ASSESSMENT OF WETLAND INVERTEBRATE AND FISH BIODIVERSITY FOR THE GNANGARA SUSTAINABILITY STRATEGY (GSS)

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Gnangara Sustainability Strategy

This document has been commissioned/produced as part of the Gnangara Sustainability Strategy (GSS). The GSS is a State Government initiative which aims to provide a framework for a whole of government approach to address land use and water planning issues associated with the Gnangara groundwater system. For more information go to www.gnangara.water.wa.gov.au

Government of Western Australia
Department of Water
Department of Agriculture and Food WA
Department for Planning and Infrastructure
Department of Environment and Conservation
Water Corporation
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Executive Summary

This report sought to review existing sources of information for aquatic fauna on the Gnangara Mound in order to:

- provide a synthesis of the richness, endemism, rarity and habitat specificity of aquatic invertebrates in wetlands;
- identify gaps in aquatic invertebrate data on the Gnangara Mound;
- provide a synthesis of the status of freshwater fishes on the Gnangara Mound;
- assess the management options for the conservation of wetlands and wetland invertebrates.

The compilation of aquatic invertebrate taxa recorded from wetlands on both the Gnangara Mound and Jandakot Mound) between 1977 and 2003, from 18 studies of 66 wetlands, has revealed a surprisingly high richness considering the comparatively small survey area and the degree of anthropogenic alteration of the plain. The total of over 550 taxa from 176 families or higher order taxonomic levels could be at least partially attributed to sampling effort. In addition, when compared to other regional surveys of wetland invertebrates, proportionate local and regional endemism appear relatively low for the survey area, and the proportion of rare taxa is also usually low. Overall it is proposed that levels of richness and endemism are attributable to geologically-recent colonizing forces associated with sea-level changes, dune formation and periods of aridity on the plain. Invertebrate colonization from multiple directions is possible: from the cooler southern, the warmer northern, and from the flowing and non-flowing wetlands on the adjacent Darling Scarp. Rare invertebrate taxa, on the other hand, appear to be associated with rare wetland types harbouring very specific (and perhaps unusual) microhabitats such as caves and tumulus springs. The work allows a re-evaluation of wetlands of importance on the Swan Coastal Plain.

High priority wetlands with ‘significant’ invertebrate fauna in terms of aquatic invertebrate richness, endemism and/or rarity include:

- aquatic habitats in a cave system in karstic areas around Yanchep;
- permanent deeper surface waters in northern linear chain wetlands of the Spearwood interdunal system;
- tumulus springs (organic mound springs) in the Ellen Brook region of the eastern Gnangara mound;
- surface waters in the Ellen Brook region of the eastern Gnangara mound; and
- habitat complexes in large shallow wetland systems on the Bassendean Dune system.

For habitat specificity, invertebrate data for 16 regularly monitored wetlands on the Gnangara Mound analysed for their frequency of occurrence in 16 different vegetation communities (as a surrogate for ‘habitat’) revealed the following generalities:

- most invertebrates were found in most habitats, and most vegetation types had similar invertebrate assemblages, suggesting relatively little habitat specificity;
- richness of invertebrates was related to sampling effort, not necessarily to habitat type;

- very few taxa showed some degree of habitat specificity;
- pattern analyses showed that the eastern Bassendean wetlands formed outliers in terms of both the vegetation communities sampled and their invertebrate assemblages.

The Moore River – Gingin Brook region appears as a significant biogeographical boundary for inland aquatic fauna and this boundary may require specific management attention or more detailed surveying to search for faunal elements thought now to be either or both locally endemic or regionally extinct.

These analyses have also highlighted a relative lack of invertebrate data from wetlands on the northeastern portion of the Gnangara Mound and immediately north of the Moore River – Gingin boundary, particularly wetlands that might conform to 'high priority' designation as above. As a result, strategic sampling was carried out in September at three locations in this region: Lake Bambum, Yeal Lake and Quin Brook. The wetlands appear to have an 'average' aquatic macroinvertebrate assemblage (including some species with restricted distribution), however they are severely nutrient-enriched and weed-infested. These 3 wetlands have now been added to Gnangara Mound Macroinvertebrate Monitoring Program (EPA Section 46) and will be monitored biannually.

For the fish of inland waters, 8 native species were known to occur in the area encompassed by the Gnangara Sustainability Strategy. Two of them may now be regionally extinct (*Nannatherina balstoni* (Balston's pygmy perch) and *Geotria australis* (lamprey)); two more are restricted and vulnerable (*Galaxiella nigrostriata* (black striped minnow) and *Galaxiella munda* (mud minnow)). Threats to fish populations from introduced species such as *Gambusia holbrooki* and *Geophagus brasilensis* and several others may be as severe as, and compound, other changes to habitat loss such as water regime change. Given the widespread and pervasive nature of hydrological change and habitat loss and degradation on the Gnangara Mound, any wetland harbouring a population of native freshwater fish should be regarded as having a high management priority.

Wetland management scenarios with regards to declining water levels often depend on the types of sediments present. Wetlands supporting nutrient-rich detrital floc will tend to become eutrophic if they dry, wetlands with pyrtic peat will tend to acidify. Where both sediment types coexist, the buffering properties of the floc will tend to override, at least temporarily (and especially where the floc is a calcareous one), the oxidative effects of the peat.

Artificial augmentation of surface water as a management tool (by reinstating anaerobia in the sediments) can reverse the effects of drawdown-induced acidification and lead to recovery of macroinvertebrate community structure. The Lake Jandabup case has demonstrated that although successful at reversing the effects of acidification, artificial augmentation will inevitably change the system in another direction. In addition, it will constitute an ongoing effort, will use a valuable resource relatively inefficiently, and will exacerbate, not address, the root causes of the problem, namely over-extraction of water and declining rainfall.

The 'Wetland Macroinvertebrate Monitoring Program of the Gnangara Mound Environmental Monitoring Project' which has been running since 1996, was able to detect biological indicators of change in three wetlands affected by drought-induced acidification, but only <u>after</u> the changes had occurred; it was not able to pick up early warning physico-chemical indicators which, if acted upon, may have prevented some of the biological changes from occurring. The long-term goal of identifying site-specific thresholds of change, can only be achieved once environmental parameters are available that can be better linked to the macroinvertebrate fauna.

Artificial supplementation can be appropriate under certain circumstances (as the successful example of Lake Jandabup has shown). However, one must be very aware that such a management strategy is trying to solve one problem whilst exacerbating another. Because of this, wetland supplementation schemes in Perth should be supported by somewhat more rigorous scientific backing than they appear to be at the present time.

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1. Introduction

1.1 Background

The Department of Environment and Conservation (DEC) has identified a number of projects for assessing the status of wetland invertebrate taxa and communities on the Gnangara Mound for the Gnangara Sustainability Strategy (GSS). The Centre for Ecosystem Management (CEM), Edith Cowan University, has been contracted to proceed with their development. The overall objective of the project is to review the status of wetland invertebrates and fish on the Gnangara Mound, their values and threats. The outputs of the project will feed into the WA Government's Gnangara Sustainability Strategy and will be used to inform decisions on the future directions of land and water use on the Gnangara Mound. The management of the project was coordinated through the Department of Environment and Conservation GSS group.

1.2 The status of wetland invertebrates on the Gnangara Mound

The wetlands of the Swan Coastal Plain (SCP) in Western Australia have undergone dramatic change over the last two hundred years, primarily due to a growing human population and associated changes in land-use. During the 1800s, the SCP endured the alienation of the land and water from indigenous Nyoongar stewardship (Marchant 1973; O'Connor *et al.* 1989), the damming of rivers flowing onto the plains, and the drainage of low-lying areas to allow for agriculture and routes of movement during wet periods (Bradby 1977). Along with this were changed fire regimes (O'Connor *et al.* 1989) and the onset of clearing of native vegetation (both of which continue to this day). These changes were exacerbated in the 1900s by further drainage, wetland infilling, successive periods of rapid urban expansion, groundwater extraction, extensive plantings of non-native pine trees, and more recently a dramatic decline in rainfall. The majority of wetlands of the Swan Coastal Plain have consequently disappeared. Most of the remaining ones have undergone one or more of a number of characteristic changes associated with: excessive nutrient loading from decades of runoff from urban or horticulture areas; the exposure of acid sulphate soils due to groundwater extraction, drainage and reduced rainfall; encroachment by terrestrial vegetation where water levels have declined; discharge of industrial, urban and agricultural chemicals to pollute waterways; sedimentation; and salinisation (for a review on aspects of these impacts, see Davis and Froend 1999; Halse 1989; Horwitz and Sommer 2005; Sommer and Horwitz 2001).

The extant wetlands have indisputable value as remnants of a once more widespread, connected coastal wetland system. They include nature reserves, declared Ramsar sites or wetlands of national importance, and wetlands in national parks, regional parks, recreational reserves, or state forest. While representatives of most wetland types (or consanguineous suites sensu Semeniuk 1987) remain on the Swan Coastal Plain, most of our knowledge of these wetlands comes from monitoring work (or limited survey work) conducted in the larger, more iconic and usually more permanent wetlands. Much of this work has utilized the invertebrate fauna as an indicator of condition, and therefore a considerable amount of information resides in these invertebrate databases.

This contract has allowed the completion of work commenced three years ago in which all records for aquatic macroinvertebrate taxa collected from wetlands on the Swan Coastal Plain in the general Perth metropolitan area were compiled in order to determine patterns of macroinvertebrate richness in wetlands, and the contribution that restricted or local endemism, or taxon rarity, make to this richness. In addition, thirteen years of monitoring Gnangara Mound wetlands as part of the "Wetland Macroinvertebrate Monitoring Program of the Gnangara Mound Environmental Monitoring Project" (Department of Water) has provided the opportunity to assess long-term trends and other issues, not normally within the scope of the yearly reporting. One of these is the association of aquatic macroinvertebrates with particular habitat types. An understanding of this aspect of invertebrate ecology will help management efforts to become more efficient, as well as to focus on critical habitats/vegetation communities.

The main aim of this research was to identify wetlands that can be regarded as being particularly rich or otherwise significant for their invertebrate components. Completion of this investigation will help focus management objectives for wetlands on the Swan Coastal Plain in general, and Gnangara Sustainability Strategy area in particular, particularly where they can be shown to have significance based on their invertebrate faunal assemblage.

1.3 Objectives

The specific objectives of this project were to:

1. Collate all known inland aquatic invertebrate records for the Gnangara Mound area, including the determination of richness and patterns of local and regional endemism;
2. Determine patterns of habitat specificity;
3. Provide a synthesis and review the status of fish on the GSS, their values and threats;
4. Identify gaps in aquatic invertebrate data for the area and conduct strategic sampling of wetlands to fill these gaps;
5. Develop a GIS spatial layer of wetland invertebrate data
6. Assess management options for the conservation of wetlands and wetland invertebrates on the Gnangara Mound.

For each of the objectives, information was drawn and collated from different sources, and each objective is presented as a separate section in this report.

2. Wetland invertebrate richness and endemism (Objective 1)

Funding from the GSS has allowed the completion of work commenced three years ago, and also the finalisation of a publication which is in the process of being submitted to an international journal (Marine and Freshwater Research). We set out to collate all available information on the occurrences of aquatic invertebrates in wetlands of the study area, sourcing materials including published works, unpublished reports and personal databases of investigators over the last 30 years. These data were assembled on a wetland by wetland basis, representing 66 wetlands, or wetland systems, in total. The wetlands were all located within the central part of the Swan Coastal Plain, bounded by Gingin Brook in the north, Rockingham in the south, and by an eastern boundary line approximated by the South-western Highway and Great Northern Highway at the foot-slopes of the Darling Scarp (see **Figure 2.1**). The focus of this paper is therefore on a study area of approximately 140 km long x 30 km wide (4200 km^2).

2.1 Methods

For each wetland or wetland system (each one representing a suite of surface waters potentially connected at some time during the year), a list was compiled of the invertebrate taxa recorded on one or more occasions. All identified taxa were assigned categories of relative endemism and rarity, so that each wetland could be characterized according to the proportion of taxa that were rare or locally endemic. Wetlands could also be assigned a richness value, representing the total number of invertebrate taxa recorded at that wetland. Because this depended on the taxonomic level recorded by individual investigators, indices were derived for species richness, genus richness and family richness for each wetland. Finally, an index of effort (the relative effort taken to sample the invertebrate community) was derived for each wetland, calculated from the sampling regimes employed by each investigator in the production of their lists. The methods to derive these statistics for each wetland are described below.

Source Material

The reference materials sourced for the establishment of the database of all known aquatic invertebrates recorded in wetlands of the SCP are outlined in **Appendix 1**. Throughout the development of the SCP aquatic invertebrate database, a number of taxa lists were produced. A composite database was initially constructed by transcribing taxa lists into the database as they were represented in the source documents. From this database species richness, genus richness and family richness lists were produced. Where full species names and morphospecies belonging to a genus were used, the family (or the most appropriate higher taxonomic unit) to which they belonged was also recorded as being present at that wetland. Where taxa were described as morphospecies belonging to a higher order taxonomic unit, the morphospecies designation was omitted and only that higher taxonomic unit was recorded (ie. "Ceratopogonidae sp. 1" was recorded in the database as "Ceratopogonidae").

To assess species richness at each wetland, higher level designations were removed from the database where finer taxonomic resolution has been recorded, in order to remove the possibility of a taxon being recorded more than once. For instance, *Austrochiltonia subtenuis* belongs to the amphipod Family Ceinidae, and so the composite database will show that both (the family and the species) are present at a wetland, however, for richness calculations, only one or the other can be used, not both. If, however, only Ceinidae were recorded from a wetland, then that record stands as a contributor to richness since no finer taxonomic designation is given. Where taxa had questionable identifications (e.g. *Biapertura ?setigera*) or were identified as an affiliated species (e.g. *Chironomus aff.alternans*), they were recorded in the database as the given species. An asterisk (*) denotes where such species were included.

To assess genus richness at each wetland, all species and morphospecies designations were removed from the species richness database, leaving only genera and higher level presence or absence (see **Table 2.2**). For instance, if a number of species of the same genus were recorded at a wetland (e.g. *Bennelongia australis, B.barangaroo and Bennelongia sp*.), the species level resolutions were removed, leaving a presence record at the genus level only (ie. *Bennelongia sp*. or *spp*.). For Family richness, all species level and genus level designations were removed from the composite database, leaving higher level presence or absence only.

Designation of Rare and Endemic taxa

Taxa occurring at only three or less wetlands were classified as rare for the purposes of this paper. This number is slightly higher than categories of 'rare' from other survey data (usually singletons or doubletons in a dataset) to adjust for the high level of sampling intensity in general experienced on the Swan Coastal Plain (and thereby make proportions of 'rare' more comparable across datasets). For each wetland the percentage of rare taxa as a proportion of the total number of taxa found at that wetland, was calculated.

Taxa known to have a distribution including and extending beyond the South West Australian Floristic Region (SWAFR, *sensu* Hopper & Gioia 2004) were considered 'widespread' (W). Taxa known to have a distribution within, and limited to the SWAFR were considered 'regionally endemic' (RE), while taxa known to have a distribution limited to the Swan Coastal Plain bioregion (sensu Thackway and Cresswell 1995) were considered 'locally endemic' (LE). Distributions were determined only for taxa identifiable to species level (as per Table 2.2) from the literature and from personal communications of taxonomic authorities. For each wetland the percentage of regionally endemic species was calculated from the total number of taxa identified or identifiable to species level.

Effort (Wetland Effort, WE)

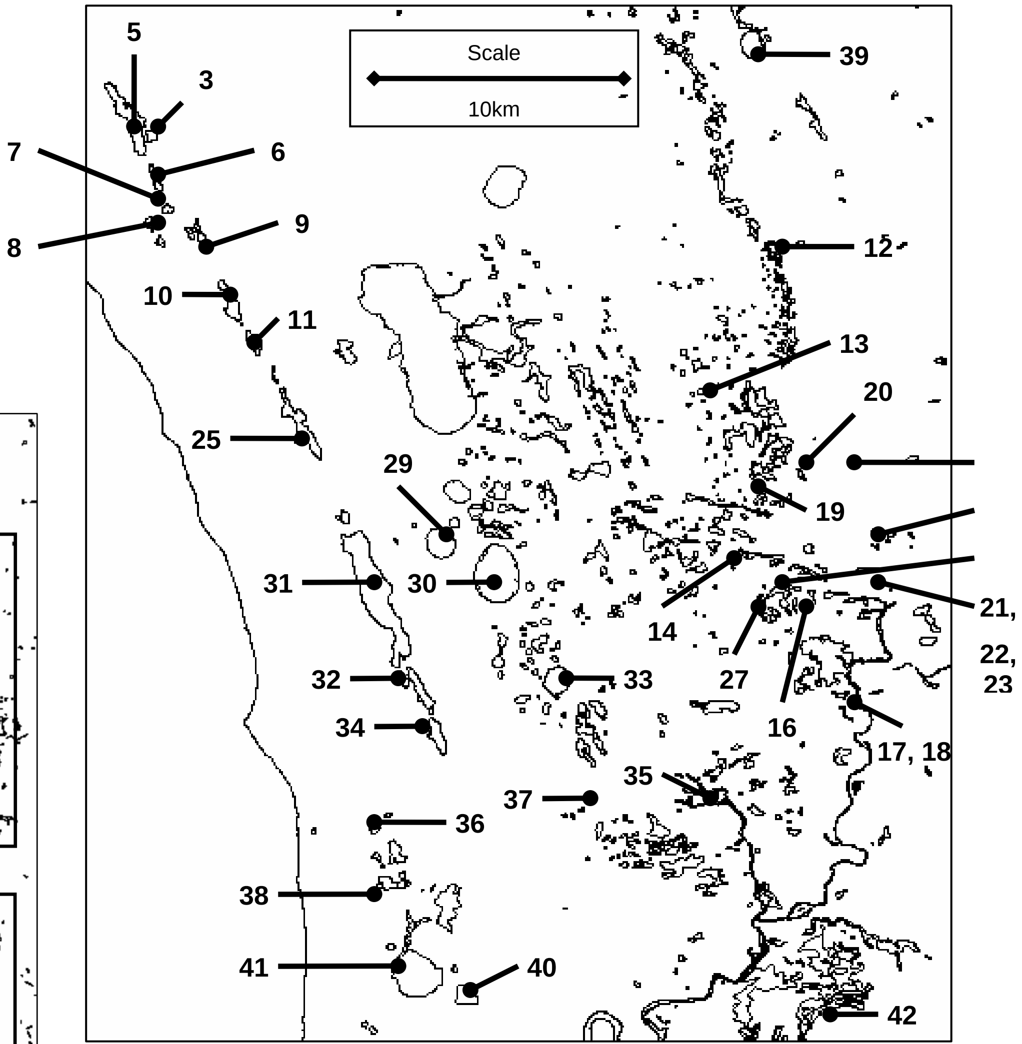
A measure of effort was calculated for each wetland or wetland system in order to determine the degree to which richness, rarity and endemism of wetlands was a function of the effort expended to collect invertebrates. The measure for the relative intensity of sampling at each wetland is a composite index, with all components scaled between the least ideal (very little effort: 1) to the most ideal (maximum effort feasible: 10), and a numerical value assigned as appropriate.

A two step process was adopted:

1. For each investigator source, an effort index was calculated (Investigator Effort, IE) by summing four separate scaled measures of effort (IE = A+B+C+D):

A - Sampling regime (the average of three measures for the number of years, the sampling period, number of samples taken on each visit);
B - wetland coverage (one measure for the relative proportion of the wetland sampled as the number of habitat types sampled per quadrant sector of the wetland);

C - sampling technique (the average of two measures for the efficiency of the effort made to capture, using the nature of the equipment used and its deployment intensity);



Inset 1a: Wetlands on the northern Swan Coastal Plain

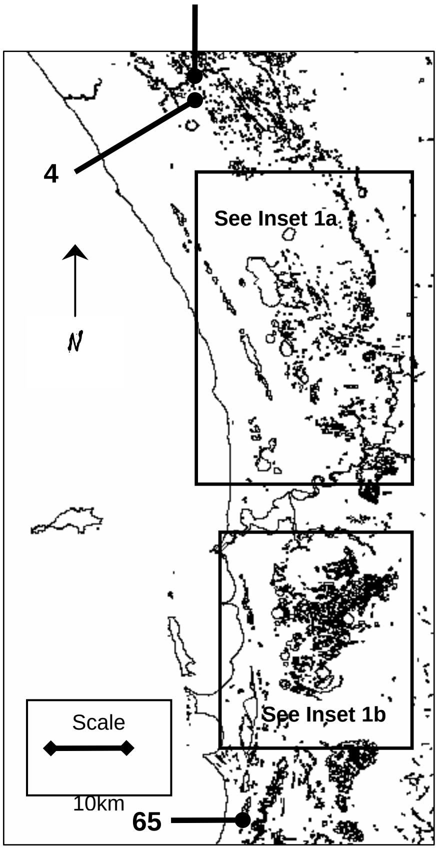
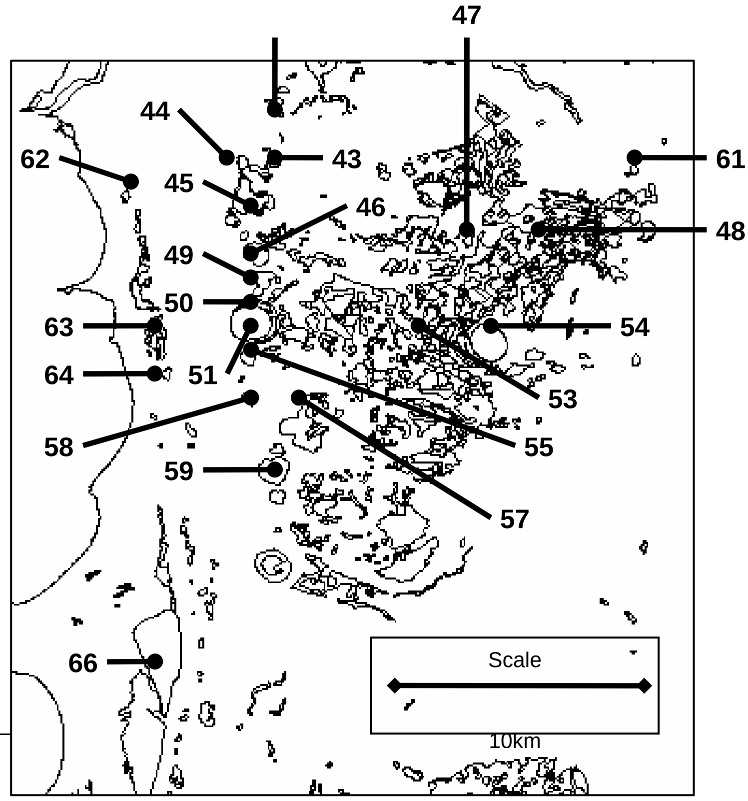


Figure 2.1: Wetlands of the Swan Coastal Plain. *Source: DoE (2004).*



Inset 1b: Wetlands on the southern Swan Coastal Plain

Table 2.1: Key to wetlands identified in Figure 2.1. Gnangara mound wetlands are shown in bold type.

