidification. A total of 62 micro- and macroinvertebrates were recorded from the 24 Yarra Yarra sites with maximum counts (*i.e.* 20 - 27 taxa) in brackish circum-neutral to alkaline waters and minimum counts (*i.e.* 0 - 5 taxa) in acidic (pH <6) and/or strongly hypersaline (>200 mS/cm) waters.

In comparison, similar surveys by WRM in the Buntine Marchagee Recovery Catchment in the northern wheatbelt, recorded a total of 135 taxa of micro- and macroinvertebrate from 21 sites, but with maximum counts (20 - 43) at the fresher (<10 mS/cm) vegetated wetlands and counts of typically less than 15 taxa at hypersaline (>50 mS/cm) wetlands (ARL 2006). More recent surveys of the macroinvertebrate fauna of 5 acidic hypersaline wetlands at Narembeen in the central wheatbelt, recorded a total of only 14 taxa (WRM 2008). Macroinvertebrate taxa richness at Yarra Yarra sites was similar to Narembeen and Buntine-Marchagee wetlands of comparable salinity and acidity (Figure 23).

Extensive surveys across the entire wheatbelt by Pinder *et. al.* (2005) revealed 957 aquatic invertebrates from 230 wetlands, but of these only 17% of taxa (~162) occurred at salinities >14 mS/cm. Pinder *et al.* (2005) recorded maximum counts of typically less than 20 taxa for hypersaline sites. Halse *et al.* (1998) report at least 174 micro- and macroinvertebrates from Lake Gregory in the Great Sandy Desert, but the majority of sites sampled were fresh and alkaline (<1 mS/cm; pH 7.5 - 9). Only 12 species were collected from two saline (ca. 36 - 117 mS/cm) sites sampled by Halse *et al.* (1998). Blinn *et al.* (2005) recorded 143 microinvertebrate taxa from 56 wheatbelt wetlands with salinities at <0.1 mS/cm - 247 mS/cm, however wetlands with salinities >10 mS/cm only averaged around 7 taxa. Blinn *et al.* (2004) also noted that while a few species were collected from extreme conditions of >200 mS/cm and pH 3, "it is possible they had died before collection and were preserved in (the) brine (of the wetlands)". These species included the rotifer *Hexarthra fennica*, the ostracod *Australocypris* sp. B, and copepods *Calamoecia trilobata* and *Meridiecyclops baylyi*. At Yarra Yarra, no microinvertebrates were recorded at pH <6 or >200 mS/cm. Yarra Yarra sites at pH >6 and 10 - 200 mS/cm averaged around 3 taxa (n = 13) and the only site at <10 mS/cm had 13 taxa.

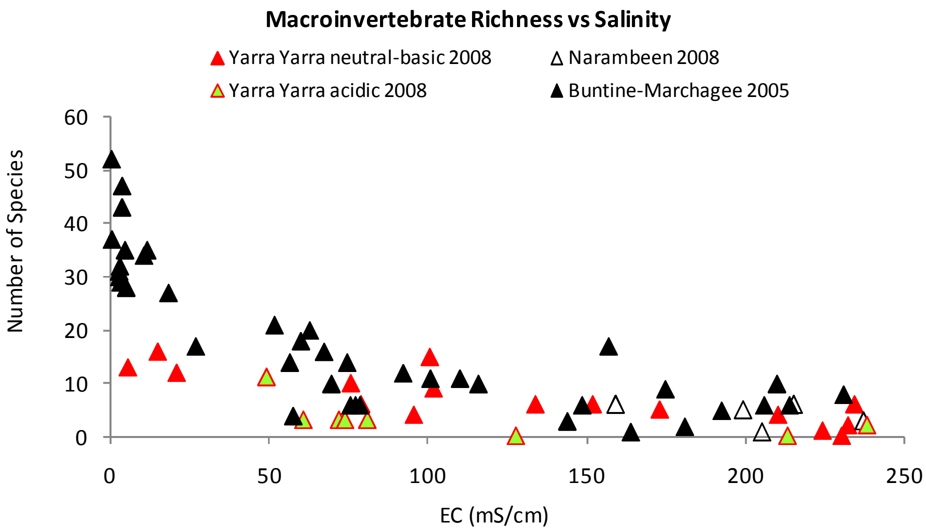


Figure 23. Macroinvertebrate species richness *versus* salinity at wetlands in the Yarra Yarra, Narembeen and Buntine-Marchagee catchments. Yarra Yarra wetlands are labelled as neutral-basic (pH >6) and acidic (pH <6). All Narambeen wetlands were acidic with pH ≤3.

The invertebrate fauna of the Yarra Yarra playas and wetlands, particularly the hypersaline sites generally consisted of ubiquitous species, commonly found across southern Australia. However, it should not be inferred that the invertebrate populations are not worthy of conservation. Species richness and abundance will vary from year to year and season to season, depending upon the water regime. It is likely that following good winter rains, and especially after a series of wet years, they will support a greater number of species. After heavy rains, many invertebrates emerge from substrates or invade from nearby waterbodies to breed in playas when surface waters are relatively fresh and pH near neutral. Rapid reproduction and maturation then occurs while conditions are at their most benign.

Halse *et al.* (2003) considered aquatic invertebrate populations to be an important component of wheatbelt biodiversity and that within Australia, the south-west appeared to be a 'hotspot' for invertebrates with drought resistant stages. This includes most of the microinvertebrate fauna and macroinvertebrates such brine shrimp and shield shrimp. Invertebrates are also a major dietary component of waterbirds.

4.2 Salinisation and Acidification

The current study along with other recent wheatbelt studies cited above, revealed macroinvertebrate community structure to be primarily influenced by salinity, whereas microinvertebrate communities appear primarily influenced by pH and secondarily by salinity. Yarra Yarra sites were ranked according to the total number of microinvertebrate taxa, total number of macroinvertebrate and total combined taxa and then ranked according to their mean rank (Figure 24). Sites at >200 mS/cm and pH <6 were those with the lowest species richness. Typically, naturally hypersaline waterbodies are associated with high pH (Hammer 1986), therefore acidic hypersaline wetlands represent extreme environmental conditions for biota (Blinn *et al.* 2004). Only a few invertebrate species occurring in the wheatbelt are considered to be acidophiles and few waterbirds use acidic saline wetlands (Halse *et al.* 2003, Blinn *et al.* 2004). Hence, acidification poses a substantial threat to the biodiversity of wheatbelt playas and wetlands. In the current study, one acidic site, site 20, did support relatively high species richness (Figure 24) but this was at <50 mS/cm. This wetland may only recently have undergone acidification and still supports remnant species more typical of circum-neutral waters.

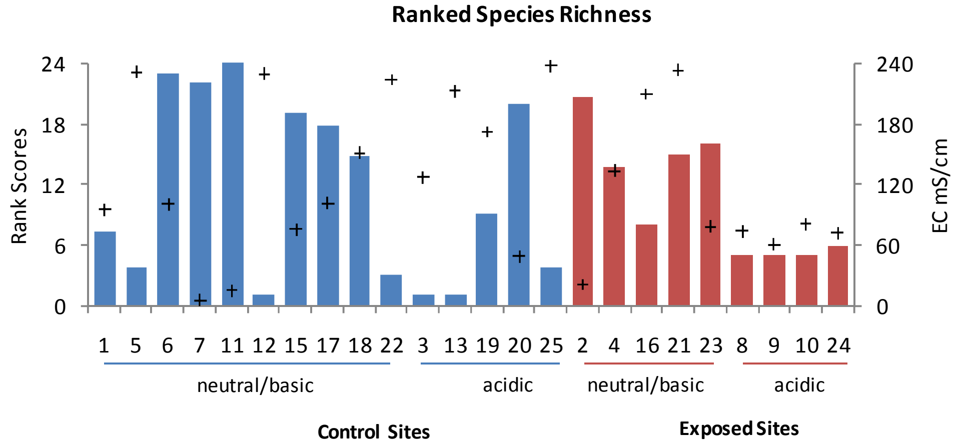


Figure 24. Rank scores for sites based on averaged rank scores for macroinvertebrate species richness, micro-invertebrate species richness and total combined species richness. The site with the highest species richness was given a rank score of "24" and the lowest richness a score of "1". Neutral/ basic = sites with pH ≥6; acidic = sites with pH <6. Salinity as EC (mS/cm) is indicated by +.