1	**Gingin Brook Pool**	**23**	**Ellen Brook Monitoring**	45	Bibra Lake
2	**Gingin Brook**	**24**	**Twin Swamps**	46	Yangebup Lake
3	**Yanchep Caves**	**25**	**Lake Neerabup**	47	Warton Swamp
4	**Tangletoe Swamp**	**26**	**Melaleuca Park**	48	Lake Balannup
5	**Loch McNess**	**27**	**Lexia Wetland 86**	49	Lake Kogolup North
6	**Lake Yonderup**	**28**	**Lexia Wetland 186**	50	Lake Kogolup South
7	**Lake Wilgarup**	**29**	**Lake Marigíniup**	51	Thomsons Lake
8	**Pipidinny Lake**	**30**	**Lake Jandabup**	52	Shirley Balla Swamp
9	**Coogee Springs**	**31**	**Lake Joondalup**	53	Gibbs Road Swamp
10	**Lake Carabooda**	**32**	**Beenyup Swamp**	54	Forrestdale Lake
11	**Lake Nowergup**	**33**	**Lake Gnangara**	55	Banganup Lake
12	**Muchea/Peter's Spring**	**34**	**Lake Goollelal**	56	Bartram Swamp
13	**Kings Spring**	**35**	**Mussel Pool**	57	Lake Mandagolup
14	**Bullsbrook Channel**	**36**	**Big Carine Swamp**	58	Lake Wattleup
15	**Bullsbrook Runnel**	**37**	**Malaga Wetlands**	59	Spectacles
16	**Edgerton Spring**	**38**	**Lake Gwelup**	60	Piney Lake
17	**Edgecombe Spring**	**39**	**Lake Chandala**	61	Mary Carroll Park
18	**Edgecombe Lake**	**40**	**Lake Monger**	62	Manning Lake
19	**Cooper Rd Swamp**	**41**	**Herdsman Lake**	63	Brownman Swamp
20	**Nursery Dam**	42	Perth Airport Swamps	64	Lake Mt Brown
21	**Ellen Brook Floodplain**	43	Murdoch Swamp	65	Lake Paganoni
22	**Ellen Brook Nature Reserve**	44	North Lake	66	Lake Cooloongup

Table 2.2: Aquatic invertebrate taxa used for the assessment of richness and endemism in wetlands on the Swan Coastal Plain. (TUR=taxonomically unresolved). Taxa identified at the species level have designated distributions (W, widespread; RE, regional endemic; LE local endemic; see text).

HIGHER TAXA	SUB/FAMILY	SPECIES	
PORIFERA			
CNIDARIA Hydrozoa		Hydra sp. or spp.	
TURBELLARIA	TUR	sp. or spp.	
	Catenulida	Stenostomum sp. or spp.	
	Dugesiidae	sp. or spp.	
	Macrostomida	Macrostomum sp or spp.	
	Dalyellioida	sp.	
	Kalyptorhynchia	Gyratrix hermaphroditus	W
	Temnocephalidae	sp. or spp.	
		Temnocephala sp.	
	Typhloplanidae	sp.	
NEMERTINI		Prostoma graecense	W
ROTIFERA		sp. or spp.	
NEMATODA	TUR	sp. or spp.	
MOLLUSCA: GASTROPODA			
	Pomatiopsidae	Coxiella striatula	RE
	Hydrobiidae	sp.	
		Potamopyrgus sp.	
	Ancylidae	Ferrissia sp. or spp.	
	Lymnaeidae	sp. or spp.	
		Pseudosuccinea columella	W
	Succineidae	Succinea sp.	
	Physidae	sp. or spp.	
		Physa sp. or spp.	
		Physa acuta	W
	Planorbidae	sp. or spp.	
		Glyptophysa sp.	
		Gyraulus sp.or spp.	
		Helisoma duryi	W
		Isodorella newcombi	W
		Physastra sp. or spp.	
MOLLUSCA BIVALVIA			
	Hyriidae	Westralunio carteri	RE
	Sphaeriidae	sp. or spp.	
		Musculium kendricki	RE
TARDIGRADA		sp. or spp.	
Eutardigrada	Hypsibiidae	Hypsibius sp.	
ENTOGNATHOUS HEXAPOD		sp.	
ANNELIDA		sp. or spp.	
Aphanoneura	Aeolosomatidae	sp. or spp.	
		Aeolosoma sp. or spp.	
		Aeolosoma aff. leidyi	W
		Aeolosoma tracanvorense	W
Oligochaeta	Enchytraeidae	sp. or spp.	
	Naididae	sp. or spp.	
		Pristina sp. or spp.	
		Pristina longiseta	W
		Pristina osborni	W
		Pristina jenkinae	W
		Pristina aequiseta	W
		Dero digitata	W
		Dero furcatus	W
		Dero nivea	W
		Dero sp.	
		Nais bretscheri	W
		Nais spp.	
	Phreodrillidae	sp. or spp.	
		Insulodrilus ?lacustris	W
	Tubificidae	sp. or spp.	
		?Aulodrilus sp.	
		Branchiura sowerbyi	W
		Antipodrilus davidis	W
		Limnodrilus hoffmeisteri	W
		Potamothrix bavaricus	W
		Tubifex tubifex	W
Hirudinea	TUR	sp. or spp.	
	Erpobdellidae	sp. or spp.	
	Glossiphoniidae	sp. or spp.	
	Richardsonidae	sp. or spp.	
ARANEAE	TUR	sp. or spp.	
ACARINA	TUR	sp. or spp.	
Mesostigmata		sp. or spp.	
Acaridida		Acaridae sp.	
Astigmata		sp. or spp.	
Oribatida		sp. or spp.	
		Trhypochthoniellus sp.	
	Nothroidea	sp. or spp.	
		Trimalaconothrus sp.	
Prostigmata	Halacaridae	sp. or spp.	
		Lobohalacarus weberi	W
		Lobohalacarus sp. or spp.	
		Soldanellonyx monardi	W
		Soldanellonyx sp.	
	Arrenuridae	sp. or spp.	
		Arrenurus balladoniensis	W
	Eylaidae	sp. or spp.	
		Eylais sp.	
	Hydrachnidae	sp. or spp.	
		Hydrachna sp.	
	Hydracarina	Gen.nov.(Thryptaturus) sp.n	LE
		Tillia sp.	
	Anisitsiellidae	Anisitsiellides sp.nov.	LE
	Hydrodromidae.	Hydrodroma sp	
	Hydrozetidae	Hydrozetes sp. or spp.	
	Limnocharidae	sp. or spp.	
		Limnochares australica	W
	Lymnesiidae	sp. or spp.	
		Limnesia sp. or spp.	
	Oxidae	sp. or spp.	
		Oxus sp.	
	Pezidae	Peza sp.	
	Pionidae	sp. or spp.	
		Acercella falcipes	W
		Piona cumberlandensis	W
		Piona murleyi	W
		Piona sp.	
	Trombidiodea	sp. or spp.	
	Unioncolidae	sp. or spp.	
		Unionicola sp.	
		Koenikea sp	
		Neumania sp.	
		Encentridophorus sp.	
CRUSTACEA Ostracoda		sp. or spp.	
	Candoniidae	sp. or spp.	
		Candona sp.	
		Candonopsis tenuis	W
		Candonopsis sp.	

Table 2.2 (cont.)

HIGHER TAXA	SUB/FAMILY	SPECIES	
	Cyprididae	*sp. or spp.*	
		Candonocypris novaezelandia	W
		Alboa wooroa	W
		Sarscypridopsis aculeata	W
		Bennelongia australis	W
		Bennelongia barangaroo	W
		Bennelongia sp.	
		Ilyodromus sp. or spp.	
		Ilyodromus dikrus	W
		Diacyperus spinosa	W
		Mytilocypris tasmanica chapm	W
		Mytilocypris ambiguosa	W
		Mytilocypris sp.	
		Eucypris virens	W
		Cypricerus salinus	W
		Cypricerus spp.	
		Cyprinotus edwardi	W
		Strandesia sp.	
		Lacrimicypris kumpar	RE
		Heterocypris incongruens	W
	Cypridopsidae	*sp. or spp.*	
		Cypretta baylyi	W
		Cypretta spp.	
		Cypretta aff globosa	RE
		Cypridopsis funebris	W
	Darwinulidae	*Darwinula sp. or spp.*	
	Gomphodellidae	*sp. or spp.*	
		Gomphodella sp. nov	
		Gomphodella maia	W
	Ilyocyprididae	*sp. or spp.*	
		Ilyocypris australiensis	W
	Lymnocytheridae	*sp. or spp.*	
		Limnocythere dorsicula	W
		Limnocythere porphyretica	W
		Limnocythere mowbrayensis	W
		Paralimnocythere sp.	
	Notodromadidae	*sp. or spp.*	
		Newnhamia fenestrata	W
		Newnhamia insolita	W
		Newnhamia sp.	
		Kennethia sp.	
CRUSTACEA Cladocera	Chydoridae	*sp. or spp.*	
		?gen.nov. (cf Rhynchochydorus)	
	Chydoridae Aloninae	*sp. or spp.*	
		Alona aff diaphana	W
		Alona sp.	
		Archepleuroxus baylyi	W
		Biapertura sp or spp.	
		Biapertura aff affinis	W
		Biapertura setigera	W
		Biapertura kendallensis	W
		Biaperura rigidicaudis	W
		Camptocercus australis	W
		Graptoleberis testudinaria	W
		Graptoleberis testudinaria occidentalis	RE
		Kurzia latissima	W
		Leydigia ciliata	W
		Leydigia leydigi	W
	Chydoridae Chydorinae	*Alonella sp*	
		Alonella clathratula	W
		Chydorus cf. sphaericus	W
		Chydorus sp.	
		Dunhevedia aff. crassa	W
		Gen et sp. Nov.	
		Monope reticulata	W
		Pleuroxus sp.	

HIGHER TAXA	SUB/FAMILY	SPECIES	
		Pseudochydorus globosa	W
		Rak obtusus	W
	Bosminidae	*sp. or spp.*	
		Bosmina meridionalis	W
	Daphniidae	*sp. or spp.*	
		Ceriodaphnia cornuta	W
		Ceriodaphnia laticaudata	W
		Ceriodaphnia quadrangula	W
		Ceriodaphnia rotunda	W
		Ceriodaphnia sp.	
		Daphnia carinata	W
		Daphnia angulata	W
		Daphnia lumholtzi	W
		Daphnia wankeltae	W
		Daphniopsis pusilla	W
		Daphniopsis sp.	
		Scapholeberis kingi	W
		Scapholeberis sp.	
		Simocephalus exspinosus	W
		Simocephalus exspinosus australiensis	W
		Simocephalus latirostris	W
		Simocephalus vetulus	W
		Simocephalus sp.	
	?Podonidae	*sp. or spp.*	
	Moinidae	*sp. or spp.*	
		Moinodaphnia macleayi	W
		Moina sp.	
	Macrothricidae	*sp. or spp.*	
		Eschinisca capensis capensi	W
		Echinisca sp.	
		Macrothrix breviseta	W
		Macrothrix sp.	
		Neothrix armata	W
	Ilyocryptidae	*sp. or spp.*	
		Ilyocryptus ?sordidus	W
		Ilyocryptus spinifer	W
		Ilyocryptus sp. or spp.	
	Sididae	*sp. or spp.*	
		Latonopsis australis	W
		Latonopsis brehmi	W
CRUSTACEA Conchostraca		*sp. or spp.*	
		Lynceus	
		Eulimnadia sp.	
		Cyzicus sp.	
CRUSTACEA Amphipoda		*sp. or spp.*	
		Hurleya sp.	LE
	Ceinidae	*sp. or spp.*	
		Austrochiltonia subtenuis	W
	Perthiidae	*sp. or spp.*	
		Perthia sp. or spp	RE
	Paramelitidae	*sp.*	
CRUSTACEA Isopoda	Amphisopidae	*sp. or spp*	
		Paramphisopus palustris	RE
	Janiridae	*sp. or spp.*	
	Oniscidae	*sp. or spp.*	
CRUSTACEA Copepoda Calanoida			
	Centropagidae	*sp. or spp.*	
		Calamoecia tasmanica	RE
		Calamoecia attenuata	RE
		Boeckella bispinosa	W
		Boeckella geniculata	RE
		Boeckella robusta	RE
		Boeckella symmetrica	W
		Boeckella triarticulata	W
		Hemiboeckella andersonae	RE

Table 2.2 (cont.)

HIGHER TAXA	SUB/FAMILY	SPECIES	
Copepoda Harparticoida		*sp. or spp.*	
	Canthocamptidae	*sp. or spp.*	
Copepoda Cyclopoida	Cyclopoidae	*sp. or spp.*	
		Microcyclops sp. or spp.	
		Mesocyclops sp.	
		Macrocyclops sp. or spp.	
		Mixocyclops sp. or spp.	
		Metacyclops sp.	
		Australocyclops	
		Ectocyclops rubescens	W
		Eucyclops sp.	
		Paracyclops chiltoni	W
		Paracyclops sp. or spp.	
		Paracyclops 'Eucyclops linderi'	?
CRUSTACEA Decapoda	Palaemonidae	*sp. or spp.*	
		Palaemonetes australis	RE
	Parastacidae	*sp. or spp.*	
		Cherax quinquecarinatus	RE
		Cherax tenuimanus	RE
HETEROPTERA	Saldidae	*sp. or spp.*	
Nepomorpha	Corixidae	*sp. or spp.*	
		Agraptocorixa hirtifrons	W
		Agraptocorixa eurynome	W
		Agraptocorixa parvipunctata	W
		Agraptocorixa sp. or spp.	
		Micronecta robusta	W
		Micronecta sp. or spp.	
		Sigara truncatipala	W
		Sigara (Tropocorixa) mullaka	RE
		Sigara (Tropocorixa) spp.	
		Diaprepocoris barycephala	W
		Diaprepocoris personata	W
	Gelastocoridae	*Nethra sp.*	
	Pleidae	*sp. or spp.*	
		Plea brunni	W
Gerromorpha	Gerridae	*sp. or spp.*	
	Hebridae	*sp. or spp.*	
	Hydrometridae	*Hydrometra spp. 1*	
	Mesoveliidae	*sp. or spp.*	
	Nepidae	*Ranatra sp.*	
	Notonectidae	*sp. or spp.*	
		Enithares sp. 1	
		Anisops sp. or spp.	
		Anisops occipitalis	W
		Anisops hyperion	W
		Anisops thienemanni	W
		Anisops gratus	W
		Anisops elstoni	W
		Anisops baylii	RE
		Anisops stali	W
		Paranisops endymion	RE
		Notonecta handlirschi	W
	Veliidae	*Microvelia sp.*	
		sp. or spp.	
COLEOPTERA	Carabidae	*sp. or spp.*	
Polyphaga	Chyrsomelidae	spp.	
	Curculionidae	*spp.*	
	Hydraenidae	*sp. or spp.*	
		Hydraena sp.	
		Ochthebius sp.	
	Hydrophilidae	*sp. or spp.*	
		Anacaena sp.	
		Berosus discolour (A)	RE
		Berosus pulchellus	W
		Berosus spp. (L)	
		Berosus spp. (A)	
		Enochrus elongatus	W
		Enochrus spp. (A)	
		Hydrophilus latipalpus	W
		Hydrophilus albipes	W
		Hydrochus sp. or spp.	
		Paracymus pygmaeus	W
		Limnoxenus sp.	
		Limnoxenus macer	W
		Limnoxenus zealandicus	W
		Helochares tenuistriatus	RE
	Sphaeridiinae	*Coelostoma ?fabricii*	W
		?Coelostoma sp.	
	Dryopoidea	*sp. or spp.*	
	Ptilodactilidae	*sp. or spp.*	
	Scirtidae (form. Helodidae)	*spp.*	
	Ptiliidae	*sp. or spp.*	
	Limnichidae	*sp. or spp.*	
	Noctuidae	*sp. or spp.*	
	Staphylinidae	*sp. or spp.*	
COLEOPTERA			
Adephaga	Dytiscidae	*sp. or spp.*	
		Hyphydrus elegans	W
		Hyphydrus sp	
		Uvarus pictipes	W
		Sternopriscus maedfooti	W
		Sternopriscus multimaculatu	W
		Sternopriscus brownii	RE
		Sternopriscus minimu	RE
		Sternopriscus marginatus	RE
		*Sternopriscus sp. or spp.**	
		Necterosoma sp.1	
		Necterosoma darwini (A&L)	RE
		Spencerhydrus pulchellus	RE
		Spencerhydrus sp.?	
		Allodessus bistrigatus	W
		Allodessus sp.	
		Gibbidessus sp.	
		Limbodessus sp. or spp.	
		Liodessus dispar	RE
		Liodessus ornatus	RE
		Liodessus sp.	
		Liodessus inornatus	RE
		Bidessus sp.	
		Antiporus femoralis	W
		Antiporus gilberti (A)	W
		Antiporus spp. (A)	
		Antiporus sp. (L)	
		Megaporus sp 1. (L)	
		Megaporus sp. 2	
		Megaporus solidus	RE
		Megaporus howitti	W
		Rhantus suturalis	W
		Rhantus sp. or spp.	
		Lancetes lanceolatus	W
		Lancetes sp.	
		Laccophilus sp.	
		Eretes australis	W
		Homeodytes atratus	W
		Homeodytes sp.	
		Homeodytes scutellaris (A&L	W
		Hydaticus sp.	
		Hyderodes crassus	RE
		Copelatus ater	RE
		Copelatus ferrugineus	W
		Copelatus sp.	

Table 2.2 (cont.)

HIGHER TAXA	SUB/FAMILY	SPECIES		HIGHER TAXA	SUB/FAMILY	SPECIES	
		Cybister tripunctatus	W			*Austroagrion cyane*	W
		Cybister sp.			Lestidae	*sp. or spp.*	
		Chostonectes sp.				*Austrolestes analis*	W
		Chostonectes gigas	W			*Austrolestes annulosus*	W
		Paroster niger	RE			*Austrolestes io*	W
		Paroster sp. A				*Austrolestes psyche*	W
		Paroster sp. B				*Austrolestes sp. or spp.*	
		Platynectes sp. or spp.			Megapodagrionida	*sp. or spp.*	
	Hydroporinae	*sp. or spp.*				*Argiolestes pusillus*	W
	Bidessini	*sp. or spp.*					
	Gyrinidae	*sp. or spp.*		COLLEMBOLA	Unidentified	*sp. or spp.*	
	Haliplidae	*sp. or spp.*					
		sp.1		LEPIDOPTERA	Pyralidae TUR	*sp. or spp.*	
		Haliplus australis	W		Nymphulinae	*sp. or spp.*	
		Haliplus fuscatus/gibbus	W	DIPTERA Nematocera	Ceratopogonid	*sp. or spp.*	
	Noteridae	*Hydrocoptus subfasciatus*	W			*Nilobezzia sp. or spp.*	
						Culicoides sp. or spp.	
EPHEMEROPTERA		*sp. or spp.*				*Bezzia sp.*	
	Baetidae	*sp. or spp.*				*Clinohelea sp.*	
		Cloeon sp.1				*Monohelea sp.*	
	Caenidae	*sp. or spp.*				*Palpomyia sp.*	
		Tasmanocoenis sp.1				*Dasyhelea sp.*	
		Tasmanocoenis tillyardi	W			*Macropelopia dalyupensis*	W
	Leptophlebiidae	*sp. or spp.*				*Harrisius sp.*	
						Limnophyes pullulus	W
PLECOPTERA	Gripopterygidae	*sp. or spp.*			Chaoborinae	*sp. or spp.*	
						Promochlonyx australiensis	W
TRICHOPTERA	Ecnomidae	*sp. or spp.*			Chironominae	*sp. or spp.*	
		Ecnomus turgidus/pansus (L)	W			*Ablabesmyia notablis*	W
		Ecnomina sp.				*Chironomus alternans*	W
	Hydroptilidae	*sp. or spp.*				*Chironomus occidentalis*	W
		Acriptoptila globosa (L)	RE			*Chironomus tepperi*	W
		Hellyethira simplex	RE			*Kiefferulus martini*	W
		Hellyethira malleoforma	W			*Kiefferulus intertincus*	W
		Hellyethira sp. A				*Dicrotendipes conjunctus*	W
		Genus I (Growns)	?			*Cryptochironomus griseidors*	W
		Oxyethira sp.				*Paratanytarsus grimmii*	W
	Leptoceridae	*sp. or spp.**				*Paratanytarsus parthenogen*	W
		Notalina spira	W			*Tanytarsus barbitarsis*	W
		Notalina fulva	W			*Tanytarsus fuscithorax*	W
		Oecetis sp. or spp.				*Tanytarsus sp.*	
		Triplectides australis	W			*Cladopelma curtivalva*	W
						?Parachironomus	
ODONATA Anisoptera	Aeshnidae	*sp. or spp.*			Orthocladiinae	*sp. or spp.*	
		Aeshnia brevistyla	W			*Cricotopus sp.*	
		Hemianax papuensis	W			*Corynoneura scutellata*	W
	Corduliidae/Hemicorduliidae	*sp. or spp.*				*Corynoneura sp.*	
		Austrogomphus sp.				*Paralimnophyes pullulus*	W
		Austrogomphus lateralis	RE			*Paratrichocladius sp.*	
		Hemicordulia tau	W			*Polypedilum nubifer*	W
		Hemicordulia australiae	W			*Polypedilum aff. K3 'Baroalb*	?
		Procordulia affinis	W			*Polypedilum seorsum*	W
	Gomphidae	*sp. or spp.*				*Polypedilum sp.*	
	Libellulidae	*sp. or spp.*				*Larsia ?albiceps*	W
		Orthetrum caledonicum	W		Culicidae	*sp. or spp.*	
		Pantala flavescens	W			*Aedes alboannulatus*	W
		Diplacodes bipunctata	W			*Aedes macintoshi*	W
		Austrothemis nigrescens	W			*Aedes stricklandi*	W
	Macrodiplactidae	*sp. or spp.*				*Anopheles (Cellia) sp.*	
	Synthemidae	*sp. or spp.*				*Anopheles sp.*	
		Synthemis ?leachii	RE			*Anopheles annulipes*	W
Zygoptera		*sp. or spp.*				*Anopheles atratipes*	W
	Coenagrionidae	*sp. or spp.*				*Culiseta atra*	RE
		Xanthagrion erythroneurum	W			*Culex annulirostris*	W
		Ischnura heterostica	W			*Culex australicus*	W
		Ischnura aurora	W			*Culex globocoxitus*	W
						Culex sp.	

Table 2.2 (cont.)

HIGHER TAXA	SUB/FAMILY	SPECIES	
	Psychodidae	*sp. or spp.*	
	Simulidae	*sp. or spp.*	
	Tanypodinae	*sp. or spp.*	
		Procladius villosimanus	W
		Procladius paludicola	W
		Coelopynia pruinosa	W
		Paramerina levidensis	W
		Paramerina parva	W
		Apsectrotanypus ?maculosus	W
	Thaumeliidae	*sp. or spp.*	
	Tipulidae	*sp. or spp.*	
Brachycera	Dolichopididae	*sp. or spp.*	
	Empididae	*sp. or spp.*	
	Ephydridae	*sp. or spp.*	
	Muscidae	*sp. or spp.*	
	Sciomyzidae	*sp. or spp.*	
	Stratiomyidae	*sp. or spp.*	
	Tabanidae	*sp. or spp.*	

D - sorting and picking process (one measure for the relative effort placed on sorting and picking a sample).

2. To account for more than one investigator, or more than one sampling regime, each wetland index was calculated as a cumulative figure as for the identification level above, and the IEs were summed starting with the highest IE value (IEa), plus half of the next highest (IEb/2), plus a quarter of the next highest (IEc/4), and so on (WE = ∑ (IEa + IEb/2 + IEc/4 +…)).

2.2 Results and discussion

General description of aquatic macroinvertebrate fauna of the SCP

The full database used for the analyses presented in this paper (including lists of the taxa recorded at individual wetlands) is available from CEM. Over 550 taxa from 176 families or higher order taxonomic levels have been recorded from the study area (**Table 2.2**). In general the macroinvertebrate fauna of the Swan Coastal Plain can be described as containing:

- some relatively diverse groups: a diverse dytiscid water beetle assemblage probably in excess of 50 species; a well represented microcrustacean fauna with over 60 cladoceran species or sub-species, over 30 copepod species, and over 40 ostracod species; at least 9 corixid and 10 notonectid species of hemipterans;
- some moderately diverse groups: 31 chironomid midge species and at least 10 culicid mosquito species (although several mosquito taxa are unlikely to be collected using standard invertebrate collection techniques), at least 11 damselfly (Zygoptera) and 12 dragonfly (Anisoptera) species, at least 28 aquatic mite taxa, about 14 inland aquatic molluscan species (some of which are introduced), and at least 17 oligochaete worm taxa.
- some relatively depauperate groups, for instance the ephemeropteran (mayfly), trichopteran (caddisfly), amphipod (scud shrimp) fauna, and that fauna regarded as belonging to clear, cool, flowing freshwater habitats (ie. Simulidae and Plecoptera).

There appear to be significant knowledge gaps for the fauna. For instance relatively little effort has been placed on the collection and identification of taxa in the Porifera (sponges), Cnidaria (freshwater Hydra), Rotifera, Turbellaria (flatworms), Nematoda (roundworms), Hirudinea (leeches), Conchostraca (clam shrimps), and so on. In some cases these gaps may simply reflect the poor state of our understanding of the taxonomy of these groups Australia-wide. In the case of the Rotifera, Hirudinea and probably Turbellaria, the taxonomic expertise exists to collect information for wetlands on the Swan Coastal Plain and these should be given some urgent priority for aquatic invertebrate surveys in the state.

Rarely, if ever, have taxa been evenly collected and identified across the majority of wetlands. These observations make comparisons across wetlands difficult, and mitigate for a systematic and thorough survey even in these, perhaps the most well-known wetlands in Western Australia. Further notes on the unevenness of the taxonomy of groups across wetlands are given below.

Richness

A synthesis of the aquatic invertebrate data for wetlands on the Swan Coastal Plain is given in **Table 2.3**. It shows, for each wetland or wetland system, the data source(s), richness values (for family, genus and species), the proportional rarity, endemism and the relative effort expended. Species richness ranges between 10 and over 140, generic richness between 10 and 119, and family richness between 8 and 76 over all of the wetlands/wetland systems. Generic richness and species richness (**Figure 2.2**; $r^2 = 0.946$) show a tighter relationship than do family and species richness (**Figure 2.3**; $r^2 = 0.752$). Hence generic level richness may be the more appropriate measure to assess richness significance for wetland systems on the Swan Coastal Plain. **Figure 2.2** shows a clear 'break' in the progression of species richness. Above the break are five wetlands with conspicuously high richness (well above 100 species: Twin Swamps, Jandabup Lake, Nowergup Lake, Thompsons Lake and Perth Airport Swamps). Another two wetlands are significant for their richness: Loch McNess and Yonderup Lake register comparatively very high family richness: 76 and 68 families respectively, around half of the families recorded in the SCP study area. Of these 7 'significant' wetlands or wetland systems, 5 are located on the Gnangara Mound.

Although richness tends to increase with increasing sampling effort (**Figure 2.4**), richness values show considerable ranges within the same or similar effort values (WE index). Nevertheless, these ranges are similar across all WE values for each richness measure. This is particularly evident at the higher end of the effort scale (>45 WE) where generic richness varies between 60 and 120 (**Figure 2.4**). Also, the three richest wetlands had widely different effort values. Assuming that the effort index is sufficiently robust, this suggests that all wetlands are not equal in their capacity to yield invertebrate richness, and that variation in richness across wetlands is not just a function of the effort expended to sample those wetlands.

Rarity

Percentages of rare taxa ranged from 0 (recorded for 10 wetlands) to 58% (for Yanchep Caves) (**Table 2.3**). No relationship was evident between generic richness and the proportion of taxa regarded as rare (**Figure 2.5**). Most wetlands recorded less than 10% rare taxa. Figure 3.4 also shows a conspicuous break between wetlands recording less than 21% rarity, and those found with more than 28% rarity. Using the criterion of more than 25% rarity, therefore, 8 wetlands can be regarded as significant in terms of rare taxa: Yanchep Caves, Twin Swamps, Ellenbrook

Table 2.3: Aquatic invertebrates found in wetlands on the Swan Coastal Plain: sources of data, richness values (at species, genus or family (or greater) levels), the number of taxa identifiable to a named species, proportional endemism (%regional endemics and number of local endemics), rarity (% of taxa at 3 or less wetlands), and relative sampling effort, for each wetland. (Gnangara mound wetlands are highlighted.)

Wetland/Wetland System	Main Source(s) of Data#	Richness			No. named species	Rarity %	Endemism		Effort
		Family	Genus	Species			%RE	LE	WE
Gingin Brook Pool	4	30	48	53	34	6	5.9	0	na
Gingin Brook	1, 5	32	32	32	0	19	0	0	38.75
Yanchep Caves	7	43	43	58	13	58	7.7	1	32.3
Tangletoe Swamp	5	26	34	38	20	0	10	0	27
Loch McNess	9, 5, 4, 3	76	87	88	28	10	25	0	48.45
Lake Yonderup	5, 4, 3	68	88	90	36	11	5.6	0	40.5
Lake Wilgarup	3	26	28	28	3	0	0	0	27
Pipidinny Lake	3	56	58	58	3	7	0	0	27
Coogee Springs	5, 4, 3	59	86	96	46	9	4.3	0	40.5
Lake Carabooda	5, 4	30	50	55	32	0	6.2	0	27
Lake Nowergup	5, 2, 4, 3	70	96	123	64	5	20.3	0	51.1
Muchea/Peter’s Spring	12, 11, 17	43	61	64	24	42	8.3	1	53.5
Kings Spring	11, 17	24	30	30	14	48	14.3	1	43
Bullsbrook Channel	12	13	14	14	4	36	50	0	32
Bullsbrook Runnel	12	14	15	15	4	20	25	0	32
Edgerton Spring	12, 17	29	37	38	7	32	28.6	0	46
Edgecombe Spring	12	11	13	13	0	8	0	0	32
Edgecombe Lake	12	22	27	27	10	15	30	0	32
Cooper Rd Swamp	12	12	17	17	5	18	0	0	32
Nursery Dam	12	21	27	28	15	36	6.7	0	32
Ellen Brook Floodplain	5	25	32	33	18	18	16.7	0	27
Ellen Brook Nature Res.	8	33	59	67	30	51	23.3	0	26.2
Ellen Brook Monitoring	1	33	33	33	0	18	0	0	23.5
Twin Swamps	8	49	108	134	75	42	22.7	0	26.2
Lake Neerabup	5, 4	42	66	75	43	0	14	0	27
Melaleuca Park EPP173	5, 4, 3, 14	47	75	83	37	4	16.2	0	40.5
Lexia Wetland 86	3	34	34	34	0	3	0	0	27
Lexia Wetland 186	3	19	19	19	0	11	0	0	27
Lake Mariginiup	5, 4, 3	56	72	74	33	1	12.1	0	40.5
Lake Jandabup	9, 5, 2, 4, 3	74	120	140	76	11	15.8	0	51.1
Lake Joondalup	5, 4, 3, 13	61	86	89	43	3	11.6	0	52.75
Beenyup Swamp	13	27	41	44	31	2	12.9	0	32.5
Lake Gnangara	5, 4, 3	34	40	41	8	12	25	0	40.5
Lake Goollelal	5, 4, 3, 13	47	62	65	34	6	17.6	0	52.75
Mussel Pool	5, 4	35	60	67	47	1	12.8	0	27
Big Carine Swamp	5, 4	33	45	49	30	2	13.3	0	27
Malaga Wetlands	5, 4	23	31	35	23	0	13	0	27
Lake Gwelup	5, 4	33	53	55	35	4	5.7	0	27
Lake Chandala	5, 4	34	64	71	38	6	10.5	0	27
Lake Monger	15, 5, 4	42	60	64	35	9	11.4	0	50.5
Herdsman Lake	5, 4	38	60	63	37	8	13.5	0	27
Perth Airport Swamps*	5, 4, 10	62	119	143	80	28	16.2	0	40.1
Murdoch Swamp	5, 2, 4	51	59	92	45	5	20.0	0	44.4
North Lake	5, 2, 4	50	64	98	57	5	19.3	0	44.4
Bibra Lake	5, 4	31	42	45	29	2	3.4	0	27
Yangebup Lake	5, 4, 18	46	55	57	22	5	4.5	0	40.5
Warton Swamp	4, 18	48	52	53	9	2	0	0	27
Lake Balannup	5, 4, 18	46	77	91	50	9	10	0	40.5
Lake Kogolup North	5, 4, 18	41	64	70	37	1	8.1	0	40.5
Lake Kogolup South	5, 4, 18	52	72	77	36	4	11.1	0	40.5
Thomsons Lake	5, 2, 4, 18	59	91	120	69	4	19.3	0	51.2
Shirley Balla Swamp	4, 18	38	38	38	0	3	0	0	27
Gibbs Road Swamp	5, 4, 18	52	65	67	28	4	10.7	0	40.5
Forrestdale Lake	5, 18	36	59	65	41	3	7.3	0	40.5
Banganup Lake	18	47	53	53	12	4	16.7	0	27
Bartram Swamp	2	51	60	92	43	4	23.3	0	31
Lake Mandagolup	5	22	31	31	15	0	13.3	0	27
Lake Wattleup	5	16	28	34	21	0	0	0	27
Spectacles	5	27	40	45	30	0	6.7	0	27
Piney Lake	5, 4	35	57	62	39	2	7.7	0	27
Mary Carroll Park	16	19	36	41	25	2	16	0	29.7
Manning Lake	4	8	10	10	7	0	14.3	0	na
Brownman Swamp	5, 4	26	41	47	29	0	3.4	0	27
Lake Mt Brown	5, 4	37	52	58	32	9	12.5	0	27
Lake Paganoni	2	25	25	25	0	0	0	0	26.8
Lake Cooloongup	5, 4	25	33	38	24	5	12.5	0	27

*Perth Airport Swamps also known as (“Munday Swamp”) 1.Department of Environment and Conservation database (see Smith, Kay *et al.* 1999) 2.Balla and Davis (1993) 3.Benier and Horwitz 2003). 4.Davis and Christidis (1997) 5.Davis et al. (1993) 6.Davis et al.(2006) 7.English et al. (2003) and Knott and Storey (2004) 8.Halse pers. comm., unpublished data. 9.Hembree and George (1978) 10.Halse and Storey (1996) 11.Jasinska (1998) 12.Jasinska & Knott (1994) 13. Kinnear et al.(1997) 14.Knott et al. (2002) 15.Lund (1992) 16.Lund and Ogden (2003) 17.Pinder (2002) 18.Wild, Davis *et al.* (2003).

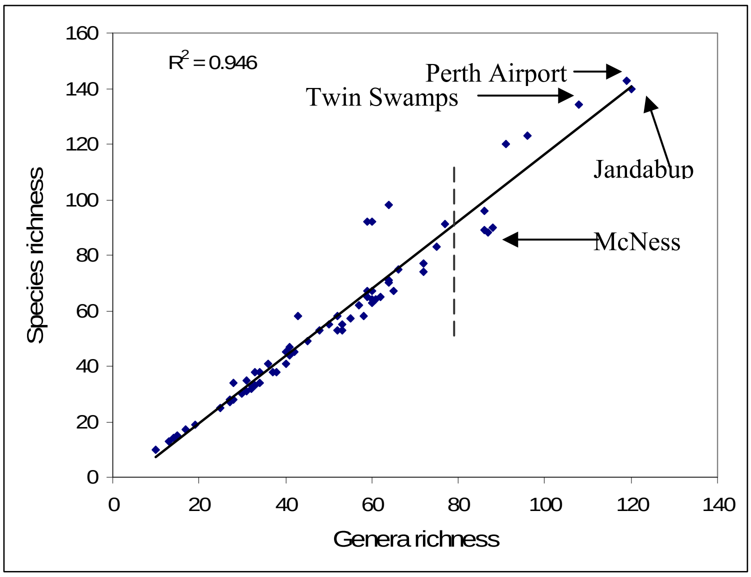


Figure 2.2: Species richness shown as a function of genera richness for macroinvertebrates of the SCP wetlands. Dotted line shows break, above which are significantly rich wetlands.

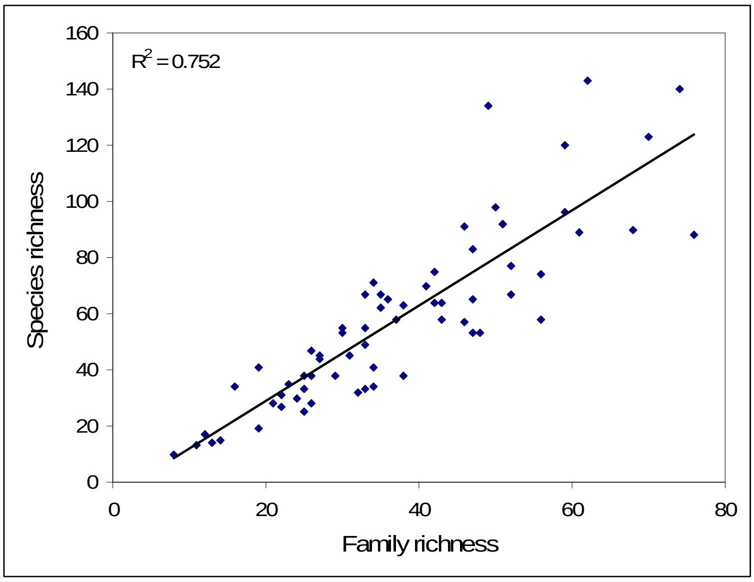


Figure 2.3: Species richness shown as a function of family richness for macroinvertebrates of the SCP wetlands.

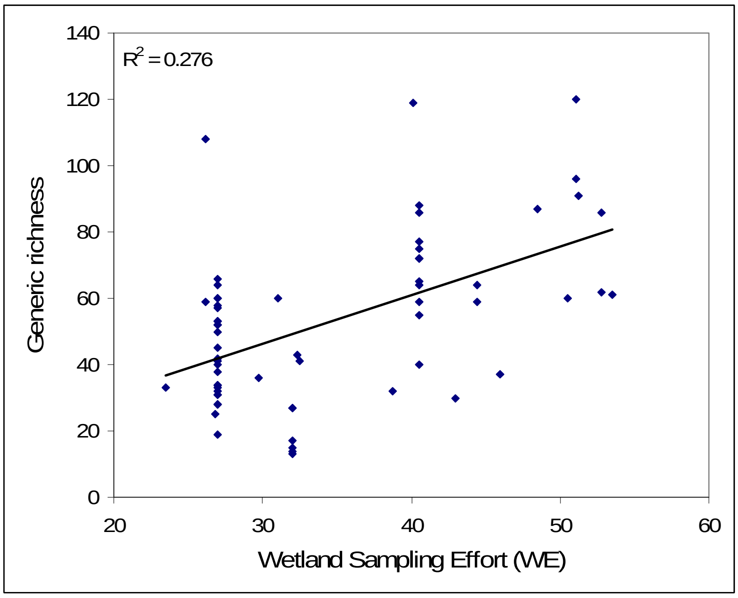


Figure 2.4: Generic richness of SCP wetlands shown as a function of the sampling effort expended at each wetland (using the sampling effort index: see text and Table 2.3).

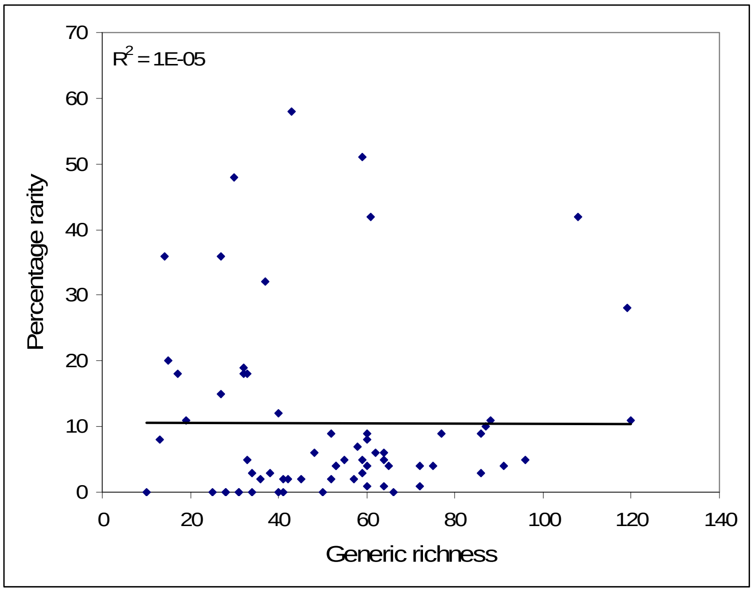


Figure 2.5: Percentage of rare taxa found at each wetland shown as a function of generic richness.

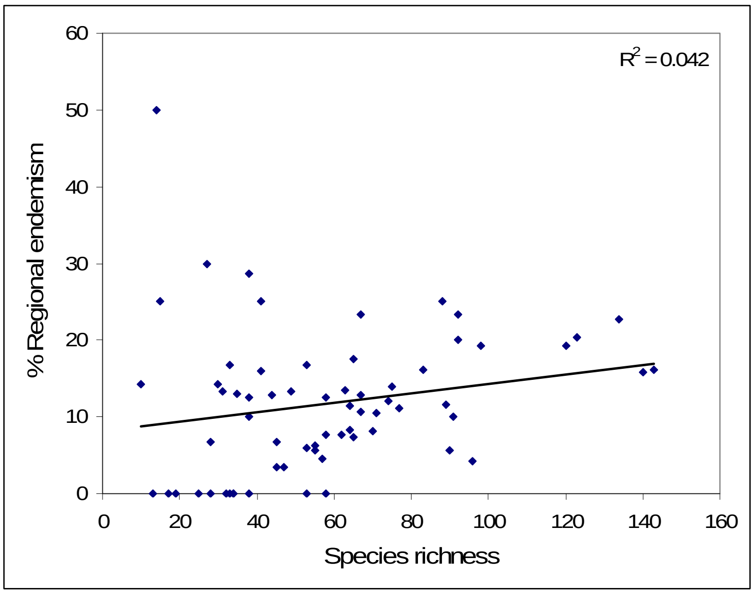


Figure 2.6: Percent regional endemics displayed as a function of species richness at wetlands on the Swan Coastal Plain.

Nature Reserve, and 5 wetlands from the tumulus mound suite. The same weak negative relationship was evident between sampling effort and the likelihood of finding rare taxa.

Endemism

A total of 243 taxa were identifiable to species and each was assigned a distribution category (**Table 2.2**) to determine relative endemism for the region and for each wetland. Only three species could be readily designated as a local endemic, restricted to the Swan Coastal Plain bioregion. One amphipod, *Hurleya* sp. appears restricted to root mat communities of the Yanchep caves. Two water mites *Thryptaturus* sp.nov. and *Anisitsiellides* sp.nov. are presently known only from tumulus mound springs in the eastern Gnangara region (Harvey, pers. comm.).

Thirty-eight taxa (15.6%) were endemic to south-western Australia. They include taxa that:

- are widespread and taxonomically well understood (like the freshwater shrimp *Palaemonetes australis*, the freshwater mussel *Westralunio carteri*),
- have been thought to be more widely distributed (with a distributional range that includes the Swan Coastal Plain), but where evidence now exists to suggest that the taxon includes several genetic forms different at least at the species level, where the Swan Coastal Plain will harbour local endemics (e.g.. saline snail *Coxiella striatula* (see Pinder *et al*. 2004), and the isopod *Paramphisopus palustris,* see Gouws and Stewart 2007).

Several wetlands had relatively high proportions (over 20%) of regionally endemic species, including Loch McNess, Lake Jandabup and Twin Swamps, three wetland systems already recognized for high levels of invertebrate richness.

The bulk of the assemblage identifiable to species (84%) were also found beyond south-western Australia, elsewhere in Western Australia, in southeastern Australia, in northern Australia, or in other parts of the world. There was a very weak positive correlation between the percentage of regional endemism and the species richness for the wetlands (r^2=0.042, **Figure 2.6**), but this relationship would be much stronger if the mound spring wetland sites were removed from the data set. The same relationships exist between the percentage of regional endemism and the effort expended at each wetland.