In contrast, many wheatbelt species are naturally salt-adapted. Recent studies suggest up to 50% of the aquatic invertebrate fauna of the wheatbelt is salt tolerant (Pinder *et al.* 2005). However, nearly half of these only occur in naturally saline waterbodies with undisturbed hydrological regimes. Secondary salinisation is believed to pose a threat even to salt-adapted species because many cannot tolerate the accompanying altered hydroperiod and salinity regime (Cramer & Hobbs 2002, Cale *et al.* 2004). There is also a significant negative correlation between biodiversity and salinity, typically with a marked decline in species richness at salinities >30 mS/cm (Pinder *et al.* 2005) and then again at >200 mS/cm (DeDekker & Geddes 1980). Previous studies have typically found the relationship between biodiversity and salinity to be logarithmic over the range <1 - 250 mS/cm. In the current study, the relationship appeared to be more or less linear because the majority of sampled sites were >50 mS/cm; *i.e.* there were no freshwater sites and only a few brackish-saline sites.

4.3 Metal Toxicity

In addition to the effects of salinisation and acidification on aquatic invertebrates of the Yarra Yarra, there is the threat posed by labile metals. Most sites in the Yarra Yarra catchment had greatly enriched dissolved metal concentrations compared to ANZECC/ARMCANZ (2000) guidelines for protection of aquatic ecosystems; in particular Cd, Cr, Cu, Ni, Se and Zn. Co concentrations together with Fe, Pb and Mn were also appreciably higher at acidic sites, regardless of exposure to deep drains. However, exposed acidic sites (8, 9, 10 & 24) supported marginally lower macroinvertebrate species richness than might be expected given the salinity (Figure 23) and somewhat greater between-site similarity in community structure than acidic reference sites, suggesting that dissolved metals in acidic drainage waters may be having a greater effect on the invertebrate fauna. Particularly high concentrations of dissolved As and Cu at site 21 may also explain why only chironomid species were recorded from this site.

Metals transported in drainage water will be deposited and accumulate in the receiving environments of the playas and wetlands. The complexing capacity of the waterbodies is not known but it is likely that rising acidic groundwater will exacerbate the potential bioavailability and hence toxicity of these metals. Levels of some metals are so high (*e.g.* 0.83 mg Cu/L at site 21) that it is probable they already exceed the complexing capacity of the playas and wetlands. Though the acidity of drain waters will be ameliorated to some extent by rainwater and neutral-basic surface sources, metals present may begin to dissolve into solution as soon as pH falls below 7. As drain waters enter wetlands and playas already influenced by rising acidic groundwater, the solubility of any metals still bound to suspended particulates and colloids will increase thereby increasing the risk to aquatic biota.

The feasibility of treating acidic, saline metal-enriched groundwater is currently being investigated by the CSIRO in relation to potable supplies for wheatbelt towns (see Franzmann *et al.* 2007). If economically viable, treatment may provide an alternative to disposal of contaminated waters in playas and wetlands.

4.4 Recommendations

Characterisation of sites showed strong relationships between invertebrate species richness and salinity (conductivity) and pH. Salinity and pH appear to provide good ability to predict biodiversity. ARL (2006) recommended that salinity and pH be used for the Buntine-Marchagee Recovery Catchment as cost-effective proxy measures of more expensive, time consuming and technically challenging invertebrate fauna monitoring. The same recommendation is made here for the Yarra Yarra catchment. Salinity and pH should be monitored on a minimum monthly basis and invertebrate fauna monitoring be conducted every 3 to 5 years. This should allow trends in biodiversity to be monitored in relation to changes in water quality. As part of management, bund walls of drains must be maintained to prevent disposal waters entering non-target playas and wetlands, *e.g.* site 10 in Mongers 55 sub-catchment and site 23 in Xantippe sub-catchment.

It is also recommended that dissolved metals be re-sampled using a smaller filter size to confirm high ambient concentrations of Cu, Fe, Mn, Pb and Zn. A 1 kDa (0.5 - 1 nm) regenerated cellulose Millipore® filter is recommended in order to isolate truly dissolved fractions (Kimball 2007). Following this, speciation measurements could be used to quantify which forms (or species) are present and provide a better estimate of the bioavailable metal concentration where the dissolved metal concentrations (< 1kDa) exceed the guideline trigger values.

Alternatively, or if dissolved metal concentrations < 1kDa prove high, Diffuse Gradients in Thin Films (DGTs) could be used for *in situ* measurement of labile metals. The DGT technique is based on a simple device that accumulates metal ions in a well-defined manner from solution. Soluble metal species diffuse through a sorption layer of known thickness (*e.g.* polyacrylamide gels or cellulose membranes bound to small resin plates) in which a concentration gradient is maintained. Behind this diffusive layer is a binding layer in which reactive metal species are bound. The mass of accumulated metal is measured following retrieval and is used to calculate the average concentration of DGT labile metal species in the bulk solution over the deployment time. In accordance with the ANZECC/ARMCANZ (2000) water quality guidelines, DGTs may be used as a speciation measurement to provide a better estimate of the bio-available metal concentration if dissolved metal concentrations exceed the guideline trigger values.

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APPENDICES


Site 12, Goodlands sub-catchment, May 2008

Appendix 1. Site photographs, taken May 2008

LAKE HILLMAN


Site 1


Site 2


Site 3

LAKE DECOURCY


Site 4


Site 5

MONGERS 55 SUB-CATCHMENT

Site 6

Site 7

Site 8

Site 9

Site 10 showing eroded bund.

Site 11

MONGERS 16 SUB-CATCHMENT

Site 15

Site 16

Site 17

Site 18

GOODLANDS 33 SUB-CATCHMENT


Site 12


Site 13


Site 19


Site 20

XANTIPPE SUB-CATCHMENT

Site 22

Site 23

Site 24

Site 25

Appendix 2. ANZECC/ARMCANZ (2000) trigger values

General Water Quality Parameters

Trigger values for the protection of aquatic ecosystems applicable to south-west Western Australia.
TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NO_x = total nitrates/nitrites; NH_4+ = ammonium

	TP (mg/L)	FRP (mg/L)	TN (mg/L)	NO_x (mg/L)	NH_3 (mg/L)	NH_4^+ (mg/L)	DO % saturation[2]	pH
Upland River[1]	0.02	0.01	0.45	0.2	0.9[3]	0.06	90	6.5 - 8.0
Lowland River[1]	0.065	0.04	1.2	0.15	0.9[3]	0.08	80 - 120	6.6 - 8.0
Lakes & Reservoirs	0.01	0.005	0.35	0.01	0.9[3]	0.01	90	6.5 - 8.0
Wetlands	0.06	0.03	1.5	0.1	0.9[3]	0.04	90 - 120	7.0 - 8.5
Estuaries	0.03	0.005	0.75	0.045	0.9	0.04	90 - 110	7.5 – 8.5
Marine inshore	0.02[4]	0.005[4]	0.23	0.005	0.9	0.005	ID	8.0 - 8.4

ID = insufficient data to derive a reliable trigger value;

[1]All values during base river flow not storm events.

[2] Derived from daytime measurements; may vary diurnally and with depth; data loggers required to assess variability.

[3] General level for slightly-moderately disturbed ecosystems; figure may not protect species from chronic toxicity.

[4] Summer (low rainfall values); values higher in winter, *e.g.* TP 0.04 mg/L, FRP 0.01 mg/L.

Metals

Trigger values for the protection of aquatic ecosystems. Values for slightly to moderately disturbed systems are shaded grey.