Interpretation of the database

Interpretation of the database is limited by its nature. Only presence/absence data were used, which means that it was not possible to determine abundances or dominance of taxa. In addition, neither sampling location (habitat) within a wetland nor sampling time (i.e. seasonality) were used as discriminatory assumptions about their inter-annual variation, whether they are intermittent residents on a yearly basis, whether they are there every year, were once recorded there, or have only recently been recorded at the wetland. In most cases this more detailed information could be found in individual source documents, but methodological and reporting inconsistencies by different investigators rendered a regional compilation of this sort unfeasible. Indeed these limitations are precisely the reasons why systematic surveys using standard methodologies are preferred for making regional assessments of biota.

The data and analyses presented in this paper cannot, therefore, be used to assess the habitat requirements of taxa, or changes in fauna over time due to environmental effects. During the period of data collection, for instance, Lake Jandabup suffered a significant drying and acidification event (Sommer and Horwitz 2001), Forrestdale Lake was also drought-affected for several years, Coogee Springs became eutrophic then dried completely and then burnt for many months (as did Wilgarup Lake), Lakes Joondalup and Monger experienced several episodes of serious eutrophication, Herdsman Lake has been part infilled and subject to pesticide exposure. The influence of such changes on invertebrate richness, rarity and endemism measures are extremely variable and mostly unknown (but see Sommer and Horwitz, 2008 subm.).

With a few exceptions, the compilation of this database has been taxonomically uncritical, assuming that the records given by authors are verified or verifiable. This assumption is somewhat problematic because the taxonomic competence of the many authors involved undoubtedly varies, as does the knowledge base in general about the taxonomy of certain invertebrate groups (which itself can change over time). While every effort has been made to provide the most up-to-date taxonomic treatment of invertebrates, there will invariably be taxonomic errors in the database. Nevertheless, the likelihood is high that in most cases each record represents a unique taxon and therefore contributes to richness calculations for each wetland.

It has been generally assumed that unless taxonomic expertise was involved, family level designations are likely to be more reliable than genus level designations, which in turn are more reliable than species level designations. This probably also holds true when amalgamations of databases like this one are involved. This is probably why family level data as a surrogate for species richness are more fashionable (e.g. Chessman 1995). When viewed as an entire database, however, the much tighter correlation between genus and species richness compared with family and species richness is perhaps unsurprising and suggests that identification to genus may be a more accurate yet expedient level for rapid and comparative assessments of richness.

There is evidence in the database to confirm that richness attributable to a wetland is a function of the sampling effort as measured by the number of visits, the number of seasons when sampling occurred, the intensity of sampling and so on. Importantly, beyond this influence, variation in invertebrate richness exists across the wetland suites. Some of this variation will be attributable to wetland condition and water quality (e.g. response to human activities as described above), habitat complexity and possibly wetland type. However, in terms of these parameters, little consistent pattern is discernable for particularly taxa-rich wetlands, with the possible exception of habitat complexity (**Table 2.4**). For instance:

- Loch McNess (southern section), with its remarkably high family richness, is permanent with unstained and clear on Spearwood dune sands, and has exceptional habitat complexity (including a spring). Yonderup and Nowergup are similar, and together these three wetlands might be regarded as the deepest and most permanent (by Swan Coastal Plain standards),

- Lake Jandabup has weakly-coloured water, a mix of diatomaceous-organic sediment and leached Bassendean dune sands, relatively shallow, with a variable drying regime but mostly with complex littoral vegetation communities that are seasonally inundated. - Twin Swamps and Perth Airport Swamps are both wetland systems consisting of closely positioned but nevertheless discrete bodies of shallow seasonal surface water on Bassendean sands, with complex littoral vegetation communities.

While any region will contain endemic species by definition, many distributions are driven by micro-habitat and climate and so are under-estimated where sampling is not intensive. Thus a species may appear to be a regional endemic until the same niche is sampled elsewhere. There are also some unexplainable distribution disjunctions, and with more mobile insects there may be annual variation in distribution according to weather (see below). The bigger, longer-term nature of the SCP dataset may overcome some of these issues. Due to taxonomic uncertainty, it might also be argued that the database could even underestimate regional endemism. As an example of this, Halse and Storey (1996) note of the species collected in their wetland investigations: "Several of the ostracod species collected from the Airport swamps were undescribed and *Cypretta* sp. 441 has not been collected anywhere previously."

Comparisons between SCP wetlands and wetland suites elsewhere

In Western Australia, at least three other regional datasets are useful for comparison purposes. The wetland systems of far south-western Australia have been sampled for invertebrates by numerous workers and while no systematic survey has been undertaken of the Warren Bioregion (*sensu* Thackway and Cresswell 1995), a meta-analysis (like the exercise conducted here) was conducted by Trayler et al. (1996). A total of 156 species were identifiable to a named invertebrate species (from a much larger set of invertebrates known from the Bioregion), for which 10 (6.4%) could be regarded as locally endemic (see also Horwitz 1997). Furthermore, 49 taxa (31.4%) were regarded as endemic to south-western Australia. Both these estimates of proportional endemism of aquatic invertebrates are much higher than those found on the Swan Coastal Plain.

Wetlands were one of the specific foci of the comprehensive biological survey of the wheatbelt region of Western Australia ((Halse *et al.* 2004; Pinder *et al.* 2004). A total of 223 wetlands were sampled (mostly once, but intensively, including nets with fine mesh pore size of 50μm) between 1997 and 2000. The survey was designed to record wetland biodiversity across the

Table 2.4: High priority wetlands on the Swan Coastal Plain in terms of richness, endemism or rarity criteria for aquatic invertebrate records. Richness (more than 80 species and more than 75 genera shown with 'X'), endemism (wetlands with known local endemic species (LE) or with greater than 20% regional endemics (RE)), rarity (wetlands with more than 25% rare taxa shown with 'X') and relative effort (WE scores classified as: L (Low) < 35, M(Moderate) 35-45, H(High) 45-50, VH(Very high) 50+). Wetlands are ordered from north to south; see Figure 1 for locations. (Gnangara mound wetlands in bold type).

HIGH PRIORITY WETLAND	Richness	Regional or Local Endemism	Rarity	Relative wetland effort	Wetland habitat descriptors
Yanchep Caves		LE	X	L	Underground karstic stream; root mat fauna
Loch McNess	X	RE		H	Permanent lake, spring, karstic system, diverse littoral vegetation communities
Lake Yonderup	X			M	Permanent lake, karstic system, unconsolidated and consolidated organic soils
Lake Nowergup	X			VH	Deep, permanent lake, Spearwood sands; diverse littoral vegetation communities, unconsolidated and consolidated organic sediment
Lake Jandabup	X	RE		VH	Semi permanent, diverse sediment types and complex littoral habitat
Twin Swamps	X	RE	X	L	Ephemeral, complex littoral habitat
Muchea/Peter's Spring		LE	X	VH	Mound spring
Kings Spring		LE	X	H	Mound spring
Bullsbrook Channel			X	L	Mound spring
Edgerton Spring		RE	X	L	Mound spring
Edgecombe Lake		RE			Small (created?) depression fed by spring
Nursery Dam			X	L	Small (created) depression fed by spring
Ellenbrook Nature Reserve		RE	X	L	Shallow seasonal clay-based wetland fed by surface run-off, with littoral vegetation.
Perth Airport Swamps	X		X	M	Ephemeral to seasonal basin wetlands with complex littoral habitats and dark water.
Thomsons Lake	X			VH	Fresh-brackish, semi-permanent lake with diverse littoral vegetation in depression straddling Bassendean and Spearwood sands. Ramsar wetland.
Bartram Swamp		RE		L	Small ephemeral coloured wetland

wheatbelt and south coast of Western Australia, a comparatively massive area of 205 000 km2 (Halse *et al.* 2004) (50 times larger than this study area). Altogether, 957 aquatic invertebrate species were recorded, with an average of 40 and a range of 0–107 species per wetland. Rotifers comprised 18% of the invertebrate fauna, and 274 species were collected only once (28.6% of the total number of taxa) (Pinder *et al*. 2004).

In another comprehensive biological survey, Halse *et al.* (2000) recorded the invertebrate fauna from 53 wetlands in the Carnarvon Basin. Wetlands were sampled in both winter and summer where possible using similar methods as those for the Wheatbelt study. A total of at least 492 aquatic invertebrate taxa were recorded, with rotifers comprising 14% of this richness. Rare species (those encountered only once) numbered 158 (roughly one third of all taxa). Richest sites were the cluster of river pools, rock pools in river channels and larger flowing streams with an average of 44 taxa recorded. Halse *et al* (2000) identified 32 taxa (6.5%) as being taxonomically undescribed and so far only known from the Carnarvon Basin, but were reluctant to claim these as 'endemic' to the region due to poorly understood distributions of aquatic invertebrates of the arid zone.

Elsewhere in Australia, Butcher's (2003) study of sixteen depressional wetlands in the western Wimmera region of Victoria is probably the most relevant and comparable although macroinvertebrates were examined (and not the smaller invertebrates collated for other studies mentioned above). Four wetlands from each of four freshwater categories (which formed a hydrological gradient from temporary to permanent), were sampled for macroinvertebrates at one and three months after filling. She recorded a total of 303 macroinvertebrate taxa; richness of macroinvertebrates did not differ across the four freshwater categories, but it did increase with habitat duration.

Biogeographic considerations

In roughly comparative terms therefore, the Swan Coastal Plain wetlands have high richness, particularly given the comparatively small geographical range of the 'survey' area (although sampling effort may have something to do with this). They have relatively low levels of local and regional endemism. Levels of 'rarity' are more difficult to assess, but this is perhaps comparably lower (although, again, this may be a function of higher sampling effort in the SCP wetlands).

Possible explanations for these patterns include the geologically-recent nature of the formation of the coastal wetlands. Wetlands on the Swan Coastal Plain included in this work are likely to have formed as aeolian depressions in the dune systems themselves formed from mid-Pleistocene to early Holocene (Semeniuk 1995, in fact are continuing to form, Semeniuk and Semeniuk 2006). Wetland biotas are likely to have developed since this period, punctuated by periods of higher sea levels (ie. in the late Pleistocene 150 000 to 130 000 years BP which would have inundated most of what is now the Swan Coastal Plain (Kendrick *et al.* 1991), and aridity. Periods of lower sea levels in wetter phases have allowed for the formation of dunes and interdunal wetlands and subsequent expansion of wetland habitat in a seaward direction. This expansion would have allowed for colonization of aquatic biota, in this instance aquatic invertebrates, from possibly three directions. Expansion northwards from southern (coastal) wetlands, which were more reliably cool and wet, and expansion westwards from the adjacent flowing waters of the Darling Scarp (ie. from another bioregion); both these expansions would have occurred during wetter phases when sea levels were at similar or lower levels compared to those today. The third, expansion southwards by northern Australian elements may have occurred as intermittent and often itinerant transgressions associated with the southward trajectory of tropical lows. These geologically-recent (and at least in terms of the last mentioned, on-going) colonizing forces might account for the bulk of the invertebrate faunal elements and together explain why richness is comparatively high but local endemism is comparatively low. Specific or concordant evidence for these colonization directions comes from a variety of sources.

For northward expansions, four species of freshwater fish endemic to Western Australia (Balston's Pygmy Perch *Nannatherina balstoni*; Black-striped minnow *Galaxiella nigrostriata*; Mud Minnow *Galaxias munda*; and Nightfish *Bostockia porosa*) have distributional ranges that are predominantly far southwestern, whose most northern representatives occur around Moore River/Gingin, and the first three of these have disjunct distributions, with these northern outliers separated by at least 100km (Morgan *et al.* 1998). To explain these disjunct distributions, Morgan *et al.* (1998) argue "…the discontinuity … may represent the loss of suitable habitat caused by widespread urban and rural development in the intervening region", no doubt referring to the significant hydrological change that has occurred on the SCP over the last two hundred years. An alternative explanation is that these are northern relicts of once more widespread distributional ranges that were fragmented during an arid phase in the Holocene (or possibly earlier, since their occurrence in the older Bassendean Dune system might be linked with genetic divergence between populations). Aquatic invertebrate examples with predominantly southern distributions and northern SCP outliers include janirid isopods and the hydrobiid gastropods. The janirid isopods are known from Yanchep cave systems (as collated here; see Jasinska and Knott (2000)), but otherwise only known from hyporheic samples in rivers and crayfish burrow samples in the inland coastal freshwater systems of the far southwestern corner of the state (Horwitz, unpubl. data). *Westrapyrgus slacksmithae* is a locally endemic aquatic snail, only known from the footslopes of the Darling Scarp north of Perth, and Moore River; its closest relative is from coastal and riverine sites in the far southwestern corner of the state (Ponder *et al.* 1999).

Westward expansions could be either of riverine or lentic origins, with the potential for invertebrates to move from the Darling Scarp, or wetlands at the foot of the Scarp, out across the plains. For invertebrates associated with flowing waters, a connection would have existed between the flowing streams that run off the Darling Scarp, and the significant flows that joined (or drained) wetlands (for instance Ellenbrook, Bennett Brook, Claisebrook, Gingin/Lennard Brooks, in the north of the study area). Again, these connections between wetlands and flowing waters have been fragmented due to recent agricultural and urban activities, but may also have experienced fragmentation due to aridity over longer time frames. In addition, relictual freshwater forms from westward expansions may be present in subterranean aquatic environments like the karstic features in the Yanchep region, and the spring seepages that manifest as tumulus mounds. Jasinska and Knott (2000) suggest "…multiple invasions of the cave streams starting in the mid- to late-Pleistocene during the karst syngenesis, especially during the wetter interglacials… aquatic animals then may have been able to move from the Darling Scarp on to the Swan Coastal Plain. In fact, the genus *Hurleya* was described from …groundwaters on the Darling Scarp…". These environments are where local endemism is likely to reside.

Jasinska and Knott (2000) describe the requisite factors for the formation of aquatic root mats in caves: "i) permanent water bodies at, ii) shallow depth, in iii) fissured cavernous rock which supports iv) the growth of trees and v) where, at least for part of the year, the local climate and soil structure create arid conditions forcing the trees to grow roots in cave waters in order to meet their water requirements." The age of the Tamala limestone in which these communities have developed, mid-Pleistocene, suggests that the fauna in them will be generally younger than this in origin (as above).

Southward expansions are tropical, subtropical or warm temperate species, and probably or nomadic, highly vagile and opportunistic in nature. An example is the dragonfly Macrodiplactidae (Urothemistidae; probably the wandering pennant *Macrodiplax cora*, sporadically collected from northern SCP wetlands), regarded by Theischinger and Hawking (2006) as essential tropical with nomadic adults. Such southward expansions have also been described for the Western Australian wheatbelt: Pinder *et al.* (2004) collected numerous northern/tropical taxa in the wheatbelt in 1999 when there was extensive cyclonic rain through the Pilbara, Murchison, and northern wheatbelt region.

High priority wetlands with significant invertebrate fauna

High priority wetlands with 'significant' invertebrate fauna (Table 3.2) in terms of aquatic invertebrate richness, endemism and/or rarity include:

- aquatic habitats in a cave system in karstic areas around Yanchep;
- permanent surface waters in karstic areas around Yanchep;
- tumulus springs (organic mound springs) in the Ellen Brook region of the eastern Gnangara mound;
- surface waters in the Ellen Brook region of the eastern Gnangara mound; and
- ephemeral clay-dominated swamps.

Again, significance can be confirmed using concordant data from non-invertebrate taxa. For instance, the critically endangered local endemic *Pseudemydura umbrina* (Western Swamp Tortoise) is known only from Ellen Brook and Twin Swamps Nature Reserves, and from one of the swamps at Perth Airport (Burbidge and Kuchling 2004). Two of the three occurrences of tumulus springs recorded in (English and Blyth 2000) retain *Hibbertia perfoliata*, a species thought to be extinct elsewhere on the Swan Coastal Plain. The wetland Melaleuca Park EPP 173 also retains a remnant population of the black-striped minnow *Galaxiella nigrostriata*.

Summary

The compilation of aquatic invertebrate taxa recorded from SCP wetlands between 1977 and 2003 has shown that:

- the aquatic invertebrate fauna of the SCP is surprisingly rich (considering the comparatively small survey area and the degree of anthropogenic alteration of the SCP, particularly in terms of wetlands);
- in general, increased richness is associated with increased sampling effort;
- wetlands on the Gnangara mound are, overall, richer than those on the Jandakot mound; seven wetlands (of a total of 66) stand out as being particularly rich (five of which are on the Gnangara mound);
- although taxonomically rich, local and regional endemism is relatively low; and
- the proportion of rare taxa is also generally low (generally < ~10%), however eight wetlands (including Yanchep Caves, the tumulus mound suite, Twin Swamps and Ellenbrook Nature Reserve) have a high number of rare taxa (> 25%).

Thus regional/local endemism and rarity do not, in general, markedly contribute to taxa richness in wetlands of the SCP, and this appears to contrast with other bioregions of south-western Australia (viz. the Warren, the wheatbelt and the Carnarvon Basin). For SCP wetlands, levels of richness and endemism have been attributed to geologically recent colonizing forces associated with the geological formation of the plain, which have allowed invertebrate colonization from multiple directions: the cooler southern, the warmer northern, and from Darling Scarp wetlands. Rare invertebrate taxa, on the other hand, appear to be associated with rare wetland types harboring very specific (and perhaps unusual) microhabitats (and often also other rare biota).

The greatest threat to wetlands on the SCP at the current time are declining surface water levels (and associated water quality problems) brought about by a combination of climate change, groundwater extraction and changes in land use. It would be unrealistic to allocate the same amount of management resources to all of these threatened wetlands. Equipped with the information presented in this paper, wetland management can be more wetland-specific, focusing on wetlands identified as being ‘significant’ in terms of aquatic invertebrates, rather than on other common criteria such as wetland type (e.g. *sensu* Semeniuk 1987). This is all the more pertinent since it is precisely these significant or unusual wetlands that are currently under the greatest threat from declining groundwater levels.

3. Invertebrate habitat specificity (Objective 2)

Thirteen years of monitoring Gnangara Mound wetlands as part of the "Wetland Macroinvertebrate Monitoring Program of the Gnangara Mound Environmental Monitoring Project" (Department of Water) has provided the opportunity to assess long-term trends and other issues, not normally within the scope of the yearly reporting. One of these is the association of aquatic macroinvertebrates with particular habitat types. An understanding of this aspect of invertebrate ecology will help management efforts to become more efficient, as well as to focus on critical habitats/vegetation communities. Sampling for the program is habitat-based (*sensu* Chessman 1995) in order to maximize the diversity of taxa able to be collected, yet no analysis has been undertaken to date to determine the efficacy of this process. For example, if sampling two aquatic vegetation communities reveals the same, or perhaps only slightly less, information as sampling four, dropping two habitats may be warranted. The resources saved could then be utilised to support the study/monitoring of 'under- studied' communities.

3.1 Methods

The sixteen wetlands sampled as part of the 'Wetland macroinvertebrate monitoring program of the Gnangara Mound Environmental Monitoring program' were initially grouped into habitat types (the majority of wetlands supporting at least three habitat types). From these the different habitat types were grouped into dominant aquatic vegetation communities. The number of wetlands supporting specific vegetation communities, and the number of times each vegetation community within each wetland was sampled, was counted ('n'). The total number of times individual invertebrate taxa were sampled from specific vegetation communities within individual wetlands was counted ('x'). Because not all wetlands or habitats were sampled at equal frequencies over the thirteen-year period, this number was then standardized by converting to a percentage:

$$\text{Percentage frequency that a taxon was sampled from a specific habitat} = \frac{x * 100}{n}$$

This figure gives an indication of temporal prevalence of individual taxa in individual vegetation communities, and was subsequently used in pattern analyses (see below). Pattern analyses were performed in order to answer the following questions:

- are there taxa or groups of taxa that are restricted to specific vegetation communities?

- what is the most common vegetation community in the monitored Gnangara mound wetlands?

- are there relatively rare or under-sampled aquatic vegetation communities?

Vegetation community, invertebrate and wetland data were each classified using an agglomerative hierarchical technique of cluster analysis (Primer v. 5.1) in order to reveal patterns or groupings of these variables. Prior to classification the invertebrate data (i.e. mean percentage of sampled frequency) were arcsine-transformed in order to normalise the data and then $\log_{10}(x+1)$-transformed in order to down-weight common taxa. Taxa occurring in less than 5 vegetation communities or wetlands (i.e. rare taxa) were excluded from the analyses. All classifications were based on the Bray-Curtis similarity measure; this will equal 100% when two wetlands/vegetation communities/invertebrates are identical, and 0% when there are no common variables. Dendrograms were produced from the classifications and major groupings were selected from these. The selected groups were subsequently coded as factors, and the SIMPER procedure in Primer was used to examine the contribution of each macroinvertebrate family to the average Bray-Curtis similarity between groups of samples.

3.2 Results and discussion

The following (dominant) aquatic vegetation communities for the 16 monitored Gnangara mound wetlands were identified:

1. *Typha orientalis* (includes dense *Typha* over organics and sparse *Typha* over organics);
2. *Baumea articulata* (includes dense *B. articulata* and sparse *B. articulata*);
3. *T. orientalis/B. articulata* mix (includes dense *B. articulata/Typha* over organics and dense *B. articulata/Typha* with charophytes over marl);
4. Mixed Cyperaceae (includes sparse, low mixed Cyperaceae over diatomaceous sediment; mixed Cyperaceae & *B. articulata* on floating organic island; mixed Baumea on silt/sand; and sparse *B. arthrophylla* on diatomaceous earth);
5. Mixed Cyperaceae with submerged herbaceous (includes charophytes, Juncaceae & *B. articulata* on marl; mixed *Baumea* & submerged herbaceous on diatomaceous sediments; *B. articulata* with submerged herbaceous; and dense mixed Cyperaceae & introduced grasses);
6. Mixed Restionaceae (includes mixed Restionaceae over sand or organics; and mixed Restionaceae over diatomaceous earth)
7. Mixed Cyperaceae and Restionaceae;
8. *Lepidosperma longitudinale* (in the presence of algae & *Myriophyllum*);
9. Mixed Restionaceae/*Lepidosperma*;
10. *B. articulata/ Lepidosperma*;
11. *Melaleuca raphiophylla/ B. articulata* (includes '*Melaleuca* roots and trunks, some *B. articulata*, organic/sand sediment'; and '*Melaeuca* trees & *B. articulata* edge of floating organic island');
12. *M. raphiophylla*/ submerged herbaceous;
13. *Astartea fascicularis* (dense *Astartea* on organic sand);
14. Submerged herbaceous (includes charophytes and/or *Ruppia* & other submerged macrophytes; and *Villarsia albiflora*);
15. Open water (includes open water over detritus/sand; open water over detritus/sand – creek; open water over diatomaceous earth; and open water over organic sediment with suspended floc);
16. Spring (*Lepidosperma* & willow roots in flowing water)

Please note that in this section the terms 'habitat' and 'dominant vegetation community' are used interchangeably even though, strictly speaking, a 'habitat' consists of numerous additional variables (e.g. water quality, sediment type, hydrology, etc.) besides vegetation type. The two most common aquatic vegetation communities encountered in the Gnangara mound wetlands were 'submerged herbaceous' (sampled in 9 out of 16 wetlands) and *T. orientalis* (sampled in 8 out of 16 wetlands). The least common (not necessarily because they are rare *per se*, but more rather rarely represented in the monitored wetlands) were 'mixed Cyperaceae/Restionaceae' (sampled only from Melaleuca Park), 'mixed *Lepidosperma*/Restionaceae' (sampled only from Lake Gnangara[*]), 'mixed *B. articulata/Lepidosperma'* (Lake Yonderup only), and the spring at Loch McNess. **Table 3.1** lists the sixteen dominant vegetation communities, the number of wetlands at which each community is present, the frequency at which each wetland supporting specific communities was visited/sampled, and the mean percentage individual taxa were sampled from each vegetation type. For example, Hirudinea was found 25.4% of the times a *T. orientalis* habitat was visited. Standard deviations were often large, especially when a taxon was found only in a small proportion of the wetlands supporting a specific habitat type (see **Appendix 2**). This highlights the inherent spatial and temporal variability of aquatic invertebrate occurrence, which in turn is likely to be due to a number of factors that influence the presence of a taxon, e.g. water quality, trophic relationships and stochastic habitat characteristics.