Metals	Trigger values for Freshwater (mg/L) Level of protection (% species)				Trigger values for Marine Water (mg/L) Level of protection (% species)			
	99%	95%	90%	80%	99%	95%	90%	80%
Arsenic (As III)	0.001	0.024	0.094	0.36	ID	ID	ID	ID
Arsenic (As V)	0.0008	0.013	0.042	0.14	ID	ID	ID	ID
Cadmium	0.00006	0.0002	0.0004	0.0008 [C]	0.0007 [B,]	0.0055 [B,C]	0.014 [B,C]	0.036 [B,A]
Chromium (Cr III)	ID	ID	ID	ID	0.0077	0.0274	0.0486	0.0906
Chromium (Cr VI)	0.00001	0.0001 [C]	0.0006 [A]	0.04 [A]	0.00014	0.0044	0.02 [C]	0.085 [C]
Cobalt	ID	ID	ID	ID	0.000005	0.001	0.014	0.15 [C]
Copper	0.001	0.0014	0.0018 [C]	0.0025 [C]	0.0003	0.0013	0.003 [C]	0.008 [A]
Iron	ID	ID	ID	ID	ID	ID	ID	ID
Lead	0.001	0.0034	0.0056	0.0094 [C]	0.0022	0.0044	0.0066 [C]	0.012 [C]
Manganese	1.2	1.9 [C]	2.5 [C]	3.6 [C]	ID	ID	ID	ID
Molybdenum	ID	ID	ID	ID	ID	ID	ID	ID
Nickel	0.008	0.011	0.013	0.017 [C]	0.007	0.07 [C]	0.2 [A]	0.56 [A]
Selenium (Total) [B]	0.005	0.011	0.018	0.034	ID	ID	ID	ID
Vanadium	ID	ID	ID	ID	0.05	0.1	0.16	0.28
Zinc	0.0024	0.008 [C]	0.015 [C]	0.031 [C]	0.007	0.015 [C]	0.023 [C]	0.043 [C]

ID = insufficient data to derive a reliable trigger value;

[A] Trigger may not protect key test species from acute or chronic toxicity; indicates that trigger value > acute toxicity value; note that trigger value should be <1/3 of acute value;

[B] Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered;

[C] Figure may not protect key species from chronic toxicity.

Appendix 3. Water quality data recorded in May 2008

Table A3-1. Results for sites YY1 to YY12.

		SITE											
PARAMETER	**UNITS**	**YY1**	**YY2**	**YY3**	**YY4**	**YY5**	**YY6**	**YY7**	**YY8**	**YY9**	**YY10**	**YY11**	**YY12**
Temp	**^{o}C**	24.70	20.60	24.00	20.50	22.00	13.80	14.00	21.70	22.40	19.60	19.90	22.70
pH		8.37	7.05	4.16	7.88	7.47	8.82	8.97	3.53	3.49	3.48	6.35	7.33
EC	**mS/cm**	95.50	20.90	127.60	133.70	232.00	100.50	5.58	73.90	60.80	80.90	14.96	230.00
DO	**%**	108.00	95.00	84.00	52.00	86.00	86.00	111.00	94.00	92.00	85.00	107.00	79.00
DO	**mg/L**	8.50	8.20	6.80	4.60	7.60	8.60	11.00	8.00	7.70	7.70	9.40	6.50
Redox	**mV**	-92.20	-82.90	154.90	-60.20	-42.40	-112.50	-123.10	192.30	195.40	194.50	27.20	-19.90
Secchi	**m**	0.00	0.00	0.00	0.00	0.00	0.47	0.85	0.00	0.00	0.00	0.00	0.00
Depth	**m**	0.07	0.20	0.07	0.32	0.05	1.00	1.50	0.05	0.05	0.18	1.00	0.10
As	**mg/L**	0.01	0.0025	0.025	0.025	0.025	0.01	0.001	0.001	0.005	0.01	0.001	0.025
CO3	**mg/L**	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ca	**mg/L**	1800	462	1830	1460	876	293	52.6	555	389	608	44.9	808
Cd	**mg/L**	0.001	0.00025	0.0025	0.0025	0.0025	0.001	0.0001	0.0001	0.0005	0.001	0.0001	0.0025
Cl	**mg/L**	37700	6320	55900	59100	173000	40300	1550	29100	22600	28600	3900	171000
Co	**mg/L**	0.001	0.0063	0.088	0.0025	0.0025	0.001	0.0004	0.035	0.058	0.074	0.0055	0.0025
Cr	**mg/L**	0.005	0.00125	0.0125	0.0125	0.0125	0.005	0.0005	0.0022	0.0025	0.005	0.0019	0.0125
Cu	**mg/L**	0.0025	0.0041	0.0025	0.0052	0.0074	0.0033	0.0024	0.0049	0.0056	0.0052	0.0033	0.014
Fe	**mg/L**	0.11	0.013	0.7	0.025	0.025	0.025	0.0025	9.4	18	14	0.041	0.025
HCO3	**mg/L**	67	31	0.5	198	64	113	61	0.5	0.5	0.5	3	70
K	**mg/L**	609	110	743	998	2880	306	37.6	546	425	555	44.3	2520
Mg	**mg/L**	2150	388	3470	3520	8320	750	93.3	1840	1500	1910	99.5	9510
Mn	**mg/L**	0.005	0.5	7.3	0.069	0.02	0.026	0.017	4.2	3.5	4.3	0.95	0.091
Mo	**mg/L**	0.01	0.0025	0.025	0.025	0.025	0.01	0.001	0.001	0.005	0.01	0.001	0.025
N_NO3	**mg/L**	0.005	0.29	7.1	0.2	0.005	0.005	0.1	0.13	0.11	0.14	0.64	0.005
N_total	**mg/L**	1.2	0.61	23	2.8	2	2	0.63	3.4	2.5	3.1	1.9	2.1
Na	**mg/L**	23200	3780	36600	36900	110000	25500	857	16600	13400	16800	3200	111000
Ni	**mg/L**	0.01	0.007	0.07	0.025	0.025	0.01	0.001	0.027	0.047	0.06	0.004	0.025
P_total	**mg/L**	0.01	0.005	0.005	0.01	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.06
Pb	**mg/L**	0.001	0.00025	0.068	0.0025	0.0025	0.001	0.0001	0.014	0.041	0.047	0.0001	0.005
SO4_S	**mg/L**	6470	1570	9050	7550	12600	1190	173	4140	3210	4030	248	15300
Se	**mg/L**	0.01	0.0025	0.025	0.025	0.025	0.01	0.001	0.001	0.005	0.01	0.001	0.025
V	**mg/L**	0.002	0.00025	0.0025	0.0095	0.0025	0.001	0.0005	0.0001	0.0005	0.001	0.0001	0.0025
Zn	**mg/L**	0.025	0.082	0.14	0.071	0.29	0.054	0.025	0.13	0.1	0.064	0.077	0.19

Table A3-1 continued. Results for sites YY13 to YY25.

		SITE											
PARAMETER	**UNITS**	**YY13**	**YY15**	**YY16**	**YY17**	**YY18**	**YY19**	**YY20**	**YY21**	**YY22**	**YY23**	**YY24**	**YY25**
Temp	**^oC**	17.70	16.10	22.80	20.20	26.00	17.80	14.10	17.10	19.10	17.80	17.10	19.50
pH		3.14	8.74	7.55	8.22	7.74	4.08	4.11	6.06	7.94	8.38	3.57	3.04
EC	**mS/cm**	213.00	75.70	210.00	101.70	151.70	172.80	49.20	234.00	224.00	78.90	72.00	238.00
DO	**%**	71.00	211.00	87.00	97.00	103.00	76.00	88.00	68.00	97.00	83.00	95.00	60.00
DO	**mg/L**	6.60	19.00	7.20	8.50	8.10	7.50	8.60	6.20	8.60	7.50	8.70	5.40
Redox	**mV**	212.70	-110.50	-42.80	-82.10	-54.70	158.60	151.60	53.00	-63.10	-90.50	187.30	219.30
Secchi	**m**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00
Depth	**m**	0.04	0.07	0.03	0.10	0.07	0.05	1.50	0.20	0.08	0.10	0.10	0.10
As	**mg/L**	0.025	0.01	0.025	0.025	0.025	0.025	0.005	0.35	0.025	0.01	0.01	0.025
CO3	**mg/L**	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Ca	**mg/L**	1070	222	630	1700	2140	2090	1280	607	1300	395	239	489
Cd	**mg/L**	0.0025	0.001	0.0025	0.0025	0.0025	0.0025	0.0005	0.0025	0.0025	0.001	0.001	0.0025
Cl	**mg/L**	121000	29700	149000	41900	71500	85000	17100	156000	131000	32200	29600	185000
Co	**mg/L**	0.17	0.001	0.0025	0.0025	0.0025	0.11	0.019	0.1	0.0025	0.001	0.041	0.058
Cr	**mg/L**	0.0125	0.005	0.0125	0.0125	0.0125	0.0125	0.0025	0.0125	0.0125	0.005	0.005	0.0125
Cu	**mg/L**	0.0025	0.0047	0.0066	0.0025	0.0025	0.0025	0.0026	0.83	0.012	0.001	0.0053	0.031
Fe	**mg/L**	3.7	0.025	0.025	0.025	0.025	0.89	6.3	0.16	0.025	0.025	32	11
HCO3	**mg/L**	0.5	332	454	159	238	0.5	0.5	21	134	299	0.5	0.5
K	**mg/L**	2420	773	3290	1120	1690	1720	263	1230	1830	520	466	1360
Mg	**mg/L**	5950	2320	14500	3040	5060	4580	515	3950	4360	1760	1810	3620
Mn	**mg/L**	4.7	0.16	0.021	0.005	0.005	4.1	2.5	1.1	0.063	0.04	2.2	2.2
Mo	**mg/L**	0.025	0.01	0.025	0.025	0.025	0.025	0.005	0.025	0.025	0.01	0.01	0.025
N_NO3	**mg/L**	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.23	0.005	0.005	0.67	0.13
N_total	**mg/L**	19	36	23	3.4	5.2	18	1.3	4.2	3.7	4.3	6.2	6.6
Na	**mg/L**	78900	16500	80900	24800	44900	53700	11300	95900	86700	19000	16400	116000
Ni	**mg/L**	0.21	0.01	0.025	0.025	0.025	0.13	0.012	0.57	0.025	0.025	0.038	0.12
P_total	**mg/L**	0.06	0.75	0.24	0.01	0.01	0.02	0.005	0.09	0.1	0.17	0.005	0.02
Pb	**mg/L**	0.043	0.001	0.0025	0.0025	0.0025	0.015	0.0017	0.0025	0.0025	0.001	0.028	0.005
SO4_S	**mg/L**	9860	2610	18600	7050	12200	8650	3300	7250	11200	3620	3720	8760
Se	**mg/L**	0.025	0.01	0.025	0.025	0.025	0.025	0.005	0.025	0.025	0.01	0.01	0.025
V	**mg/L**	0.0025	0.011	0.0025	0.0025	0.0025	0.0025	0.0005	0.0025	0.0025	0.0059	0.001	0.0025
Zn	**mg/L**	0.19	0.09	0.23	0.025	0.071	0.15	0.11	0.44	0.25	0.069	0.13	0.052

Appendix 4. Microinvertebrate fauna

Table A4-1. Systematic list of microinvertebrate taxa recorded from the Yarra Yarra wetlands in May 2008. Values are relative abundance (refer section 2.4). Cons. Cat. (conservation category): Aus = cosmopolitan/Australia and beyond, however not necessarily worldwide; I = indeterminate.

TAXA	CONS. CAT.	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24	25
PROTISTA																									
CILIOPHORA																									
Stentor sp.	Indet	--	--	--	302	--	189	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ROTIFERA																									
Brachionidae																									
Brachionus angularis Gosse	Aus	--	--	--	--	--	--	1	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Brachionus plicatilis s.l.	Aus	--	153	--	--	--	--	--	--	--	--	285	--	--	13	--	--	--	--	--	--	--	--	--	--
Brachionus ibericus s.l.	Aus	--	--	--	--	--	--	119	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?*Brachionus*	Indet	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexarthridae																									
Hexarthra cf. *fennica*	Indet	--	43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexarthra jenkinae (de Beauchamp, 1932)	Aus	--	--	--	--	--	--	41	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Notommatidae																									
Cephalodella catellina (Müller, 1786)	Aus	--	--	--	--	--	--	--	--	--	--	18	--	--	--	--	--	--	--	--	--	--	--	--	--
?Synchaetidae	Indet																								
?*Synchaeta*	Indet	--	47	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polyarthra dolichoptera (Idelson, 1925)	Aus	--	--	--	--	--	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Indeterminate sp.	Indet	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
CRUSTACEA																									
CLADOCERA																									
Daphniidae																									
Daphnia sp.	Indet	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Macrotrichidae																									
Macrothrix sp.	Indet	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Moinidae																									
Moina sp.	Aus	--	1	--	--	--	--	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
COPEPODA																									
CYCLOPOIDA																									
Apocyclops dengizicus (Lepeschkin, 1900)	Aus	--	11	--	2	--	1	7	--	--	--	--	--	--	8	--	1	--	--	--	--	--	3	--	--
Metacyclops cf. *arnaudi* (copepodites)	Indet	294	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Metacyclops sp.	Indet	--	--	--	--	--	--	2	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
copepodites	Indet	--	--	--	--	--	6	29	1	--	--	1	--	--	20	--	23	3	--	--	--	--	85	--	--
nauplii	Indet	6	40	--	--	--	63	92	--	--	--	6	--	--	1	--	--	--	--	--	--	--	220	--	--
CALANOIDA																									
Boeckella cf. *triarticulata*	Indet	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Boeckella sp. (female)	Indet	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
OSTRACODA																									
cf. *Australocypris*	Indet	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyprinotus edwardi McKenzie, 1978	Aus	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
cf. *Diacypris* sp.	Indet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	62	--	--	--	--	--	--	--
Mytilocypris sp.	Aus	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1	2	--	--	--	--	--	--	--
Reticypris sp.	Indet	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--
Total number of taxa		**2**	**9**	**0**	**2**	**0**	**5**	**13**	**1**	**0**	**0**	**7**	**0**	**0**	**5**	**0**	**3**	**4**	**0**	**0**	**0**	**0**	**3**	**0**	**0**

Appendix 5. Macroinvertebrate fauna

Table A5-1. Systematic list of macroinvertebrate taxa recorded from the Yarra Yarra wetlands in May 2008. Values are log-abundance, *i.e.* log10 scale where 1 = 1 individuals, 2 = 2-10, 3 = 11-100, 4 = 101-1000, 5 = >1001. Pres = evidence of past presence (*e.g.* dead individuals) but not collected live during the current study. Cons. Cat. (conservation category): Aus = cosmopolitan/Australia and beyond, however not necessarily worldwide; WA = Western Australia only; SW = endemic to south-western WA; Indet = indeterminate.