T. orientalis, *B. articulata* and *M. raphiophylla/B. articulata* supported the highest number of invertebrate taxa (75, 75 and 74 taxa respectively). This equates to ~90% of invertebrate families being present in three (out of a total of sixteen) vegetation communities. Habitats supporting submerged herbaceous species also had comparatively high numbers of invertebrates (72). 'Mixed Restionaceae/*Lepidosperma*', 'Mixed Cyperaceae/Restionaceae' and '*B.articulata/Lepidosperma*' had the lowest taxa richness (28, 39 and 46 respectively). It would appear however that these figures were at least to some degree related to the frequency of visitation (r^2= 0.693, $p<0.01$, n= 16). Even when the least frequented habitat types are removed (see above), taxa richness is significantly correlated to the number of visits (r^2= 0.654, $p<0.01$, n= 14; **Figure 3.1**). This corresponds with results from the previous section where it was found that increased sampling effort ('wetland effort' WE) was associated with increased species richness. When the ratio 'taxa richness'/'number of visits' is regarded it can be seen that the four 'poorly sampled' habitats support a relatively high number of taxa, considering the low sampling frequency (**Figure 3.2**). Conversely, the well-sampled habitats have comparatively low richness, considering the high sampling frequency. This can be explained by considering classical ecological theory which states that the rate of increase in species richness in a community decreases as area increases (i.e., the 'species-area curve; Arrhenius 1921). This can be extrapolated to the number of samples versus species richness. Thus this ratio may be a good way to assess which habitat types (or wetlands) are under-represented in a monitoring program.

For the purpose of this report, invertebrate taxa found in three or less habitat types were arbitrarily defined as 'habitat-specific' taxa. There were only four such taxa: Simuliidae (Black fly larvae; these are lotic species – Williams 1980) sampled only in the spring at Loch McNess; the amphipod Perthidae (sampled from the *Astartea* and *B. articulata* vegetation communites at Melaleuca Park only); Carabidae (sampled from 'Mixed Restionaceae', '*Melaleuca*/*B. articulata'* and 'submerged herbaceous'); and Temnocephalidea (sampled from the '*Astartea'* and 'Mixed Cyperaceae/Restionaceae' communities at Melaleuca Park, and from the spring at Loch McNess). Simuliids were sampled relatively frequently from the Loch McNess spring (26% of the time), however the other three taxa were rare even within the habitats in which they were found (<10% of the time). A further six taxa were relatively restricted, occurring only in four or five vegetation communities (see **Table 3.1**). These were Janiridae, Saldidae, Empididae, Ptilodactilidae, Gomphodeliidae and Eylaidae. These were all also infrequently

[*] This vegetation community no longer exists at Lake Gnangara because of the sustained decline in water levels. Remaining fringing Restionaceae are no longer inundated, and *Lepidosperma* has migrated towards the centre of the lake where there is more likely to be water in winter.

Table 3.1: Dominant vegetation communities in monitored Gnangara mound wetlands, the number of wetlands supporting each community, the frequency at which each wetland supporting specific communities was visited/sampled, and the mean percentage individual taxa were sampled from each vegetation type (standard deviations are given in Appendix 2).

Vegetation community	*Typha orientalis*	*Baumea articulata*	*T. orientalis/B. articulata*	Mixed Cyperaceae	Mixed Cyperaceae with submerged herbaceous	Mixed Restionaceae	Mixed Cyperaceae and Restionaceae	*Lepidosperma longitudinale*	*Mixed Restionaceae/ Lepidosperma*	*B. articulata/ Lepidosperma*	*Melaleuca raphiophylla/ B. articulata*	*M. raphiophylla /* submerged herbaceous	*Astartea fascicularis*	Submerged herbaceous	Open water	Spring (*Lepidosperma* & willow roots in flowing water)	**Taxa prevalence**
No. of wetlands (n)	8	5	4	2	5	3	1	4	1	1	5	3	4	9	6	1	
Wetlands (no. of	Coogee (8)	Jandabup (1)	McNess south (13)	Jandabup (36)	Jandabup (15)	Gnangara (8)	Melaleuca Park (12)	Gnangara (2)	Gnangara (9)	Yonderup (15)	Goollelal (23)	Coogee (9)	Lexia 86 (7)	Coogee (7)	Gnangara (21)	McNess south (23)	
habitat visits)	Gnangara (13)	Gnangara (7)	Nowergup (8)	McNess south (23)	Mariginiup (14)	Jandabup (12)		McNess south (13)			Joondalup north (20)	Goollelal (23)	Lexia 186a (9)	Jandabup (8)	Jandabup (14)		
	Goollelal (23)	Joondalup north (20)	Pipidinny (26)		Nowergup (6)	Lexia 86 (14)		Yonderup (21)			Nowergup (13)	Joondalup south (16)	Lexia 186b (3)	Joondalup north (23)	Joondalup north (1)		
	Joondalup south (15)	Melaleuca Park (11)	Yonderup (12)		Pipidinny (29)			Pipidinny (6)			McNess south (25)		Melaleuca Park (20)	Joondaup south (21)	Mariginiup (5)		
	Mariginiup (16)	Yonderup (42)			Wilgarup (6)						Wilgarup (12)			Mariginiup (15)	Melaleuca Park (5)		
	McNess north (20)													McNess north (13)	Nowergup (19)		
	Nowergup (36)													Nowergup (4)			
	Pipidinny (8)													Pipidinny (17)			
														Yonderup (11)			
(Hydra)	1.3	0.48	2.08	8.3	2.7							1.45					**6**
NEMATODA	0.8	1.43	4.17			5.16		3.6		13.33	1.7	2.9	3.57	1			**10**
TURBELLARIA	18.2	2.96	20.83	8.5	10	2.78	8.3	12.6		13.33	16.9	7.87		10.5	6.8		**13**
TEMNOCEPHALIDEA							8.3						2.5			4.35	**3**
Hirudinea	25.4	14.93	12.26	10.5	8.1	8.33	8.3	13.5			25.2	34.85	8.39	17.9	5.8	17.39	**14**
Oligochaeta	39.5	24.27	52.56	38	41.2	10.71		28.2	11.11	53.33	28.9	32.84	9.58	45.1	22.5	43.48	**15**
Ancylidae	2.9	2.01		3.6	1.4			3.1		6.67	2.5	5.62		0.5	1.2		**10**
Lymnaeidae	4	3.53	4.17	7.1	6					13.33	2.9	3.7		2.3	1.2	13.04	**11**
Physidae	42.4	17.90	25.24		27.8			24.1		33.33	40.7	73.12		39.9	28.5	8.7	**11**
Planorbidae	10	7.06	27.00	13.3	20.9	11.11				6.67	9.5	28.16		9.3	6.2	4.35	**12**
Sphaeriidae	1.7	1.05	5.77	1.4	2.8									1.5	9.7	17.39	**8**
Arrenuridae	12.5	2.00	2.88	14.1	27.4	5.56		5.4			21.2	29.4		9.2	1.2		**11**
Eylaidae	2		5.05					4.2				2.08		8.4			**5**
Hydrachnidae	10.2	2.48	4.09	4.2	9.5	9.92				6.67	3.9	19.91	11.11	12			**11**
Hydrodromidae	4.5	3.29		2.8	4.7	2.78	25	1.9			1	5.79	7.78	2.4	3.3	4.35	**13**
Limnocharidae	0.3	3.00	0.96		3.3						5			10.6	0.8		**7**
Limnesiidae	23.1	15.50	13.06	2.8	13.7	4.76	58.3	6.7	11.11	13.33	10.9	41.44	17.32	19.7	1.6	26.09	**16**
Oribatida	4.7	12.41	1.92	9.7	12.4	17.26	8.3	8.3			3	2.9	1.25	6.3	1.7	8.7	**14**
Oxidae	3.5	2.38	6.25	6.5				7.4		26.67	4.1	5.15				47.83	**9**
Pionidae	35.5	13.96	16.51	10.5	33.2	2.78		16.8		13.33	19.9	48.04	6.07	28.1	4.3	21.74	**14**
Unidentified	12.4	5.96	15.30	9.3	11			2.4	11.11		11.1	14.47	2.78	19.1	8.8	17.39	**13**
Unioncolidae	5.5	16.54	18.91	22.3			100	11.7	11.11	46.67	11.5	8.33	23.85	2.8		17.39	**13**
Ceinidae	32.2	33.44	46.31	62	29.3	21.83		43.6		20	52.2	25.27		34.1	40.1	78.26	**13**
Perthidae		5.45											7.14				**2**
Amphisopidae	49.3	14.95	8.89	43.4	55.7	16.67		12.5			38.1	64.1		37.8	32.3	39.13	**12**
Janiridae	1.6											3.7		3.2		8.7	**4**
Palaemonidae	19.9	26.62	55.85	45.7	8.3			53		80	56.5	36.68	1.25	22.6	17.5	86.96	**13**
Parastacidae	2.7	20.69	3.85	5.6	14.8	15.48	83.3	9.2	11.11	13.33	3.4	1.45	37.56	5.9	20.6	43.48	**16**
Caenidae	4.9	12.13	9.05	19.2	10.7	8.33		13.9		26.67	6.5	10.14		5.3	12	43.48	**13**
Baetidae	9.9	20.82	25.16	30.3	10.8	11.11		28.2		53.33	10.7	8.33		10.3	7.2	43.48	**13**
COLLEMBOLA	1.3	0.95	5.05		4.3	12.3		1.2		6.67	4.8	7.24	10.1	3.6	6.7	4.35	**13**
Aeshnidae	40.6	38.98	26.12	36.1	37.5	29.37	16.7	49.8	33.33	13.33	15.8	32.47	10.28	28	10.7	8.7	**16**
Coenagrionidae	18.1	16.98	36.22	26.6	33.8	16.67	33.3	33.9	22.22	46.67	23.6	32.49	7.78	23.6	16.1	4.35	**16**
Cordulidae	15.7	17.61	14.34	15.3	16.6	12.1		5	33.33	26.67	4.7	15.46	6.35	17.3	12.1	30.43	**15**
Gomphidae	3.8	3.81	6.73	2.2	1.4			5.5			0.8			0.7			**8**
Lestidae	39.9	36.36	23.72	42.5	56.7	45.44	58.3	39	22.22	33.33	17.7	23.27	44.42	37.3	28.2	4.35	**16**
Libellulidae	11.4	14.28	22.20	30.7	37.4	23.61		9.5	11.11	6.67	4.9	16.09	1.25	26.4	48.9	13.04	**15**
Ecnomidae	5.2	17.41	5.21	6.9	2.7	10.71					2.6	2.08	3.75	13.1	5.3	8.7	**12**
Hydroptilidae	10.2	10.05	25.08	30.3	8.9	11.11		30.1		73.33	15.4	7.25		19.2	1.7	52.17	**13**
Leptoceridae	51.4	46.09	61.06	66.7	51.9	32.54	100	55.2		86.67	60.5	66.54	22.32	49.3	51	73.91	**15**
Corixidae	62.6	55.51	40.63	27.4	51.9	31.75	50	39.6	44.44	53.33	45.8	71.5	31.03	73.3	69	13.04	**16**
Hydrometridae	1	0.48		1.4	0.7	2.78	8.3						1.25	1.4		4.35	**9**
Mesoveliidae	8.1	11.46	7.29	17.5	18.9	14.88	25	7.1	11.11	13.33	5.1	11.4	5.28	0.7	6.7	21.74	**16**
Nepidae		4.35	2.08	6.9	4.8		8.3	1.9		6.67	3	5.79	6.07	2.8		4.35	**12**
Notonectidae	54.5	33.32	24.92	44.4	53.4	38.69	58.3	15.6	33.33	13.33	28.8	66.15	20.65	46.8	34.3	30.43	**16**
Naucoridae	0.8	1.05		5.6	1.3						1		1.25	2.8			**7**
Saldidae	0.8	0.48							11.11					3.6	5.3		**5**
Veliidae	9.1	17.82	6.97	9.1	11.1	12.7	41.7	22		13.33	2.9	7.7	40.85	2	13.3	13.04	**15**
Ceratopogonidae	30.4	27.59	23.32	21.2	23.5	49.6		43	77.78	46.67	11	6.43	13.15	25.4	12.7	21.74	**15**
Chaoborinae		3.64	22.92				8.3				0	0	2.5				**6**
Chironominae	86.7	66.47	60.10	71.7	64.9	51.39	58.3	72.2	55.56	86.67	66.8	92.76	46.96	85.2	68.4	65.22	**16**
Culicidae	19.7	18.62	17.79	6.9	42.6	28.77	41.7	35.9	22.22		24.8	18.52	47.18	21.2	15.8	17.39	**15**
Empididae	0.8			2.2							0.8	0				13.04	**5**
Ephydridae	2.2		0.96		3.3			1.2			0	0		1.6			**7**
Orthocladiinae	28.4	27.29	32.29	27.1	17	19.05	83.3	39.5	11.11	46.67	27.5	20.55	21.11	24.4	25.2	39.13	**16**
Simulidae																26.09	**1**
Stratiomyidae	12.6	7.90	12.10	1.4	13.4	2.78	0	9.7		6.67	8.1	20.27		6.9	4.2	8.7	**14**
Tabanidae	0.6	1.95	6.17		4	7.54	0	1.9			2.8	0		1.1	0.9	13.04	**12**
Tanypodinae	59.5	54.57	59.78	52.8	51.5	45.04	33.3	55.3	44.44	66.67	41.6	70.41	30.02	67.9	65.9	69.57	**16**
Tipulidae		3.96			3.3					6.67	1.9	0		0.5		4.35	**7**
Pyralidae	6.4	4.25	3.13	1.4	2.9		8.3	1.9	11.11		6.9	7.24	1.25	7.9	3.3		**13**
Carabidae						4.17					1.7	0		0.7			**4**
Chyrsomelidae		1.00		4.2	1.4						1	2.08		0.9	1.2		**7**
Curculionidae	3.1	9.36	3.13	6.9	3.3	19.25	25	5	11.11				16.9	4.4	4.5	4.35	**13**
Dytiscidae	65.9	71.59	52.48	51.3	70.7	78.17	91.7	85.9	88.89	46.67	55.9	63.22	83.27	66.5	74.9	43.48	**16**
Haliplidae	3.4	3.82		1.4	5.6	2.78		4.2			1.7	2.08		9			**9**
Hydraenidae	1.6	2.77	1.92	1.4	4	2.78	8.3	2.4			0.8	3.7	1.25	4.2		4.35	**13**
Hydrophilidae	54.5	50.08	37.50	37.1	49.5	63.49	41.7	55	77.78	33.33	26.4	40.98	40.16	51.8	38.4	26.09	**16**
Limnichidae	1.7	14.31		11.1	1.4	26.39	25		44.44		0.8		6.25		6.7		**10**
Ptilodactilidae	0.6	2.86			6.2	4.17					3.3						**5**
Scirtidae	7.6	23.02		15.3	38.6	7.54	58.3	1.9	33.33		20	2.9	17.6	2.7	6.7	4.35	**14**
Staphylinidae	1.6	1.82	2.08		6.7		8.3				1.7	2.08	1.25				**8**
Unidentified		1.82		3.6							1.7			1.4		8.7	**5**
Calanoida	26.1	35.47	33.33	47	40.9	26.98	91.7	30.3		53.33	28.7	40.94	56.17	38.7	48.8	13.04	**15**
Cyclopoida	55.6	47.93	34.29	35.4	38.7	30.16	50	43.1	22.22	53.33	38.5	48.18	48.17	55.6	44.2	65.22	**16**
Harpacticoida	3.6	2.96	0.96	6.3	3.4					13.33	2.5	28.82		2.2	0.9	8.7	**11**
Cyprididae	64.8	51.56	71.63	65	70.4	42.06	8.3	54.3	11.11	80	58.2	81.8	30.85	86.5	49.5	47.83	**16**
Gomphodellidae	0.6	0.48	2.08					3.6			1.8						**5**
Notodromadidae	11.1	1.95	5.77		19.1			21		13.33	11	1.45		15.9	0.8		**10**
Unidentified Ostracoda	0.8		9.62	8.7							4					8.7	**5**
Chydoridae	37.1	32.93	32.45	47.3	33.5	27.38	8.3	27.9		53.33	22.8	46.78	13.57	40.5	10.5	43.48	**15**
Daphniidae	40.6	20.92	13.86	41.4	34.7	21.83	50	19.9		20	18.3	47.58	25.48	46.5	18.1	8.7	**15**
Macrothricidae	6.8	29.97	5.93	27.4	15.1	32.14	8.3	15.6	55.56	6.67	5.5	3.7	14.58	3.9	19.5	13.04	**16**
Moinidae	0.3			2.8	1.3						0.8			2.9		4.35	**6**
Habitat richness	**75**	**75**	**65**	**65**	**69**	**52**	**39**	**58**	**28**	**46**	**74**	**68**	**49**	**72**	**57**	**61**	

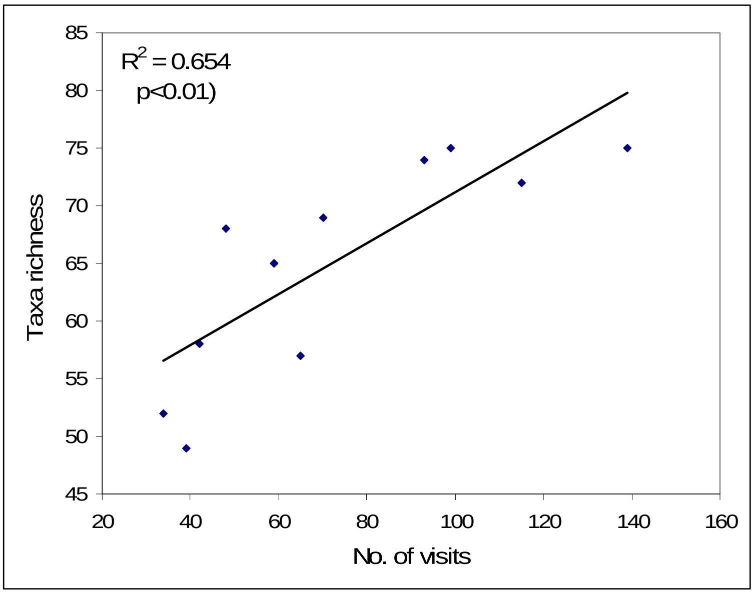


Figure 3.1: Invertebrate taxa richness shown as a function of the total number of visits to individual habitat types (aquatic vegetation communities).

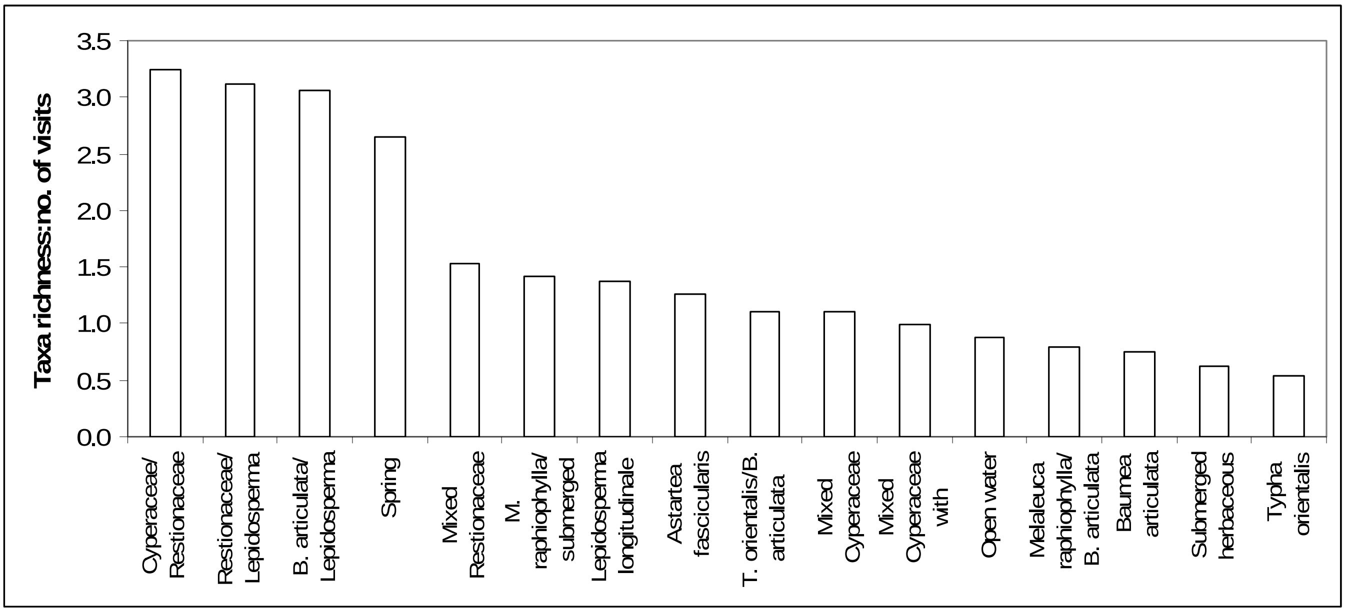


Figure 3.2: Ratio of invertebrate taxa richness/number of visits per habitat type in each habitat type.

sampled (largely <10% of the time). The following taxa were found in all vegetation communities: Limnesiidae, Parastacidae, Aeshnidae, Coenagrionidae, Lestidae, Corixidae, Notonectidae, Mesoveliidae, Orthocladinae, Chironominae, Tanypodinae, Dytiscidae, Hydrophilidae, Cyclopoida, Cyprididae and Macrothricidae. These were not only found in all habitats but were also generally sampled comparatively frequently (**Table 3.1**). The dendrogram in **Figure 3.3** summarizes above findings, and gives some additional information. It shows that in terms of aquatic invertebrate occurrence frequency, the group '*Astartea*', 'Mixed Cyperaceae/Restionaceae' and 'Restionaceae/*Lepidosperma*' (= group 1) display only ~68% similarity with all other vegetation communities, making this group an outlier. SIMPER analysis (Primer v. 5.1) suggests that the main basis for the grouping is similarities in mean percentage of occurrence of Dytiscidae (which had very high occurrences [84 -92%] in these vegetation communities), Chironominae, Lestidae, Cyclopoida, Corixidae and Hydrophilidae. Other communalities were the conspicuous absence of Amphisopidae, Ceinidae, Caenidae and Baetidae. These latter communalities were the main reasons these vegetation communities were outliers.

'*Baumea/Lepidosperma*' and the Loch McNess 'Spring' (= Group 4) can be considered to be the next outlier group, displaying ~ 78% similarity with the rest of the vegetation communities. This group is primarily characterized by similarities in occurrences of Palaemonidae (percentage of occurrence 80 - 87%), Leptoceridae (percentage of occurrence 74 -87%), chironomids, Cyclopoida, Hydroptilidae and Cyprididae. Important contributing factors for the separation of this group is the absence of the common mite Arrenuridae, and the comparatively frequent occurrence of the relatively uncommon mite Oxidae. The remaining habitats display 79% similarity. The most similar group (= Group 2), displaying just under 90% similarity, contains the most frequently visited and richest habitat types (as discussed above): 'submerged herbaceous', '*Typha*', 'mixed Cyperaceae with submerged herbaceous', '*Baumea*' and '*Melaleuca/Baumea'*. The group is characterized by the presence and similar occurrence frequencies of Chironomidae, Dytiscidae, Cyprididae, Corixidae, Leptoceridae, Cyclopoida, Hydrophilidae, Notonectidae and Oligochaeta. The group comprising '*Melaleuca*/submerged herbaceous', 'Mixed Cyperaceae', '*Lepidosperma*', '*Typha/B. articulata'*, 'Open water' and 'Mixed Restionaceae' (= Group 3) is very similar to Group 2 (only 16% dissimilarity). What mainly separates the two groups are higher occurrence frequencies of Physidae, Notodromadidae, Limnocharidae, and Scirtidae in Group 2, higher occurrence frequencies of Limnichidae, Unioncoloididae and Oxidae in Group 3, and the absence of Tipulidae in Group 3.

A classification of invertebrates based on habitat associations was also performed but revealed little additional information. Compared to terrestrial systems, habitat/invertebrate faunal associations in freshwater aquatic systems are difficult to assess because other factors, in particular water quality and hydrological regime often override habitat factors. Given non-habitat requirements are met, certain invertebrates do have particular habitat (as defined by dominant vegetation communities) preferences (which are well-known), e.g. Leptocerid trichopterans require macrophyte stalks and woody sticks for their cases, parasitic taxa require the presence of host animals, etc. However most of the aquatic vegetation communities in the wetlands sampled would provide these necessities. Certainly invertebrate assemblages in lotic (i.e. flowing) and lentic (i.e. non-flowing) are different, however we are dealing here with only lentic systems (apart from the spring site at Loch McNess which is slowly flowing), hence the large similarities in aquatic invertebrate composition.

A classification of wetlands based on the same invertebrate variables as above (i.e. mean percent occurrence) revealed separation between the Bassendean and Spearwood wetlands (**Figure 3.4**). This again highlights the influence of non-vegetation factors. In the SIMPER analysis (which was carried out in order to aid interpretation of the groupings), Lake Jandabup (whose lakebed lies half on Spearwood and half on Bassendean soils) was classed as a Bassendean wetland, however, the dendrogram in **Figure 3.4** groups it with the Spearwood wetlands. This suggests that the Jandabup invertebrate fauna is more characteristic of Spearwood than Bassendean wetlands located more to the east-northeast of the mound. The main contributing factors for the separation are that Physidae, Palaemonidae, Amphisopidae, Planorbidae, Ceinidae and Arrenuridae occur more frequently in the Spearwood wetlands, and Curculionidae, Macrothricidae, Parastacidae and Veliidae occur more frequently in Bassendean wetlands. Bassendean wetlands tend to be coloured and base-poor, usually with low pH. It is therefore reasonable that taxa with calcareous shells or carapace would be comparatively rarer in these wetlands (Sommer and Horwitz subm. 2008). Macrothricidae are acid-tolerant cladocerans and good indicators of acidification (Sommer and Horwitz 2001 & 2008). Crayfish of the Parastacidae family (in spite of having a calcareous carapace) appear to be acid-tolerant as they occur in many acidic environments (particularly in coloured wetlands) in the southwest region of WA; however the exact mechanisms responsible have not been investigated.

The way the Spearwood wetlands are grouped in **Figure 3.4** is interesting because it sheds some light onto non-vegetation environmental factors that influence invertebrate community structure. For example, the group comprising Jandabup and Mariginiup (85.3% similarity), both wetlands containing diatomaceous sediments and similar hydrological regime (when the latter is not being artificially supplemented), is characterized by high occurrence frequencies of Dytiscidae, Cyprididae, Corixidae and Hydrophilidae. The main differences between the two wetlands and the other Spearwood wetlands are the lack of palaemonid shrimps and much lower occurrence of Physidae snails in the former. Another major difference is the much more frequent occurrence of Macrothricidae in Jandabup and Mariginiup than in the other Spearwood wetlands. This is most

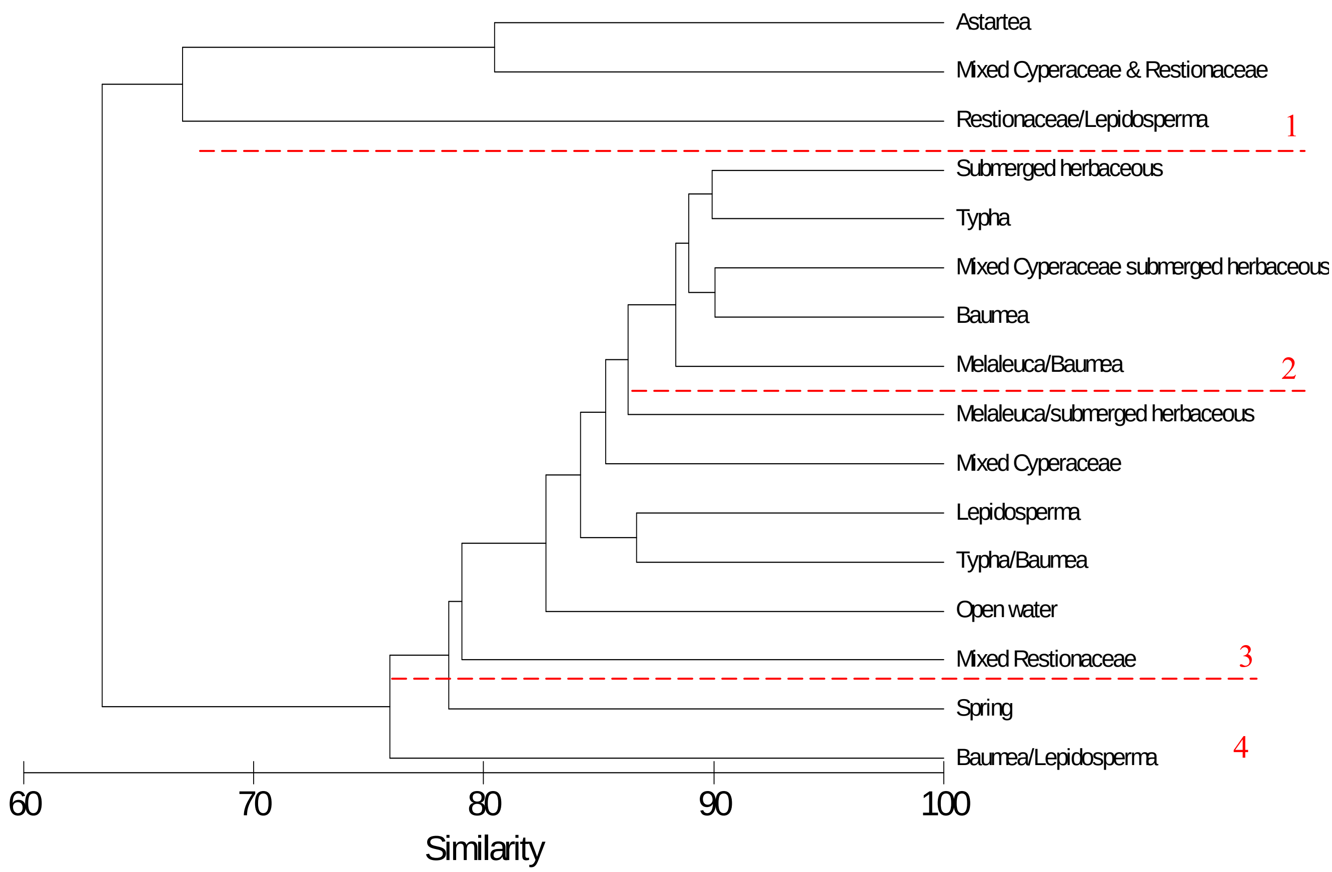


Figure 3.3: Dendrogram based on Bray and Curtis similarities of wetland vegetation communities characterized by invertebrate mean percentage of occurrence (see text). The data were arcsine and log10+1

transformed prior to classification. Rare taxa (occurring <5 habitat types) were omitted from the analysis. Dashed lines mark the cut levels for four groups. Group characteristics are described in the text.

likely a reflection of the fact that the two wetlands suffer from episodic acidification events. The group comprising Nowergup, McNess north, Yonderup, McNess south and Goollelal display 84% similarity in terms of invertebrate community structure. Apart from McNess north, these are all permanent wetlands with comparatively deep water and a layer of suspended detrital floc. They are characterized mainly by high occurrence frequencies of chironomid larvae and oligochaete worms. Both of these taxa are known to feed on detrital material, including bacteria found therein (Williams 1980) The group comprising Pipidinny and Joondalup (north and south) also support suspended detrital floc, however this is more of a calcareous floc, and these wetlands are shallower and much more seasonal than the previous group. These wetlands are also characterized by high occurrences of chironomids, however also by high occurrences of snails (Physidae) and Corixidae. Coogee and Wilgarup are outliers amongst the Spearwood wetlands mainly because they no longer contain surface water (and hence were visited less frequently, and often when water levels and water chemistry was extreme). The main reason the two Lexia 186 sites separate from the other Bassendean wetlands is that the former lack Aeshnidae, Leptoceridae and Limnesiidae, taxa which were frequently sampled from the latter. Leptoceridae, e.g., were sampled from Melaleuca Park during every visit. It would appear then, that *Astartea* does not provide the building materials required for leptocerid cases. On the other hand Parastacidae (*Cherax quinquecarinatus*) were more frequently sampled from the Lexia 186 wetlands. These differences may be partially due to the fact Lexia 186a & b were sampled less often than the other wetlands (see discussion above).

Finally, the monitored Gnangara mound wetlands were classified based on the presence/absence of

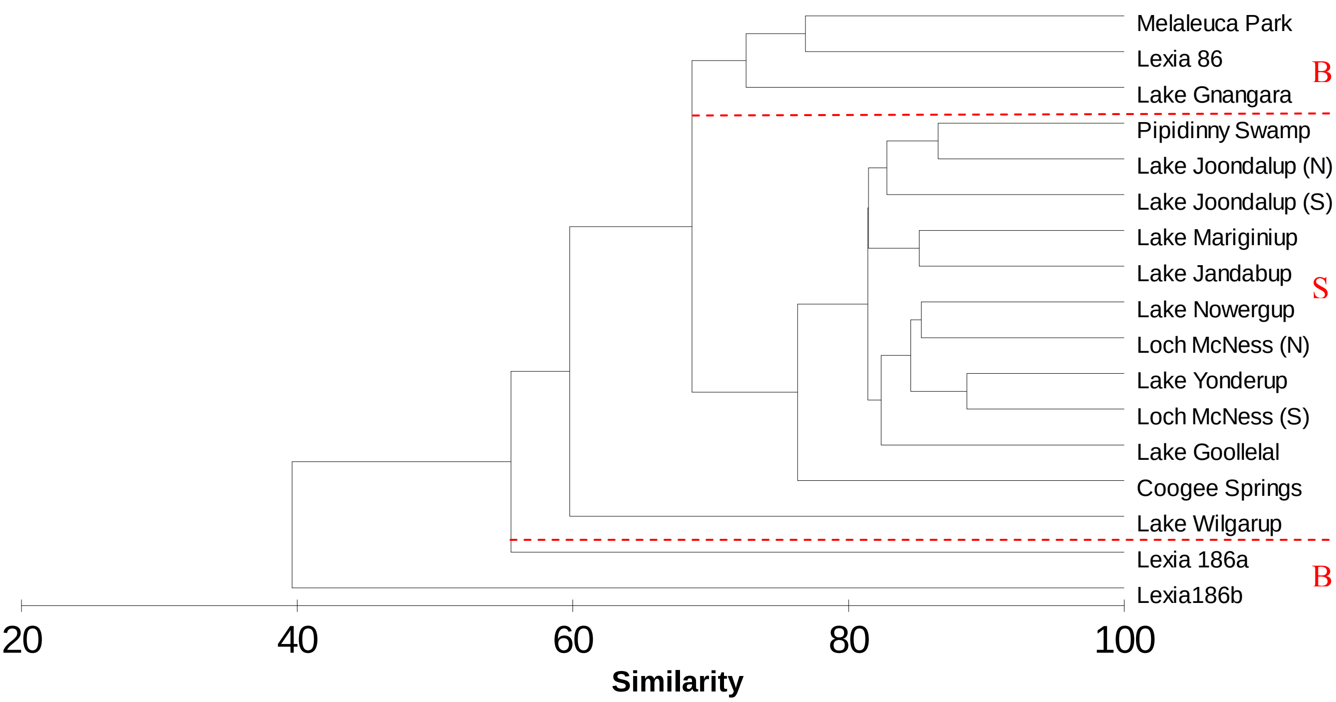


Figure 3.4: Dendrogram based on Bray and Curtis similarities of monitored Gnangara mound wetlands characterized by invertebrate mean percentage of occurrence (see text). The data were arcsine and $\log_{10}(x+1)$ transformed prior to classification. Rare taxa (occurring in <5 wetlands) were omitted from the analysis.

Dashed lines mark the cut levels separating Bassendean (B) and Spearwood (S) wetlands. Group characteristics are described in the text.

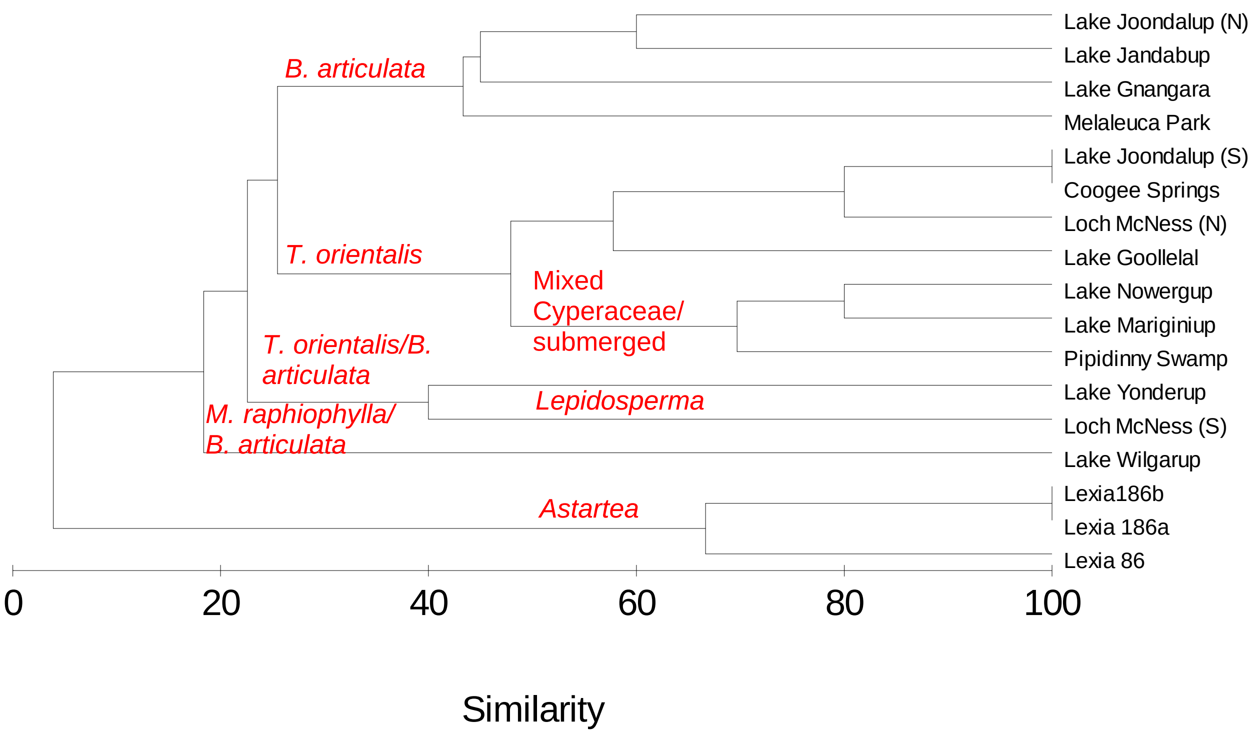


Figure 3.5: Dendrogram based on Bray and Curtis similarities of monitored Gnangara mound wetlands characterized dominant vegetation communities (presence/absence data).

the sixteen identified dominant vegetation communities (**Figure 3.5**). Apart from the Lexia wetlands, this classification does not correspond well with the ordination of wetlands based on invertebrates (**Figure 3.4**). This is primarily because individual wetlands support a number of vegetation communities, and again demonstrates the importance of non-vegetation factors in determining invertebrate community structure.

In summary, sixteen dominant vegetation communities were identified in the monitored Gnangara mound wetlands. The two most common ones were '*Typha orientalis*' and 'submerged herabaceous'. The least common ones in the monitoring program were 'Mixed Cyperaceae/Restionaceae', '*Lepidosperma*/Restionceae', and the spring at Loch McNess. Over thirteen years of sampling '*T. orientalis*, *B. articulata*' and '*M. raphiophylla/B. articulata*' supported the highest number of invertebrate taxa (each supporting ~90% of all of the taxa sampled). 'Mixed Restionaceae/*Lepidosperma*', 'Mixed Cyperaceae/Restionaceae' and '*B.articulata/Lepidosperma*' had the lowest taxa richness. In considering the significance of these statistics, it must be acknowledged that taxa richness includes introduced species (and other not necessarily 'desirable' species). Furthermore, richness data were found to be significantly correlated with sampling effort, and therefore it is not possible to determine, for Gnangara mound wetlands, which habitat type supports the greatest diversity of aquatic invertebrates. Care should be taken not to base the conservation value of habitats or sites solely on taxa, or species richness.

Four taxa showed some degree of habitat-specificity: Simuliidae (spring at Loch McNess), Perthidae (*Astartea* and *B. articulata* communities at Lexia 86 and Melaleuca Park EPP173), Carabidae ('Mixed Restionaceae', '*Melaleuca*/*B. articulata'* and 'submerged herbaceous'); and Temnocephalidea (sampled from the '*Astartea'* and 'Mixed Cyperaceae/Restionaceae' communities at Melaleuca Park, and from the spring at Loch McNess). Limnesiidae, Parastacidae, Aeshnidae, Coenagrionidae, Lestidae, Corixidae, Notonectidae, Mesoveliidae, Orthocladinae, Chironominae, Tanypodinae, Dytiscidae, Hydrophilidae, Cyclopoida, Cyprididae and Macrothricidae were all entirely habitat-inspecific; these were all sampled frequently from every dominant vegetation community.

Pattern analyses suggest that invertebrate assemblages of most of the vegetation types were very similar (at least 79% similarity). The exceptions are, on the one hand, the '*Astartea*' and 'Cyperaceae & Restionaceae' communites at Melaleuca Park and the Lexia wetlands, and on the other, the Loch McNess spring and the '*Baumea/Lepidosperma*' community at Lake Yonderup. Melaleuca Park and the Lexia wetlands were also outliers when wetlands were classified based on invertebrate occurrence frequencies. This classification clearly distinguished between Bassendean and Spearwood wetlands, the exception being Lake Jandabup whose invertebrate community was more similar to a Spearwood, than a Bassendean community. In general, acid-tolerant invertebrates (plus *Cherax quinquecarinatus)* were more prevalent in the Bassendean wetlands, while animals with calcareous shells or carapace (Palaemonidae being the characteristic example) were more prevalent in the alkaline Spearwood wetlands. Palaemonid shrimps were however absent from Lakes Jandabup and Mariginiup, most likely because these two wetlands experience episodic acidification.

The emerging overall pattern is that the eastern Bassendean wetlands (i.e. Melaleuca Park and the Lexia wetlands) formed outliers both in terms of vegetation communities as well as in invertebrate assemblages. The fact that these wetlands were also 'under-sampled' compared to the other monitored wetlands suggests that management efforts should be intensified in these areas in order to be able to properly compare their biodiversity values with the more intensively monitored wetlands. Unfortunately it is also these eastern Gnangara mound wetlands that are suffering most from declining water levels.