TAXA	***CONS***	***SITE***																							
	CAT	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24	25
MOLLUSCA																									
GASTROPODA																									
Pomatiopsidae																									
Coxiella ?pyrrhostoma	Aus	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ARACHNIDA																									
ACARIFORMES	Indet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--
CRUSTACEA																									
BRANCHIOPODA																									
Indeterminate spp.*	Indet	--	--	--	1	--	3	--	--	--	--	--	--	--	--	--	--	--	1	--	2	--	3	--	--
Parartemidae																									
Paratemia spp. (female)	Indet	2	--	--	1	--	--	--	--	--	--	--	--	--	--	1	1	--	2	--	--	--	--	--	--
Paratemia longicaudata	WA	2	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Paratemia contracta	SW	--	2	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--
Paratemia servyenti	WA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	--	--
Triopsidae																									
Triops australiensis	Aus	--	--	--	--	--	--	Pres	--	--	--	--	--	--	Pres	--	--	--	--	--	--	--	--	--	--
INSECTA																									
ODONATA																									
ANISOPTERA																									
Hemicorduliidae																									
Hemicordulia tau	Aus	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
ZYGOPTERA																									
Lestidae																									
Austrolestes annulosus	Aus	--	--	--	--	--	--	3	--	--	--	--	--	--	1	--	--	--	--	2	--	--	--	--	--
HEMIPTERA																									
Notonectidae																									
Anisops sp. (female)	Indet	--	--	--	--	--	--	3	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Anisops thienemanni	Aus	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Corixidae																									
Micronecta robusta	Aus	--	--	--	--	--	--	3	1	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Corixidae spp. (juvenile)	Indet	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
COLEOPTERA																									
Dytiscidae		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Indetreminate sp.*	Indet	--	--	--	--	--	2	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	2	1	--
Antiporus sp. (larvae)	Indet	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Eretes australis	Aus	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--
Necterosoma sp. (larvae)	Indet	--	--	--	1	--	--	--	--	--	1	--	--	--	2	--	2	--	--	3	--	--	2	--	--
Necterosoma darwini	WA	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	1	--	2	--	--	--	--	--
Sternopriscus sp. (female)	Indet	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tribe Bidessini (larvae)	Indet	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Hydrophilidae																									
Berosus pulchellus	Aus	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Berosus macumbensis	Aus	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Berosus sp. (larvae)	Indet	--	--	--	--	--	--	--	--	--	--	2	--	--	1	--	1	--	--	1	--	--	--	--	--
DIPTERA																									
Indeterminate larvae	Indet	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	1
Chironomidae																									
Chrionomid spp. (pupae)	Indet	--	3	--	3	--	3	2	--	--	--	2	--	--	3	3	3	3	--	3	2	--	2	--	--

Table A5-1 continued.

TAXA	***CONS CAT***	***SITE***																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	24	25
Chironominae																									
Chironomus aff. *alternans*	Aus	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--
Chironomus tepperi	Aus	--	4	--	--	--	--	2	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--
Cryptochironomus greseidorsum	Aus	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Tanytarsus barbitarsus	Aus	2	3	--	5	2	5	3	3	2	--	3	--	--	5	4	5	5	2	4	3	3	4	3	--
Tanytarsus semibarbitarsus	Aus	--	--	--	--	--	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--
Dicrotendipes ?jobetius	Indet	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Polypedilum nubifer	Aus	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Tanypodinae		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Procladius paludicola	Aus	--	1	--	--	--	3	3	1	--	--	3	--	--	3	--	3	2	--	--	--	--	--	--	--
Orthocladiinae		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Paralimnophes ?pullulus (V42)	Aus	--	3	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	2	--	--	--	--	--
Athericidae																									
Athericidae sp.	Indet	1	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ceratopogonidae																									
Ceratopogoninae spp.	Indet	--	2	--	--	--	1	3	--	3	--	2	--	--	3	--	3	2	--	3	--	--	--	2	--
Dasyheleinae sp.	Indet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2
Ceratopogoninae spp. (pupae)	Indet	--	2	--	--	--	2	2	--	--	--	--	--	--	--	--	2	2	--	2	2	--	--	--	--
Culicidae																									
Culex sp.	Indet	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dolichopodidae																									
Dolichopodidae sp.	Indet	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--
Simulidae																									
Simulium sp.	Indet	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--
Tabanidae																									
Tabanus sp.	Indet	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Syrphidae																									
Syrphidae sp.	Indet	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Stratiomyidae																									
Stratiomyidae spp.	Indet	--	--	--	--	--	2	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--
Ephydridae																									
Ephydridae sp.	Indet	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--
Ephydridae sp. (pupa)		--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Muscidae																									
Muscidae sp.	Indet	--	1	--	--	--	3	--	--	--	--	--	--	--	--	--	1	--	--	1	--	--	--	--	--
TRICHOPTERA																									
Leptoceridae																									
Leptoceridae sp. (juvenile)	WA	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Total number of taxa		**4**	**12**	**0**	**6**	**2**	**15**	**13**	**3**	**3**	**3**	**16**	**0**	**0**	**10**	**4**	**9**	**6**	**5**	**11**	**6**	**1**	**6**	**3**	**2**

*immature and/or damaged

Appendix 6. Field data sheets

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Lake Hillman reference site* ***YY1***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 515080*	Northing	*6647205*
Date of sampling	*19/5/08*	Time of sampling	*12:55*
Air temperature (°C)	*~22°C*		
Weather conditions	*Clear, sunny, warm, no wind*		
Comments on photos	*#1, 2, 3*		

Water Quality

Water temperature (°C)	*24.7*	
pH (pH units)	*8.37*	
Redox (mV)	*-92.2*	
Conductivity (mS/cm)	*95.5*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*108 %*	*8.5 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.07*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments

Human Impacts

In water	
In fringing vegetation	
Land use in catchment	*Gypsum mining*

Fauna

	Molluscs ☑ *Coxiella sp. on bank* Water birds Frogs Other *Brine shrimp, copepods*
Other Comments	*Algal mats* *Samphire* *Dead shrub stumps on bed of gypsum ~250 mm deep, underlain by grey muds*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Lake Hillman impact site **YY2***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 517922*	Northing	*6645252*
Date of sampling	*19/5/08*	Time of sampling	*14:00*
Air temperature (°C)	*~22°C*		
Weather conditions	*Clear, sunny, warm, no wind*		
Comments on photos	*#4, 5, 6*		

Water Quality

Water temperature (°C)	*20.6*	
pH (pH units)	*7.05*	
Redox (mV)	*-82.9*	
Conductivity (mS/cm)	*20.9*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*95 %*	*8.2 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.20*

Benthos

Salt crust	No Yes Thickness (mm) *Benthic mat*
Shrub stumps	No Yes Comments
Substrate	Comments

Human Impacts

In water	
In fringing vegetation	
Land use in catchment	*Gypsum mining*

Fauna

	Molluscs Water birds ☑ *Shelduck* Frogs ☑ *Tadpoles* Other *Brine shrimp, chironomid larvae, beetles*
Other Comments	*Sampled in fringing samphire.* *Gypsum crystals; strong smell of sulphur off playa* *White scum/silvery layer on surface and foam/scum along shore – Ian Fordyce mentioned aluminium sulphate can cause white scum in some lakes.*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Lake Hillman reference site **YY3***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 516515*	Northing	*66447222*
Date of sampling	*19/5/08*	Time of sampling	*15:20*
Air temperature (°C)	*~22°C*		
Weather conditions	*Clear, sunny, warm, light breeze*		
Comments on photos	*#7, 8, 9, 10*		
Water Quality			
Water temperature (°C)	*24.0*		
pH (pH units)	*4.16*		
Redox (mV)	*154.9*		
Conductivity (mS/cm)	*127.6*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*84 %*	*6.8 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*0.07*	
Benthos			
Salt crust	No Yes	Thickness (mm)	*Gypsum ~2 cm*
Shrub stumps	No Yes	Comments	
Substrate	Comments	*Fine silt*	
Human Impacts			
In water			
In fringing vegetation			
Land use in catchment	*Arable farmland along one side*		
Fauna			
	Molluscs Water birds Frogs Other		
Other Comments	*Small basin (400 m x 150 m) on edge of main lake.* *Robert Nixon (farmer/miner) said it never gets inundated from main lake, but water level could be connected through aquifer/groundwater.* *Farmland to SW side approx. 50 m from water's edge.* *Gypsum crystal across surface of substrate beneath water.*		

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Lake DeCourcy exposed site* ***YY4***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 513349*	Northing	*6653367*
Date of sampling	*19/5/08*	Time of sampling	*16:30*
Air temperature (°C)	*~22°C*		
Weather conditions	*Clear, sunny, warm, light breeze*		
Comments on photos	*#11, 12, 13, 14*		

Water Quality

Water temperature (°C)	*20.5*	
pH (pH units)	*7.88*	
Redox (mV)	*-60.2*	
Conductivity (mS/cm)	*133.7*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*52 %*	*4.6 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.32*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Soft, black anoxic ooze*

Human Impacts

In water	*Drain into playa*
In fringing vegetation	
Land use in catchment	

Fauna

	Molluscs Water birds ☑ *Swan, Dotterel, Mountain Duck, Teal(?)* Frogs Other *Abundant brine shrimp and chironomid larvae*