4. Synthesis and review of the status of freshwater fish on the Gnangara Mound, their values and threats (Objective 3)

Another interest of the GSS is the status of (freshwater) fish biodiversity in Gnangara Mound wetlands (including Gin Gin Brook, Ellenbrook, but not Swan River). Of a total of ten native, exclusively freshwater, fish species found in south-west Western Australia, only six species from four families have been sampled from the northern Swan Coastal Plain (SCP) in recent surveys: *Tandanus bostocki* (Plotosidae); *Galaxias occidentalis*, *Galaxiella nigrostriata*, *Galaxiella munda* (Galaxiidae), *Bostockia porosa* (Percichthydae) and *Edelia vittata* (Nannopercidae) (Balla and Davis 1993; Bamford *et al.* 1998; Knott *et al.* 2002; Morgan 2008; Morgan *et al.* 2000; Morgan *et al.* 1996; Morgan *et al.* 1998). During these surveys, *Geotria australis* (Geotriidae) and *Nannatherina balstoni* (Nannopercidae) were notably absent from areas where they had previously been known to occur. Whilst *N. balstoni* is believed to be regionally extinct (ie. on the SCP), it remains unclear as yet whether *G. australis* has also been lost to the region. Several of those species still occurring on the SCP exist in disjunct relict populations in the Moore River Catchment (*G. munda, G. occidentalis*) (Morgan 2008; Morgan *et al*. 2000; Morgan *et al.* 1996; Morgan *et al.* 1998), at Melaleuca Park (*G. nigrostriata*) (Knott *et al.* 2002) and Bennett Brook (*G. occidentalis*) (Bamford *et al.* 1998; Bennet Brook Baseline Study of Flora and Fauna 1999). Three species with marine affiliations *Leptatherina wallacei* (Atherinidae), *Pseudogobius olorum* and *Afurcagobius suppositus* (Gobidae) also occur in these habitats (Morgan *et al.* 1996; Morgan *et al.* 1998), as do several introduced species including *Carassius auratus, Cyprinus carpio* (Cyprinidae) (Bamford *et al.* 1998; Bennet Brook Baseline Study of Flora and Fauna 1999), *Gambusia holbrooki* (Pociliidae) (Bamford *et al*. 1998; Bennet Brook Baseline Study of Flora and Fauna 1999; Morgan 2008; Morgan *et al.* 2000; Morgan et al. 1996; Morgan *et al.* 1998) and more recently *Geophagus brasiliensis* (Perciformes) (M. de Graaf, personal communication, May 21, 2008).

Whilst the freshwater invertebrate and fish fauna of south-west Western Australia have been described by Bunn and Davies (1990) as being depauperate compared to the fauna of south-eastern Australia, Williams et al. (1991) hypothesise that faunal assemblages of the region may be more resistant and resilient to changes in salinity and/or represented by halo-tolerant remnants of earlier, more diverse fauna. More recently, Horwitz (1997) pointed out that as Bunn and Davies' work is based on flowing waters and invertebrate fauna, and in view of the work by Williams *et al.* (1991), uncertainty arises as to the role of salinity, flowing-versus non-flowing nature of freshwater ecosystems, localised levels of primary productivity and fish fauna versus invertebrate fauna. Given the increasing exploitation of resources and escalating threatening processes that occur on the SCP, a case for high priority application of the systematic treatment of freshwater fishes of the region can be made, especially if conservation of our surviving fish species is a priority. Comprehensive fish/invertebrate surveys of most waterways across Western Australia will be conducted over the next few years under the FARWH (Framework for the Assessment of River and Wetland Health) project and should result in relatively detailed distribution maps of freshwater fauna (T. Storer, personal communication, May 20, 2008). It is not clear however, if jurisdictional issues will be ironed out in the process.

4.1 Methods

A desktop review of the literature (historic and current) was undertaken using the names of wetlands and watercourses in the study area as well as common and species names of endemic and exotic freshwater fish species as key words. These terms were identified by preliminary literature review. Environmental reports, species management and recovery plans, river, wetland and area management plans, theses and journal articles available through the library services of Edith Cowan University, Murdoch University, University of Western Australia, the West Australian State Library and the Library of the Western Australian Museum were accessed. On-line search engines of government and non-government organisations reviewed include those accessible on the websites of: the Department of Environment and Conservation; Australian Government Environment Portal; Department of Environment and Heritage; Department of Fisheries Western Australia; Commonwealth Scientific and Industrial Research Organisation (CSIRO); Museum of Western Australia as well departments of Zoology, Ecology and Biological Sciences of west Australian universities and associated professionals. On-line database search engines used include: Google Scholar, MetaQuest Research Portal and alternative database access (inDOOR). Databases used include: Blackwell Synergy, Expanded Academic ASAP and Science Direct including journals published by Elsevier Science, Scirus, Academic Research Library, ProQuest and SpringerLink,. The SFX Article Locator was used to find the full text of a known article reference that could not be otherwise found.

In relation to distribution, several endemic freshwater species include extent and/or disjunct outlier populations found in the upper Moore River catchment, directly north of the study area. Hence, the literature and data available and pertinent to this report is largely inclusive of the upper Moore River catchment. Considering the natural ranges of these endemics include these northern populations, it has been ascertained that in order to adequately address the values and threats of these endemic species in the context of the Gnangara Sustainability Strategy, these populations are entirely relevant. As such, they have been included in this report.

4.2 Results and discussion

4.2.1 Endemic Species

***Galaxiella nigrostriata (*Black-striped Minnow)**

Galaxiella nigrostriata is a relatively common, demersal, sub-tropical freshwater species characterized by a 1 year life cycle. It occurs in permanent and ephemeral typically acidic (pH – 6) (Morgan *et al.* 1996) and darkly tannin-stained swamps, ditches and pools of peat flats (Allen *et al.* 2002). With average total lengths of 44mm (m) and 48mm (f) this tiny multiple spawner breeds mainly in winter and early spring with most individuals dying soon after spawning (Morgan 1999). *G. nigrostriata* takes its prey mainly from the water column and surface, with microcrustacea, dipterans and rotifers found to form the bulk of this species' diet (Pen *et al.* 1993). *G. nigrostriata* is able to aestivate in damp bottom sediments in order to survive dry seasons and drought conditions (Pusey and Edward 1990).

Endemic to coastal south-western Australia, *G. nigrostria's* distribution is restricted between Augusta and Albany, except for disjunct populations discovered at Bunbury and Gingin (Allen cited in Morgan *et al.* 1996) and more recently at Melaleuca Park (EPP 173), Ellen Brook (Knott *et al.* 2002) (**Table 4.1**). Habitat alteration due to urban expansion and rural development, groundwater extraction and highway construction pose the largest threat to the *G. nigrostriata* population of EPP 173 (Smith *et al.* 2002). Morgan *et al.* (1996) have also identified introduced species as a threat to this species. *C. carpio, G. holbrooki* and *Geophagus sp*. may pose a serious threat to the population at EPP 173.

Unable to tolerate water temperatures over 26°C, preferring temperatures of 14.5°C, the survival of the small population at Melaleuca Park EPP173 is thought to be dependent on strong thermal stratification occurring during the summer months (Smith *et al.* 2002), therefore synergistic effects of increased groundwater extraction and increased temperatures on the back of climate change pose an added threat.

Galaxiella nigrostriata is not listed under the Wildlife Conservation Act 1950 (Specially Protected Fauna) or EPBC Act 1999 (EPBC Act List of Threatened Fauna). It is listed as lower risk, near threatened (LRnt) on the IUCN Redlist (IUCN, 2007)

Galaxiella munda (Mud Minnow)

This bentho-pelagic, subtropical, scaleless species has an average maximum length of 58mm, is found in a wide variety habitats including streams, lakes, ephemeral and permanent pools and slow-flowing streams usually associated with peat flats (Morgan 1999), usually tannin stained and acidic (pH 3.0-6.0) (Allen *et al.* 2002). Whilst described by Sarty and Allen (1978) as being capable of aestivating during drought, Pusey and Edward (1990) argue that rather than aestivating, the mud minnow moves out of temporary waters before they dry out. *G. munda* is a multiple spawner depositing clutches of eggs amongst flooded vegetation from July to October and dying a few months following spawning (Pen *et al*. 1991). *G. munda* preys predominantly on terrestrial fauna at the surface, cladocerans and copepods in the water column and dipterans at the benthos (Pen *et al.* 1991).

Galaxiella munda is endemic to the south-west of Western Australia, distributed from Margaret River in the west to Albany in the east with a disjunct relict population in the Moore River Catchment (Morgan *et al.* 1998) (**Table 4.1**).

As for *G. nigostriata*, it is believed that habitat alteration due to urban expansion and rural development are the most likely causes of the large distances between the main populations of *G. munda* between Margaret River and Albany and the disjunct Gingin population (Morgan *et al.* 1996). Believed to be rare throughout most of it's distribution, habitat alteration including dam construction, groundwater extraction, agriculture and forestry practices, resultant altered flow regimes and associated salinisatation, siltation and eutrophication plus competition and predation by the introduced *G. holbrooki* are the major threats to *G. munda* (Gill and Morgan 1997).

Conservation Status: Listed in Schedule 1 of the Western Australian Wildlife Conservation Act 1950 as wildlife that is rare or likely to become extinct, in need of special protection (Minister for the Environment 2008). Whilst *G. munda* is not listed under the EPBC Act 1999 (EPBC Act List of Threatened Fauna) the species is listed as lower risk, near threatened (LRnt) on the IUCN Redlist (IUCN 2007).

Galaxias occidentalis (Western Minnow)

Found in a wide variety of habitats, including streams, lakes, ephemeral and permanent pools displaying a preference for fast flowing water, *Galaxias occidentalis* is a small, scaleless species with a maximum length of approximately 19 cm (Allen 1989). *G. occidentalis* feeds during both the day and night (Morgan *et al.* 1996), preys primarily on macro-invertebrates and spawns late June to late September after migrating to upstream tributaries (Morgan 1999). Reaching maturity at 1 year with similar spawning habits to *G. munda* (ie. spawning once per year), and rarely surviving beyond the second year (Morgan *et al.* 1996). *G. occidentalis* is able to tolerate brackish conditions (Pen and Potter 1991a) and is widely known as one the most abundant freshwater species of south-west Western Australia (McDowall and Frankenberg 1981; Pen and Potter 1991a) along with *Edelia Vitatta*.

G. occidentalis' range extends from Winchester, 250km north of Perth to Waychinnicup Creek, 80km east of Albany and so widely distributed throughout the south-west it is found in all catchments within its range with the exception of Lake Quitjup (Morgan *et al.* 1996). On the Swan Coastal Plain *G. occidentalis* occurs in the Moore River catchment and at Bennett Brook (**Table 4.1**).

As for all the freshwater fishes of south-western Australia, habitat alteration and introduced species pose the greatest threat to *G. occidentalis*. Morgan *et al.* (1996) cite observations of *G. Holbrooki* demonstrating aggressive behavior towards *G. occidentalis,* pinpointing areas of the south-west where populations of this species become absent or rare where *G. Holbrooki* is abundant (e.g. Muir Watershed).

G. occidentalis is not listed under the Western Australian Wildlife Conservation Act 1950 as fauna needing special protection, the EPBC Act 1999 (EPBC Act List of Threatened Fauna) or IUCN Redlist (IUCN 2007).

*Tandanus bostocki (*Freshwater Cobbler)

Tandanus bostocki is a dermersal freshwater catfish with a life span of nine years or longer (Morgan *et al*. 1996) and reaching a maximum size of approximately 50 cm TL (Sarti and Allen 1978). *T. bostocki* is tolerant to brackish conditions, occuring in ponds, slow-flowing streams and reservoirs (Morgan *et al.* 1996). Insect larvae, freshwater crayfish, shrimp, molluscs and fish provide much of the diet of this species (Morgan *et al.* 1996). Breeding occurs during late spring & summer from the fourth year of life. Females deposit their spawn in a circular nest comprising a shallow depression lined with sticks or stones, to be guarded and fanned by the male until hatched (Allen 1982). *T. bostocki* is south-west Western Australia's largest and only endemic species sought by recreational anglers (Morgan *et al*. 1996).

Endemic to south-west Western Australia *T. bostocki*'s range extends from Moore River to Frankland River and is common in the Moore River catchment (Allen 1982).Habitat alteration is considered a possible threat to some populations (Morgan *et al.* 1996). *T. bostocki* is not listed under not listed under the Western Australian Wildlife Conservation Act 1950 as fauna needing special protection, the EPBC Act 1999 (EPBC Act List of Threatened Fauna) or IUCN Redlist (IUCN 2007).

Bostockia porosa (Nightfish)

Found in a wide variety of habitats including streams, lakes, ephemeral and permanent pools (Morgan 1999), *Bostockia porosa* is a nocturnal fish with a preference for cool running water and is typically found under ledges and rocks or amongst inundated vegetation during the day (Allen 1982). Males usually mature in the first year and females during their second year with spawning occurring late August and September (Sarti and Allen 1978). The life cycle of the species typically lasts for 2 years. *B. porosa* grows to a maximum size of ≈ 15 cm TL (Allen *et al.* 2002). Dipteran larvae form a large portion of the diet of all size classes whilst odonatan nympths, gastropods and decapods become increasingly important as size increases (Morgan *et al.* 1996).

Endemic to south-west Western Australia and distributed between Moore River and Albany, *B. porosa* is one of the most common and abundant endemic freshwater species of the region

(Morgan *et al*. 1996). Habitat alteration and introduced species including *C. carpio, G. holbrooki* and *Geophagus sp*. may pose threats to some populations. For instance in studies of the lower south-west *B. porosa* is listed as rare or uncommon in waterbodies where *G. holbrooki* persist in large numbers (Morgan *et al*. 1996).

***Edelia vittata* (Western Pygmy Perch)**

E. vittata is a relatively small species (maximum length ≈ 6.8cm) occurring in a wide variety of freshwater habitats including streams, lakes, ephemeral and permanent pools (Morgan 1999). It is usually found in fresh or slightly brackish clear or tannin stained water amongst macrophytes, debris and fringing vegetation (Allen *et al*. 2002). Reaching sexual maturity in the first year with a maximum life expectancy of 5 years, *E. vittata* is a multiple spawner that moves far up tributaries in early winter to spawn between mid-winter and late spring, maximising dispersal of offspring in the catchment (Allen *et al*. 2002). With the entire spring growth season spent reaching maximum size *E. vittata* are benefited with increased odds for survival over the harsh summer/autumn that follows (Balla 1994). Juvenile *E. vittata* feed on small dipteran larvae and crustacea with adults preying upon trichoptera larvae and insects (Sarti and Allen 1978). *E. vittata* has a tendency to shift prey requirements, giving the species early access to a wider variety of prey choices when summering in permanent pools, thereby reducing niche overlap and competition with other species (Pusey and Edward 1990).

Endemic to south-west Western Australia *E. vittata* is distributed between Arrowsmith River, 300km north of Perth and Phillips River, East of Albany. In the study area *E. vitatta* occurs in the Moore River catchment, Yellagonga wetlands, Mussel Pool and throughout Bennett Brook (**Table 4.1**).

Still considered relatively common and abundant, there appears to be no immediate concern for this species (Morgan *et al.* 1996; Morgan *et al.* 1998), however as for all the small freshwater fishes of the region, habitat alteration and introduced species may pose a threat to particular populations. For instance, Morgan *et al*. (1996) discuss the relative rarity of *E. vittata* in lakes of the Swan Coastal Plain where *G. holbrooki* is abundant compared to lakes of the south-west (e.g. Lakes Wilson and Smith) where *E. vittata* is abundant and *G. holbrooki* is absent. In a survey of the south-west undertaken by Morgan *et al*. (1996), only one single lake could be found where stable and abundant populations of both *E. vittata* and *G. holbrooki* could be found together. In this instance, although *G. holbrooki* was observed attacking *E. vittata*, and *E. vittata* carried excessive caudal fin damage in comparisons to nearby populations where *G. holbrooki* is less abundant, the presence of suitable cover in the form of macrophytes and algae appeared to be a critical component of the shared habitat, providing essential respite and enabling the resident population of *E. vittata* to persist.

4.2.2 Introduced Species

***Carassius auratus* (Goldfish)**

Carassius auratus is an extremely hardy species with a maximum size of approximately 36cm TL and 1.5kg that is able to tolerate turbid conditions, extreme temperatures (Sarti and Allen 1978) and low oxygen concentrations. It has a preference for slow moving or still water (Allen *et al.* 2002). Like many successful invaders *C. auratus* is an omnivore, consuming detritus, vegetation, small invertebrates and fishes (Sarti and Allen 1978). Breeding occurs during spring and summer when temperatures exceed 16°C. Whilst *C. auratus* is a large species in comparison to other fishes of the region, it is both a poor angling fish and poor eating.

Native to eastern Asia, Japan and China and introduced to Australia in the 1860's *C. auratus* has a worldwide distribution (Allen *et al.* 2002). In Australia *C. auratus* is common in the Murray Darling river system and rivers of Queensland, New South Wales and Victoria (Allen *et al.* 2002) and rivers and wetlands of the Swan Coastal Plain (Sarti and Allen 1978).

Cyprinus carpio **(Common Carp/European Carp)**

Cyprinus carpio is a hardy subtropical freshwater fish species tolerant of a wide range of conditions including brackish environments, turbidity and extreme temperatures (3-35°C). I has a preference for large water bodies, slow moving or standing water and soft substrates (Kottelat 1997). *C. carpio* may grow to 120 cm in length, weigh up to 40kg and live for up to 35 years or more (Kottelat 1997), however in Australia the species seldom exceeds 30-40cm and 1.5kg (Allen *et al.* 2002). An opportunistic omnivore, *C. carpio* feeds on molluscs, annelids, crustaceans, aquatic insects, aquatic plants and seeds, algae and detritus (Kottelat 1997). Spawning from spring to mid summer, a single female is able to produce approximately 300,000 eggs which are laid in a sticky mass amongst vegetation in shallow margins of water bodies. *C. carpio* is known to cause significant environmental degradation whilst grubbing for food in the benthic sediments (Allen *et al.* 2002). This feeding behaviour increases turbidity and releases nutrients into the water column, resulting in increased algal blooms as well as loss of vegetative cover and food for native species (Kottelat 1997).

Endemic to Europe, Russia, China, India and south-east Asia, *C. carpio* is distributed across the globe (Kottelat 1997). As for *C. auratus, C. carpio* is common in the Murray Darling River system and rivers of Queensland, New South Wales and Victoria (Allen *et al.* 2002). In the study area, *C. carpio* has been found at Loch McNess, Lake Goollelal, Herdsman Lake (industrial) and Floreat Waters, Emu Lake and Bennett Brook.

Gambusia holbrooki **(Mosquito fish)**

Gambusia holbrooki is a relatively small (maximum total length ≈ 6 cm) exotic freshwater species introduced to Australia in the 1920's and to Western Australia in 1934 as an aquarium fish, and in misguided attempts to control mosquito populations (Allen *et al.* 2002). It has the ability to tolerate a wide range of temperature and salinity conditions (Pen and Potter 1991b)(Pen and Potter 1991b). G. *holbrooki* has a preference for shallow, still water, dark substrate and areas with submerged vegetation providing lateral concealment (Casterlin and Reynolds 1977). Breeding usually commences when water temperatures exceed 15-16°C and daylight exceeds 750-780 minutes. Fertilisation occurs internally and the female bears live young (Morgan *et al.* 1998). With both spring and summer breeding groups, individual fish generally die in the summer in which they reach maturity (Pen and Potter 1991b). *G. Holbrooki* is a generalist predator taking a wide variety of prey items from the water column and surface (Morgan *et al.* 1996). This highly successful invader, and typically abundant species, displays aggressive behaviour. It is known to cause caudal fin damage, displacing endemic species in areas where fringing vegetation and/or habitat structure do not provide enough shelter for native species (Morgan *et al.* 1998).

Native to north and central American rivers draining into the Gulf of Mexico, *G. Holbrooki* is now considered the most widely distributed freshwater fish species in the world (Service 1996) and the dominant fish species in wetlands of the Swan Coastal Plain (Pen and Potter 1991b) (**Table 4.1**) .

***Geophagus brasiliensis* (Pearl Cichlid, Pearl Earth-eater)**

Geophagus brasiliensis is an aggressive, territorial freshwater fish capable of growing to a maximum of 30cm and able to tolerate brackish conditions, pH range between pH 6 – 8.2 and water temperatures 10^{o}C – 30^{o}C (Mazzoni and Iglesias-Rios 2002). In its natural range, *G. brasiliensis* is found primarily in lentic habitat (Mazzoni and Iglesias-Rios 2002). *G. brasiliensis* will pair up at 5-7.5cm and breed at 10cm if pH and temperature conditions are met (pH 6.5-7.0, 24 – 27^{o}C). These diurnal species are substratum spawners, with newly hatched eggs guarded by one or both parents in a shoal until they reach approximately 35mm TL (Lowe-McConnell 1969). In their native habitat *G. brasiliensis* are omnivores displaying large feeding diversity with small fish, shrimp, algae and invertebrates recorded in one study of 106 cichlids (Lowe-McConnell 1969). In another study, Flavio et al. (2004) identified Ephemoptera, Odonata, Trichoptera and Dipteran larvae as forming the bulk of the diet, supplemented by gastropods and algae. *G. brasiliensis* earned the common name "eartheater" by their habit of taking a mouthful of substrate into their low-slung mouths, passing it through their gills over gill rakers filtering food debris (Lowe-McConnell 1969).

G. brasiliensis is endemic to South America, distributed in streams, rivers, and lagoons of coastal drainages of south-east Brazil and Uraguay (Mazzoni and Iglesias-Rios 2002). As a popular and attractive aquarium and food species, *G. brasiliensis* has been introduced into the Philippines and Australia, with introductions into quarries and ornamental pools at Bajool and Rockhampton, Queensland occurring in 1989 (McKay 1989). *G. brasiliensis* were first discovered in Bennett Brook in April 2006. The discovery elicited a dramatic response with a Cichlid Response Taskforce comprising officers from the Department of Fisheries, Department of Environment, Department of Water, Swan River Trust, City of Swan, and representatives from Murdoch University, Whiteman Park and the North Metro Catchment Group and immediate action in the form of controlled explosions and poisoning of the affected waterway was undertaken (Department of Fisheries 2006). Despite the taskforce's best efforts to halt the spread of *G. brasiliensis* a recent survey carried out in March/April of this year found earlier hopes of preventing the downstream spread of the species are now considered unachievable (Bray and Astbury 2008). Whilst a range of survey, harm minimisation techniques and spread prevention options are being applied, it is expected that this species will cause significant damage to habitat, perhaps resulting in the loss of whole populations of endemic fish species in the longer term (Department of Fisheries 2006). Bennett Brook populations of *G. occidentalis*, *B. porosa,* and *E. vittata* may be under considerable and imminent threat as winter rains facilitate dispersal of this species.

4.2.3 Estuarine species

***Leptatherina wallacei* (Western Hardyhead)**

Leptatherina wallacei is a small (maximum size to 70mm TL) schooling fish, usually abundant and commonly occurring in estuaries, streams, rivers and lakes in coastal areas of it's range (Morgan *et al*. 1996) where it can usually be found near the surface around vegetation and woody debris (*Allen et al.* 2002). This omnivore feeds on unicellular algae, polychaetes, planktonic crustaceans and flying insects (Morgan *et al*. 1998). With a lengthy spawning period extending through spring and summer *L. wallacei* reach sexual maturity, breed and die in during first year of life (Morgan *et al.* 1996).