Other Comments	*Samphire*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Lake DeCourcy reference site* ***YY5***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 5092999*	Northing	*6656261*
Date of sampling	*19/5/08*	Time of sampling	*17:15*
Air temperature (°C)	*~22°C*		
Weather conditions	*Clear, sunny, warm, light breeze*		
Comments on photos	*#15, 16, 17*		

Water Quality		
Water temperature (°C)	*22.0*	
pH (pH units)	*7.47*	
Redox (mV)	*-42.4*	
Conductivity (mS/cm)	*232*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*86 %*	*7.6 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.05*

Benthos	
Salt crust	No Yes ☑ Thickness (mm) *2 mm*
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Firm and slippery on top; thin salt crust*
Human Impacts	
In water	
In fringing vegetation	*Farmland*
Land use in catchment	
Fauna	
	Molluscs Water birds Frogs Other
Other Comments	*White benthic mat* *Samphire* *Large broad expanse of shallow water subject to wind sheer*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Mongers 55 sub-catchment reference site **YY6***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 5092999*	Northing	*6656261*
Date of sampling	*20/5/08*	Time of sampling	*09:10*
Air temperature (°C)	*~16°C*		
Weather conditions	*Cloudy, no wind*		
Comments on photos	*# 18, 19, 20, 21, 22 - Jibberling Drain; #23, 24, 25, 26 - site YY6*		
Water Quality			
Water temperature (°C)	*13.8*		
pH (pH units)	*8.82*		
Redox (mV)	*-112.5*		
Conductivity (mS/cm)	*100.5*		
Secchi disc (m)	*0.47*		
Dissolved Oxygen	*86 %*	*8.6 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*>1 (deep)*	
Benthos			
Salt crust	No ☑ Yes Thickness (mm)		
Shrub stumps	No Yes ☑ Comments		
Substrate	Comments		
Human Impacts			
In water			
In fringing vegetation	*Salt – dead trees*		
Land use in catchment	*Farming*		
Fauna			
	Molluscs Water birds ☑ *Shelduck (x10), Teal (?)* Frogs Other *Brine shrimp, chironomid larvae, ostracods, copepods*		
Other Comments	*Wetland fully inundated; approx. 250 m diameter; water up to fringing samphire*		

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Mongers 55 sub-catchment, Tinika Lake / Boat Lake reference site* ***YY7***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 477939*	Northing	*6693209*
Date of sampling	*20/5/08*	Time of sampling	*10:15*
Air temperature (°C)	*~17°C*		
Weather conditions	*High cloud, sunny, warm, light breeze*		
Comments on photos	*#27, 28, 29*		

Water Quality

Water temperature (°C)	*14.0*	
pH (pH units)	*8.97*	
Redox (mV)	*-123.1*	
Conductivity (mS/cm)	*5.58*	
Secchi disc (m)	*0.85 – 0.90*	
Dissolved Oxygen	*111 %*	*11.0 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*~1.5 at deepest*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Just fine sediment*

Human Impacts

In water	*Some filamentous green algae around edges*
In fringing vegetation	
Land use in catchment	

Fauna

	Molluscs Water birds ☑ Frogs *No frogs when sampled but see comment below* Other
Other Comments	*Landowner Wayne Johnson and Tyson (the dog) mentioned shield shrimps were seen when the Lake first filled. Frogs were also present, but all left the lake and climbed into the drain – reckons 'hundreds' left the lake, but all died in the drain.* *Drain runs past the edge of the Lake, but does not affect the Lake. Some dead trees around the edge; samphire down to water's edge; water level at time of sampling high and into samphire.*

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Mongers 55 sub-catchment exposed site **YY8***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 4799559*	Northing	*6695763*
Date of sampling	*20/5/08*	Time of sampling	*11:40*
Air temperature (°C)	*~19°C*		
Weather conditions	*High cloud, sunny, warm, still*		
Comments on photos	*#30,31,32,33,34*		

Water Quality

Water temperature (°C)	*21.7*	
pH (pH units)	*3.53*	
Redox (mV)	*192.3*	
Conductivity (mS/cm)	*73.9*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*94 %*	*8.0 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.05*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Orange Fe-oxide precipitate/sludge across bed*

Human Impacts

In water	*Drain water*
In fringing vegetation	
Land use in catchment	

Fauna

	Molluscs Water birds Frogs Other

Other Comments	*Extremely degraded site at bottom end of drain where it discharges into Lake Monger.*

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Mongers 55 sub-catchment, Crystal Lake/15-ha-Lake, exposed site* ***YY9***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 478748*	Northing	*6693995*
Date of sampling	*20/5/08*	Time of sampling	*12:25*
Air temperature (°C)	*~19°C*		
Weather conditions	*High cloud, sunny, warm, light breeze*		
Comments on photos	*#35, 36, 37, 38*		

Water Quality

Water temperature (°C)	*22.4*	
pH (pH units)	*3.49*	
Redox (mV)	*195.4*	
Conductivity (mS/cm)	*60.8*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*92 %*	*7.7 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.05*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Lot of very fine Fe-oxide silt/slime*

Human Impacts

In water	*Drain into and out of wetland*
In fringing vegetation	*Some dead trees*
Land use in catchment	

Fauna

	Molluscs Water birds ☑ *Some bird footprints in silt – species unknown* Frogs Other
Other Comments	*Extremely degraded* *Drain into and out of lake. Approx one quarter of lake bed with water cove, but very shallow. Water enters at south, flows around east side and out at north end. Flow ~2-3L/sec.* *This site located upstream of site #8; deep drain flows through wetland.*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Mongers 55 sub-catchment, exposed site* ***YY10***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 478797*	Northing	*6694561*
Date of sampling	*20/5/08*	Time of sampling	*12:25*
Air temperature (°C)	*~19°C*		
Weather conditions	*High cloud, sunny, warm, light breeze -flies*		
Comments on photos	*#39,40,41*		

Water Quality		
Water temperature (°C)	*19.6*	
pH (pH units)	*3.48*	
Redox (mV)	*194.5*	
Conductivity (mS/cm)	*80.9*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*85 %*	*7.7 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.18*

Benthos	
Salt crust	No Yes Thickness (mm)
Shrub stumps	No Yes Comments
Substrate	Comments *Gypsum crystals; algae.*
Human Impacts	
In water	
In fringing vegetation	
Land use in catchment	
Fauna	
	Molluscs Water birds Frogs Other
Other Comments	*Extremely degraded; bunds of deep drain eroded & drainage waters flow into wetland.*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Mongers 55 sub-catchment, reference site* ***YY11***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 478257*	Northing	*6691517*
Date of sampling	*20/5/08*	Time of sampling	*14:25*
Air temperature (°C)	*~19°C*		
Weather conditions	*High light cloud, sunny, warm, no breeze*		
Comments on photos	*#42, 43, 44*		
Water Quality			
Water temperature (°C)	*19.9*		
pH (pH units)	*6.35*		
Redox (mV)	*27.2*		
Conductivity (mS/cm)	*14.96*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*107 %*	*9.4 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*>1.0*	
Benthos			
Salt crust	No Yes Thickness (mm)		
Shrub stumps	No Yes ☑ Comments *Dead trees along shoreline*		
Substrate	Comments		
Human Impacts			
In water	*Dead trees indicative of increased inundation and salinisation*		
In fringing vegetation	*Paddock to 30 m from water; cattle in riparian zone and in water*		
Land use in catchment	*Cattle, pasture, crops*		
Fauna			
	Molluscs Water birds ☑ *Mountain Duck* Frogs Other		
Other Comments	*Lake set in farm land – dead trees suggest increased inundation and secondary salinisation. Ian Fordyce commented that when dry he had cored middle of lake and found groundwater at pH ~4.0 approx. 40 cm below the salt crust.*		

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Goodlands sub-catchment, reference site* ***YY12***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 5034486*	Northing	*6664779*
Date of sampling	*20/5/08*	Time of sampling	*16:10*
Air temperature (°C)	*~19°C*		
Weather conditions	*High thin cloud, sunny, warm, light breeze*		
Comments on photos	*#45, 46, 47, 48*		

Water Quality

Water temperature (°C)	*22.7*	
pH (pH units)	*7.33*	
Redox (mV)	*-19.9*	
Conductivity (mS/cm)	*230*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*79 %*	*6.5 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.10*

Benthos

Salt crust	No Yes ☑ Thickness (mm) *0.5 cm*
Shrub stumps	No ☑ Yes Comments *Salt and lots of it!*
Substrate	Comments

Human Impacts

In water	
In fringing vegetation	*Farmland to the west – 50 m from lake – native veg on all other sides*
Land use in catchment	

Fauna

	Molluscs Water birds Frogs Other

Other Comments	*Salt lake just to north side of causeway.* *Salt crust on exposed flats around lake and salt crust across lake bed; pink – benthic mats? Diatoms?*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Goodlands sub-catchment, reference site **YY13** (future exposed site)*		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 508992*	Northing	*6663990*
Date of sampling	*20/5/08*	Time of sampling	*17:15*
Air temperature (°C)	*~19°C*		
Weather conditions	*Clear, bright, warm, still – sun setting*		
Comments on photos	*#45, 46, 47, 48*		
Water Quality			
Water temperature (°C)	*22.7*		
pH (pH units)	*7.33*		
Redox (mV)	*-19.9*		
Conductivity (mS/cm)	*230*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*79 %*	*6.5 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*0.10*	
Benthos			
Salt crust	No Yes ☑ Thickness (mm) *0.5 cm*		
Shrub stumps	No ☑ Yes Comments		
Substrate	Comments *Salt and lots of it!*		
Human Impacts			
In water			
In fringing vegetation	*Farmland to the west – 50 m from lake – native veg on all other sides*		
Land use in catchment			
Fauna			
	Molluscs Water birds Frogs Other		
Other Comments	*Salt lake just to north side of causeway.* *Salt crust on exposed flats around lake and salt crust across lake bed; pink – benthic mats? Diatoms?*		

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Mongers 16 sub-catchment, Swan Lake, reference site **YY14*** *Not sampled for fauna*		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 470979*	Northing	*6718591*
Date of sampling	*21/5/08*	Time of sampling	*09:15*
Air temperature (°C)	*??*		
Weather conditions	*Clear, bright, warm, still*		
Comments on photos	*#55, 56*		
Water Quality			
Water temperature (°C)	*11.8*		
pH (pH units)	*8.88*		
Redox (mV)	*-117.1*		
Conductivity (mS/cm)	*4.71*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*74 %*	*7.6 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*0.15*	
Benthos			
Salt crust	No ☑ Yes Thickness (mm)		
Shrub stumps	No ☑ Yes Comments		
Substrate	Comments *Dead samphire across lake bed together with globula green macrophyte. Lot of detrital organics.*		
Human Impacts			
In water			
In fringing vegetation	*Some past grazing?*		
Land use in catchment	*Sheep and arable land*		
Fauna			
	Molluscs Water birds ☑ *Mountain Duck, Grey Teal* Frogs Other ☑ *Concostracan & shield shrimps dead along shore; one live shield shrimp*		
Other Comments	*Small ?perched basin ~200m across* *Dead samphire suggests recent invasion or increased inundation* *This site probably not directly comparable to other sites as it is not on the main line drainage channel. It is perched and set off the lower channel. Main line (dry) lakes are saline.*		

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Mongers 16 sub-catchment, reference site* ***YY15*** *(?potentially exposed)*		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 471404*	Northing	*6719355*
Date of sampling	*21/5/08*	Time of sampling	*10:10*
Air temperature (°C)	*??*		
Weather conditions	*Clear, sunny, warm, still*		
Comments on photos	*#57, 58*		

Water Quality

Water temperature (°C)	*16.1*	
pH (pH units)	*8.74*	
Redox (mV)	*-110.5*	
Conductivity (mS/cm)	*75.7*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*211 %*	*19 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.07*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No Yes ☑ Comments
Substrate	Comments *Deep samphire; soft anoxic black slime with 100% cover of Ruppia.*

Human Impacts

In water	*Pea-green water – algal bloom active*
In fringing vegetation	*Samphire - ~100 m buffer to arable land/grazing land*
Land use in catchment	*Grazing / arable land*

Fauna

	Molluscs Water birds Frogs Other
Other Comments	*Small (50 m diam.) receding basin* *Ruppia across floor of lake* *Shield shrimp 'skins' along shore area*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Mongers 16 sub-catchment, exposed site* ***YY16***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 471726*	Northing	*6718710*
Date of sampling	*21/5/08*	Time of sampling	*10:55*
Air temperature (°C)	*??*		
Weather conditions	*Clear, sunny, warm, still*		
Comments on photos	*#59, 60, 61*		

Water Quality

Water temperature (°C)	*22.8*	
pH (pH units)	*7.54*	
Redox (mV)	*-42.8*	
Conductivity (mS/cm)	*210*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*87 %*	*7.2 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.04*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Soft, slimy sediment; anoxic, black sub-layer; Ruppia dead across surface*

Human Impacts

In water	*Sheep*
In fringing vegetation	*Sheep grazing*
Land use in catchment	*Grazing / arable land*

Fauna

	Molluscs Water birds Frogs Other
Other Comments	*Orange-green iridescent 'oil' slick across surface of lake* *Oval lake- receding - dead Ruppia along shores; only approx. 50% of lake inundated.*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Mongers 16 sub-catchment, exposed site **YY17** (?potentially exposed)*		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 471903*	Northing	*6719202*
Date of sampling	*21/5/08*	Time of sampling	*11:25*
Air temperature (°C)	*??*		
Weather conditions	*Clear, sunny, warm, still*		
Comments on photos	*#62, 63, 64*		
Water Quality			
Water temperature (°C)	*20.8*		
pH (pH units)	*8.22*		
Redox (mV)	*-82.1*		
Conductivity (mS/cm)	*101.7*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*97 %*	*8.5 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*0.10*	
Benthos			
Salt crust	No ☑ Yes Thickness (mm)		
Shrub stumps	No ☑ Yes Comments		
Substrate	Comments *Soft, slimy silty but firm under top ~5 cm; sparse Ruppia across bed*		
Human Impacts			
In water	*Receives inflow from upstream chain of lakes (e.g. site 16)*		
In fringing vegetation	*Sheep grazing*		
Land use in catchment	*Grazing / arable land*		
Fauna			
	Molluscs Water birds ☑ *None present but many footprints – likely Dotterels* Frogs Other ☑ *Brine shrimp (small), ostracods*		
Other Comments	*Oval lake ~300 m across* *Water level drawn down ~10 m from samphire fringe* *Obvious inflow channel and delta to the north-west*		

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Mongers 16 sub-catchment, reference site **YY18***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 471748*	Northing	*6718277*
Date of sampling	*21/5/08*	Time of sampling	*13:35*
Air temperature (°C)	*??*		
Weather conditions	*Clear, sunny, warm, light breeze*		
Comments on photos	*#65, 66, 67*		
Water Quality			
Water temperature (°C)	*26.0*		
pH (pH units)	*7.74*		
Redox (mV)	*-54.7*		
Conductivity (mS/cm)	*151.7*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*103 %*	*8.1 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*0.07*	
Benthos			
Salt crust	No ☑ Yes Thickness (mm)		
Shrub stumps	No ☑ Yes Comments		
Substrate	Comments *Fine, soft silt over black anoxic layer; patchy Ruppia beds (~5% cover)*		
Human Impacts			
In water			
In fringing vegetation	*Sheep grazing*		
Land use in catchment	*Grazing / arable land*		
Fauna			
	Molluscs Water birds ☑ *None present but many tracks* Frogs Other ☑ *Chironomid larvae and pupae, ostracods*		
Other Comments	*Small oval lake ~200 m across*		

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Goodlands sub-catchment, reference site **YY19** (future exposed site)*		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 508629*	Northing	*6664863*
Date of sampling	*21/5/08*	Time of sampling	*16:55*
Air temperature (°C)	*??*		
Weather conditions	*Clear, sunny, warm, light breeze*		
Comments on photos	*#68, 69, 70*		

Water Quality

Water temperature (°C)	*17.8*	
pH (pH units)	*4.08*	
Redox (mV)	*158.6*	
Conductivity (mS/cm)	*172.8*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*76 %*	*7.5 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.05*

Benthos

Salt crust	No Yes ☑ Thickness (mm) *1 - 2 mm*
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Gypsum crystals*

Human Impacts

In water	*Fence through wetland*
In fringing vegetation	
Land use in catchment	*Sheep grazing*

Fauna

	Molluscs Water birds Frogs Other ☑ *Brine shrimp, copepods*
Other Comments	

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Goodlands sub-catchment, reference site* ***YY20***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 508966*	Northing	*6664599*
Date of sampling	*22/5/08*	Time of sampling	*09:00*
Air temperature (°C)	*??*		
Weather conditions	*Clear, sunny, cool, moderate wind*		
Comments on photos	*#71, 72, 73*		

Water Quality

Water temperature (°C)	*14.1*		
pH (pH units)	*4.11*		
Redox (mV)	*151.6*		
Conductivity (mS/cm)	*49.2*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*88 %*	*8.6 mg/L*	
Water depth	Top of post to water surface (m)		*--*
	Top of post to sediment (m)		*--*
	Total water depth (m)		*~1.5*

Benthos

Salt crust	No Yes Thickness (mm)
Shrub stumps	No Yes ☑ Comments *Around edge above inundation level*
Substrate	Comments *Soft around edges*

Human Impacts

In water	*Drain in and out of wetland; increased inundation*
In fringing vegetation	*Sheep grazing ~30 m to east*
Land use in catchment	*Grazing / arable lands*

Fauna

	Molluscs Water birds ☑ *Mountain Duck (x2)* Frogs Other
Other Comments	*Lake surrounded by trees and shrubs (some dead) on south, west and north sides* *Local surface drain enters from east and flows out to the north – discharges into #19 on high flows*

YARRA YARRA AQUATIC MONITORING MAY 2008			
Site Name & Number	*Goodlands sub-catchment, exposed site* ***YY21***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 505020*	Northing	*6659760*
Date of sampling	*22/5/08*	Time of sampling	*10:30*
Air temperature (°C)	*??*		
Weather conditions	*100% cloud cover, rain, strong WSW wind*		
Comments on photos	*No photos – raining too hard*		

Water Quality		
Water temperature (°C)	*17.1*	
pH (pH units)	*6.06*	
Redox (mV)	*53*	
Conductivity (mS/cm)	*234*	
Secchi disc (m)	*0.10 – stirred up by wind*	
Dissolved Oxygen	*68 %*	*6.2 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*~0.20*

Benthos	
Salt crust	No Yes ☑ Thickness (mm) *2 – 3 mm around edge*
Shrub stumps	No Yes ☑ Comments *A few small remnants*
Substrate	Comments

Human Impacts	
In water	*Drain flows in from south and out to the north*
In fringing vegetation	*Sheep grazing*
Land use in catchment	*Grazing / arable lands to east*

Fauna	
	Molluscs Water birds Frogs Other
Other Comments	*Very large playa, strongly affected by wind fetch* *Native veg with to the south, west and north; trees (some dead) to south and north* *Deep drain into and out of lake – drain likely contributes only a small percentage of total inflow to the lake.*

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Xantippe sub-catchment, reference site* ***YY22***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 504639*	Northing	*6652252*
Date of sampling	*22/5/08*	Time of sampling	*12:10*
Air temperature (°C)	*??*		
Weather conditions	*100% cloud cover, light rain, moderate WSW wind*		
Comments on photos	*#74, 75, 76*		

Water Quality

Water temperature (°C)	*19.1*	
pH (pH units)	*7.94*	
Redox (mV)	*-63.1*	
Conductivity (mS/cm)	*224*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*97 %*	*8.6 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.08*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Firm, sandy bed*

Human Impacts

In water	
In fringing vegetation	*Sheep grazing*
Land use in catchment	*Grazing / arable lands to east; samphire and trees to south, north and west*

Fauna

	Molluscs Water birds Frogs Other
Other Comments	

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Xantippe sub-catchment, exposed site **YY23***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 503349*	Northing	*6653220*
Date of sampling	*22/5/08*	Time of sampling	*14:00*
Air temperature (°C)	*??*		
Weather conditions	*100% cloud cover, light rain, moderate WSW wind*		
Comments on photos	*#77 - 84 (4 of the drain)*		

Water Quality

Water temperature (°C)	*17.8*		
pH (pH units)	*8.38*		
Redox (mV)	*-90.5*		
Conductivity (mS/cm)	*78.9*		
Secchi disc (m)	*>depth*		
Dissolved Oxygen	*83 %*	*7.5 mg/L*	
Water depth	Top of post to water surface (m)	*--*	
	Top of post to sediment (m)	*--*	
	Total water depth (m)	*0.10*	

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No Yes ☑ Comments *Some around edge, but not inundated*
Substrate	Comments *Sludgy over black anoxic layer*

Human Impacts

In water	*Drain discharges into wetland under high flows*
In fringing vegetation	*Erosion from drain*
Land use in catchment	

Fauna

	Molluscs Water birds ☑ *Avocets (x4)* Frogs Other
Other Comments	*Extremely degraded; drain bunds eroded and sheet flows bring drainage waters into eastern side of wetland.* *Bund intact on east side but absent on west; drain full of very orange sand!*

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Xantippe sub-catchment, exposed site* ***YY24***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 503722*	Northing	*6653531*
Date of sampling	*22/5/08*	Time of sampling	*14:30*
Air temperature (°C)	*??*		
Weather conditions	*100% cloud cover, showers, moderate SW wind*		
Comments on photos	*#85 - 96*		

Water Quality

Water temperature (°C)	*17.1*	
pH (pH units)	*3.57*	
Redox (mV)	*187.3*	
Conductivity (mS/cm)	*72.0*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*95 %*	*8.7 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.10*

Benthos

Salt crust	No ☑ Yes Thickness (mm)
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Fine silt ~10 cm deep – grey/red on top, black anoxic below*

Human Impacts

In water	*Drain, silt, acid etc*
In fringing vegetation	*Drain, erosion, grazing*
Land use in catchment	*Arable lands to east and west - ~100 m buffer*

Fauna

	Molluscs Water birds Frogs Other

Other Comments

Extremely degraded; deep drain flows through #23 and into #24; large deposits of silt from drain.

Drain into lake badly eroded - bunds mostly gone, channel mostly infilled.

Approx 10 cm of fine, red-brown silt/mud across both exposed and inundated lake bed substrates; eroded silt/sediment from drain.

Delta from drain into lake.

Fine grey silt in suspension when sampling.

Outflow for drain on far side (not visited).

YARRA YARRA AQUATIC MONITORING MAY 2008

Site Name & Number	*Xantippe sub-catchment, reference site **YY25***		
Name(s) of recorders	*Jess Lynas, Adam Harman, Andrew Storey*		
Easting	*50 504016*	Northing	*6651490*
Date of sampling	*22/5/08*	Time of sampling	*15:45*
Air temperature (°C)	*??*		
Weather conditions	*100% cloud cover, showers, moderate WSW wind*		
Comments on photos	*#97, 98, 99*		

Water Quality

Water temperature (°C)	*19.5*	
pH (pH units)	*3.04*	
Redox (mV)	*219.3*	
Conductivity (mS/cm)	*238*	
Secchi disc (m)	*>depth*	
Dissolved Oxygen	*60 %*	*5.4 mg/L*
Water depth	Top of post to water surface (m)	*--*
	Top of post to sediment (m)	*--*
	Total water depth (m)	*0.10*

Benthos

Salt crust	No Yes ☑ Thickness (mm) *Too thick to break through*
Shrub stumps	No ☑ Yes Comments
Substrate	Comments *Very hard, even, flat salt crust over very clear water*

Human Impacts

In water	
In fringing vegetation	*Heavily grazed by sheep*
Land use in catchment	*Grazing / arable lands*

Fauna

	Molluscs Water birds Frogs Other
Other Comments	*Irregular band of fringing samphire*