The West Australian distribution of *L. wallacei* extends from Moore River, Gingin to the Pallingup River, east of Albany (Morgan *et al*. 1998). As *L. wallacei* is considered common and abundant over its extensive range with no specific threats identified, there appears to be no need for specific conservation classification or recommendations at this time.

Afurcagobius suppositus (South-western goby)

Afurcagobius suppositus grows to a maximum size of approximately 90mm and is commonly found in rivers, lower reaches of freshwater streams or resting on the silt or muddy benthos of brackish estuaries and coastal lakes (Allen *et al*. 2002) with a keen preference for heavy cover (Morgan *et al*. 1998). *A. suppositus* preys upon dipteran larvae and hemipterans during all seasons with teleosts, tricopterans, ephemopterans, bivalves and terrestrial insects supplementing the diet seasonally (Morgan *et al.* 1998). Whilst the breeding biology of *A. suppositus* is undocumented it is thought that breeding occurs at the end of the first year during late spring and early summer with males typically guarding a nest shared by several females and concealed under stones or amongst macrophytes (Gill, cited in Morgan *et al*. 1996).

Endemic to south-western Australia, *A. suppositus* is widely distributed and common in coastal areas between Moore River, and from Gingin in the north to Denmark in the south (Allen *et al*. 2002).

As *A. suppositus* is generally common and abundant throughout its range there appears to be little threat to the species at this time, however loss of habitat and habitat alteration due to agricultural and forestry practices may threaten some populations through altered inflow and siltation.

_Pseudogobius olorum (_Swan River goby)

Pseudogobius olorum grows to a maximum size of about 60mm, can usually be found in areas with muddy or rocky substrates or amongst weeds (Allen 1982), and is able to inhabit freshwater, hypersaline and eutrophic waters and tolerate extreme temperatures (Halse 1981). With a life cycle typically less than a year *P. olorum* spawns in spring and autumn with the offspring themselves spawning at five and seven months old respectively, with only a few of each group surviving to breed in a second season (Morgan *et al.* 1996).

Endemic to Western Australia, *P. olorum* is widely distributed and common in coastal areas between Moore River, Gingin in the north to Esperance in the east. The classification of fish from eastern Australia into this taxon is under revision and no longer valid according to Larson (cited in Morgan *et al.* 1996). As for *L. wallacei*, *P. olorum* is common and abundant over its extensive range, with no specific threats identified.

4.2.4 Freshwater fish species possibly lost to the region or regionally extinct

Geotria australis (Pouched Lamprey)

Geotria australis is a temperate, demersal, jawless eel-like species. It inhabits muddy burrows of the upper reaches of freshwater coastal streams, filter-feeding on micro-organisms during the first four years of life until metamorphosis occurs (Sarti and Allen 1978) at which time the larvae (ammocoetes) develop eyes and suctorial disc (Morgan *et al.* 1996). The young adults migrate downstream to become parasitic on sea fishes for approximately two years. *G. australis* grows to approximately 650mm in length (Morgan *et al*. 1996). Once fully grown, they cease feeding and migrate up freshwater streams, travelling mainly at night to spawn during October/November some 15 -16 months later (Morgan *et al*. 1996). They die soon after spawning (Fernholm 1990). *G. australis* have been observed leaving the water, wriggling up the bank to bypass obstacles to migration (Allen et al., 2002), although they may often be found below weirs and dams during their spawning migration (Morgan *et al.* 1996).

Globally, *G. australis* are distributed throughout the Atlantic, Indian and Pacific oceans including coastal regions of all southern continents, extending into rivers of southern Chile and Argentina (Fernholm 1990). Distribution in Australia includes southern coastal drainages including Perth to Albany, WA; St Vincent's Gulf, South Australia to Lake's Entrance Victoria and Tasmania (*Allen et al.* 2002). Common in rivers south of Margaret River and rare northwards to the Swan River, a single sighting has been recorded in the Moore River in 1977 by Sarti and Allen (1978), although its present occurrence on the Swan Coastal Plain is doubtful (**Table 4.1**).

Habitat alteration through dam construction, groundwater extraction, agricultural and forestry practices and associated altered flow regimes, salinisation, siltation and eutrophication resulting in the loss of ammocoete beds in the upper catchments have been identified as the main threats to *G. australis* by Morgan *et al*. (1996), whilst the construction of large dams located on the migration route can act as barriers to migration. Because *G. australis* has an extensive distribution and relatively large populations, the species is not listed under the Western Australian Wildlife Conservation Act 1950 as fauna needing special protection, the EPBC Act 1999 (EPBC Act List of Threatened Fauna 2008) or the IUCN Redlist (IUCN 2007).

Nannatherina balstoni (Balston's Pygmy Perch)

The rarest of all the endemic freshwater fishes of south-west Western Australia, *Nannatherina balstoni* is described as being moderately abundant in ephemeral pools and creeks of peat flats and adjacent forested areas (Morgan 1999). Preferring generally dark and acidic (pH 3.9 -6.0) shallow pools with distinct seasonal temperature variations, this species is known to recolonise temporary pools during flood events (Morgan *et al,* 1996). Spawning in their first year with a maximum size of 90mm TL, *N. balstoni* larvae are typically found in very shallow water (<10cm) amongst ripararian vegetation during winter and spring. They move into deeper water as size increases (Morgan *et al*. 1998). Juveniles of the species feed on aquatic invertebrates, especially cladocerans, with a dietry shift to adult hymenopterans, coleopterans, and dipterans occurring during all seasons as total length exceeds 25mm (Morgan *et al.* 1995).

N. balstoni is endemic to the south-west of Western Australia, distributed from Margaret River in the west to Albany in the east. A previously recorded relict population located at Moore River, near Gin Gin is now presumed extinct (Department of the Environment World Heritage and the Arts 2006). Thought to still occur in thirteen primary locations in a number of river systems, it is thought approximately 12,000 individuals usually exist in the wild at any given time, with fewer than 1,000 individuals occurring in each population.

N. balstoni is listed in Schedule 1 of the Western Australian Wildlife Conservation Act 1950 as wildlife that is rare or likely to become extinct, in need of special protection (Minister for the Environment 2008). It is listed as vulnerable under Criterion 2 under EPBC Act 1999 "The species' geographic distribution is precarious for the survival of the species and is very restricted, restricted or limited" (Department of the Environment 2006, p. 2). A lack of historical data prevents the species being listed under Criterion 3 where the "Estimated total number of mature individuals is limited to a particular degree and: (a) evidence suggests that the number will continue to decline at a particular rate; or (b) the number is likely to continue to decline and its geographic distribution is precarious for its survival" (Department of the Environment, 2006, p. 2).

Specific threats to the Balston's Pygmy Perch include salinisation of waterways, habitat degradation and competition and predation by introduced species (Department of the Environment 2006). It is believed that salinisation has restricted the distribution range of the species to less than 50% of its former range (Department of the Environment 2006). In addition, urban and rural development in the northern limit of *N. balstoni's* former range, plus construction of water points, mineral sand exploration and mining activities, groundwater extraction and forestry and agricultural practices with associated alterations to streamflow, salinisation, siltation and eutrophication pose threats to surviving populations (Morgan *et al.* 1996). In addition, competition and predation by feral fishes, including *G. holbrrooki,* pose similar threats to *N. balstoni* as for *E. vittata* (its closest Western Australian relative) (Gill *et al.* 1999).

4.2.5 Conservation of freshwater fish in wetlands of the Gnangara mound

Fish are not a conspicuous feature of Gnangara mound wetlands, at least not of the better-known ones. This is probably primarily because many of the wetlands are shallow and ephemeral, but possibly also because the few endemic fish adapted to such marginal environmental conditions, most of which are small and unattractive to anglers, have been lost due to a myriad of reasons (see above). Most wetlands that do support fish, harbour introduced species such as *G. holbrooki*. What this means is that those few wetlands in the GSS study area that do (still) contain endemic species (perhaps with the exception of the locally common and widespread *Pseudogobius olorum*) should automatically be considered to have high conservation value and be managed accordingly.

Of the eight freshwater fish previously known to occur on the northern SCP, one endemic species *N. balstoni* has become regionally extinct and is listed as rare, or likely to become extinct, whilst another, *Geotria australis,* has not been recorded in recent studies. With *G. munda* and *G. nigrostriatra* also listed as restricted or vulnerable, prospects for the freshwater fish fauna and biodiversity values of freshwater ecosystems on the Gnangara mound provide reason for concern. Another freshwater fish not recently recorded and possibly lost to the region (*G. australis*), has a wider distribution with Australian, Indian and Pacific populations. Because of its widespread distribution, there is currently no concern for this species nationally, and its loss from the study area may also be considered to be of lesser concern. The fact remains however, that the numerous threatening processes described above, particularly habitat loss and degradation, continue to occur, potentially resulting in further loss of fish species (Bamford *et al.* 1998; Knott *et al.* 2002; Morgan 2008; Morgan *et al.* 2000). In addition, elevated salinity levels, competition and predation by introduced species and/or changes in water temperature have been implicated in the severe declines and/or extinction of populations of *N. balstoni*, E. *vittata, B. porosa* and *B.munda* (Morgan *et al,* 2000). Water temperature issues and increasing urbanisation pressure remain major concerns for the survival of a relict population of *G. nigrostriata* (Knott *et al,* 2002) at Ellen Brook, whilst exotic species *G. holbrooki,* and *G. brasiliensis* continue to threaten populations of endemic species *G.occidentalis, E. vittata, B. porosa.*

The FARWH project (DEC) is expected to enhance our current knowledge regarding the distribution of freshwater fauna on the Gnangara mound in general (T. Storer, personal communication, May 20, 2008), however it remains to be seen whether the sampling regime will be able to provide comprehensive enough information on freshwater fishes (e.g. distribution, habitat preferences, feeding and spawning behaviour, etc.), given the broad overall scope of this project. This has been a major shortfall of past surveys. In particular, this review suggests that fish populations occurring towards their northern distribution limits (some areas of which fall just north of the GSS study area), or in roadside pools or other 'unfashionable' habitats, are not often sampled. Past and/or future sampling regimes may fail to record these northern, possibly relict populations before they become extinct. In terms of the GSS, and for the Swan Coastal Plain in general, there is a case for conducting a systematic survey of freshwater fish, using proven, rigid methods designed for fish surveys (and not simply relying on incidentally-caught fish whilst targeting aquatic invertebrates). In doing so, attention should also be devoted to the endemic freshwater fish of the northern/northeastern area of the mound (ideally including the area just north of Moore River). In the meantime, management efforts should continue to focus on the conservation of the known threatened communities on the mound such as Bennett and Ellen Brook.

Table 4.1a: Records of freshwater fish species of the northern Swan Coastal Plain. Superscripts are source references and detailed in Table 3.4b.

Wetland		**Moore River**				**Spearwood Linear Wetlands**							
Species	General References	Regan's Ford/ Upper Moore River	Lake Beermullah	Lower Moore River/ Gingin Brook	Lake Bambun	Yanchep Caves	Loch McNess	Lake Yonderup	Lake Joondalup	Lake Goollelal	Pipidinny Swamp	Nowergup Lake	Lake Carabooda
Galaxiella nigrostriata	G[2.3. 4.7.]	X[7]		X[2.7.]									
Galaxiella munda	G[2.3.4.5.7]	X[5.7.]		X[2.5.7.9.10]									
Galaxias occidentalis	G[1.3.4.]	H[1.] M[9.]		X[9.10.]	H[1.]								
Tandanus bostocki	G[3]	H[1.] M[9.] X[3.4.9.]		X[9.10.]									
Bostockia porosa	G[2.3.4.7.]	H[1.]		X[2.3 9.10.] .	H[1.] X[10.]	X[11.]?	H[1.] X[10.]	P					
Edelia vittata	G[2.3.7.]	H[1.] M[9.]		X[2.3.7.9.10.]					X[13.] ?	X[13.]			
Estaurine species													
Leptatherina wallacei	G[2.7.]			X[2.7.9.]									
Afurcagobius suppositus	G[1.2.7.]	H[1.]		M[9.] X[2.7.9.10.]									
Pseudogobius olorum	G[3.]	H[1.] X[9.]	H[1.]	M[9.] X[9.10.]	H[1.]		P	P	H[1.] X[13.14.] P	X[13.14.] P			
Introduced species													
Carassius auratus	G[3.] SCP[16.]			X[9.16.]			H[1.] X[10.] P	P	H[1.] X[13.] ?				
Cyprinus carpio							P		X[13.] ?	X[13.]			
Gambusia holbrooki	G[3.]	H[1.] X[9.]	H[1.]	X[9.10.14.]	H[1.]		H[1.] X[10. 14.] P	X[14.] **P**	H[1.] X[13.14.] P	X[13.14.] P	P	P	X[14.]
Geophagus sp. (Geophagus brasiliensis ?)													

X - Cited in literature 1990 to 2008

H -Historic: Cited in theliterature up tp and including 1990

M - Western Australian Museum records, numerical annotations indicate the citing of WAM by an author of the indicated reference

G - General Reference ie. regional (where distributional ranges indicate possible occurrence in wetlands on the Gnangara Mound

SCP - Referenced to Swan Coastal Plain

P- Indicates occurrence recorded as part of the Gnangara Mound macroinvertebrate monitoring program

? Signifies past coccurrence for which reasons exist to doubt present occurrence

PC - Personal Communication

Table 4.1a: (cont.)

	South-west Mound Wetlands				East Wanneroo Wetlands				Bennet Brook.		Ellen Brook	
Species	Big Carine Swamp.	Lake Gwelup	Herdsman Lake Industrial	Floreat Waters	Lake Mariginup	Lake Jandabup	Malaga Wetlands	Mussel Pool	Emu Lake	Bennett Brook	Lake Chandala	Ellen Brook including Melaleuca Park (EPP 173)
Galaxiella nigrostriata												X[5.6.9.]
Galaxiella munda												H[1.]
Galaxias occidentalis										X[8.12.]	H[1.]	H[1.]
Tandanus bostocki												X[1]
Bostockia porosa										X[8.12.]	H[1.]	H[1.] X[11.]
Edelia vittata								X[14.]		X[8. 12.]	H[1.]	H[1.9.]
Estaurine species												
Leptatherina wallacei										X[8.]		
Afurcagobius suppositus												H[1.]
Pseudogobius olorum		P	X[14.]	X[14.]	X[14.] P					X[8. 12.]	H[1.]	H[1.]
Introduced species												
Carassius auratus						H[1.] ?			X[8.]	X[8.]	H[1.]	X[9.]
Cyprinus carpio			X[15.]	X[15.]					X[8.]	X[8.12.]		
Gambusia holbrooki	X[14.]	X[14.]	X[14.15.]	X[14.15.]	X[14.] P	X[14.]?	X[14.]	X[14.]	H[1.] X[8.]	X[8.12.]	H[1.]	X[14.]
geophagus sp. (geophagus brasiliensis?)										PC[17.]		

? Signifies past coccurrence for which reasons exist to doubt present occurrence

X- Cited in literature 1990 to present

H -Historic, cited in the literature prior and up to 1990

M - Museum Records, Numerical annotation indicates Museum records cited by an author of another work.

G - General Reference ie. regional (where distributional ranges indicate possible occurrence in wetlands on gnangara Mound)

SCP - Referenced to Swan Coastal Plain

PC - Personal Communication

Table 4.1b: Sources of fish information for the northern Swan Coastal Plain referred to in Table 3.4a.

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2. Morgan, D. L., Gill, H. S., & Potter, I. C. (1998). Distribution, identification and biology of freshwater fishes in south-western Australia. Supplement No. 56. *Records of the Australian Museum*, 97. [Cites species sampled on-site over several sampling occasions 1994 -1996 together with records collected from the Western Australian Museum (WAM) including those reported by other authors.]
3. Allen, G. R., Midgley, S. H., & Allen, M. (2002). *Fieldguide to the freshwater fishes of Australia*. Perth: Western Australian Museum. [Cites known species distribution ranges using information collected from field surveys over many years, records of museums from all Australian states and specialist publications.]
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5. Knott, B., Jasinska, E. J., & Smith, K. D. (2002). Limnology and aquatic fauna of EPP 173, Melaleuca Park, refuge for an outlier population of the Black-stripe minnow *Galaxiella nigrostriata* (Galaxiidae), in southwestern Australia. *Records of the Western Australian Museum*, 21, 291-298. [Cites data collected through nine sampling occasions November 1994 to November 2007.]
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8. Bamford, M., Morgan, D., & Gill, H. (1998). *The freshwater fish fauna of Bennet Brook Perth*: Bennet Brook Catchment Group. [Cites species sampled on-site over several sampling occasions spring 1997 - summer 1998.]
9. Morgan, D., Gill, H., & Cole, N. (2000). *The fish of the Moore River Catchment*. Perth: Murdoch University. [Cites accurate (point based) distributional records from 3 sources: literature, museum records, and survey samples collected September 1996 – September 1998.]
10. Morgan, D. (2008). Freshwater fish sampled in the Gingin Region. [Cites accurate (point based) distributional records from survey samples and records of the WAM.]
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Success Hill Action Group. [Cites two sampling occasions during the autumn and winter of 1995 and references Sarti & Allen (1978).]
13. Yellagonga Regional Park Management Plan 2002-2013. Retrieved March 3, 2008. from http://www.naturebase.net/pdf/nature/management/yellagonga_rp_mp.pdf. [Cites Western Australian Water Authority 1995 publication *Review of Proposed Changes to Environmental Conditions , Gnangara Mound Groundwater Resources (Section 46), Water Authority of Western Australia.]*
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5. Identification of gaps and strategic sampling (Objective 4)

5.1 Introduction

Information drawn from Objectives 1 - 3 were used to identify gaps and plan a strategic sampling regime. There are clearly wetland suites on the mound about which much is known (e.g. the Spearwood linear suite, the south-western wetlands of the mound, some of the more western Bassendean wetlands, and some riverine systems). However, given there are some 600 wetlands on the mound (http://portal.water.wa.gov.au/portal/page/portal/gss/Projects/BiodiversityValuesMound), and records exist for some 42 of these, it is reasonable to assume that there would be some significant gaps, at least in terms of the geographical coverage of the area. The review of the status of aquatic invertebrates, habitat specificity of the invertebrates, and also the review of the status of freshwater fish on the Gnangara mound (Objectives 1, 2 and 3 of this report) all point to data lacking from

- the more or less permanent black-water wetlands in the north-eastern section of the mound (including the area just north of Moore River; and
- portions of the Pinjarra Plain.

It is quite likely that these areas harbour endemics, and perhaps rare species, including fish. It is therefore in this region (shown in **Figure 5.1**) that CEM has proposed to conduct its strategic sampling.

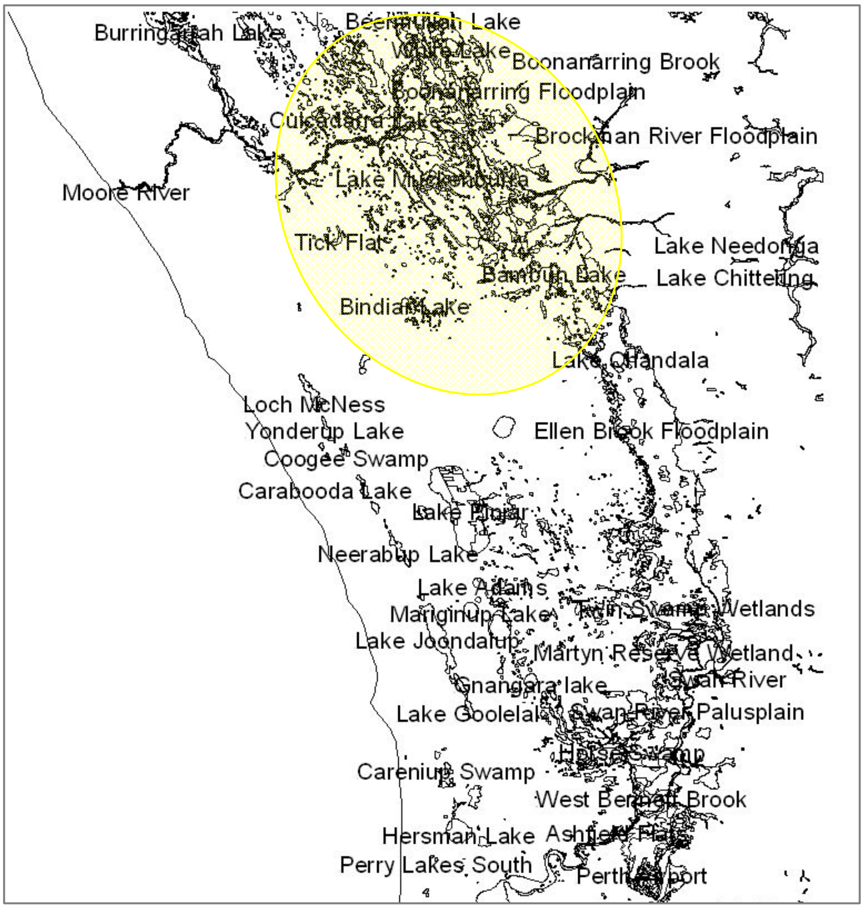


Figure 5.1: Gnangara Sustainability Strategy study area. Yellow oval shows poorly studied area of the mound.

5.2 Methods

5.2.1 Study sites

Discussions regarding the selection of suitable sites were held with DEC in July, and in August Brent Johnson (DEC) and Bea Sommer (ECU) conducted a reconnoitring trip in the north-eastern section of the mound. Three wetlands were identified: Quin Brook (a seasonally inundated creek), Lake Bambun (a permanently inundated lake), and a large permanent un-named lake in the northern section of Yeal Nature Reserve which is referred to as 'Yeal Lake' in this report. Their geographic positions are shown in **Figure 5.2.**

Bambun Lake (31°25'30"S, 115°53'23"E; ~ 0.385 km^2) is one of a group of wetlands consisting of Bumbun, Nambung and Mungala which are vested in Bampanup Nature Reserve (Reserve A26756). It is surrounded by private pasture and agricultural land, and a number of agricultural drains feed into it. These surrounding land-uses have caused weed infestation and eutrophication problems in the past, and there has also been concern of there being insufficient reserved land to form an effective buffer zone (Anon. 1981). The area supports a rich wildlife dependent on aquatic habitats and is important for their conservation. Bambun Lake is known to harbour three

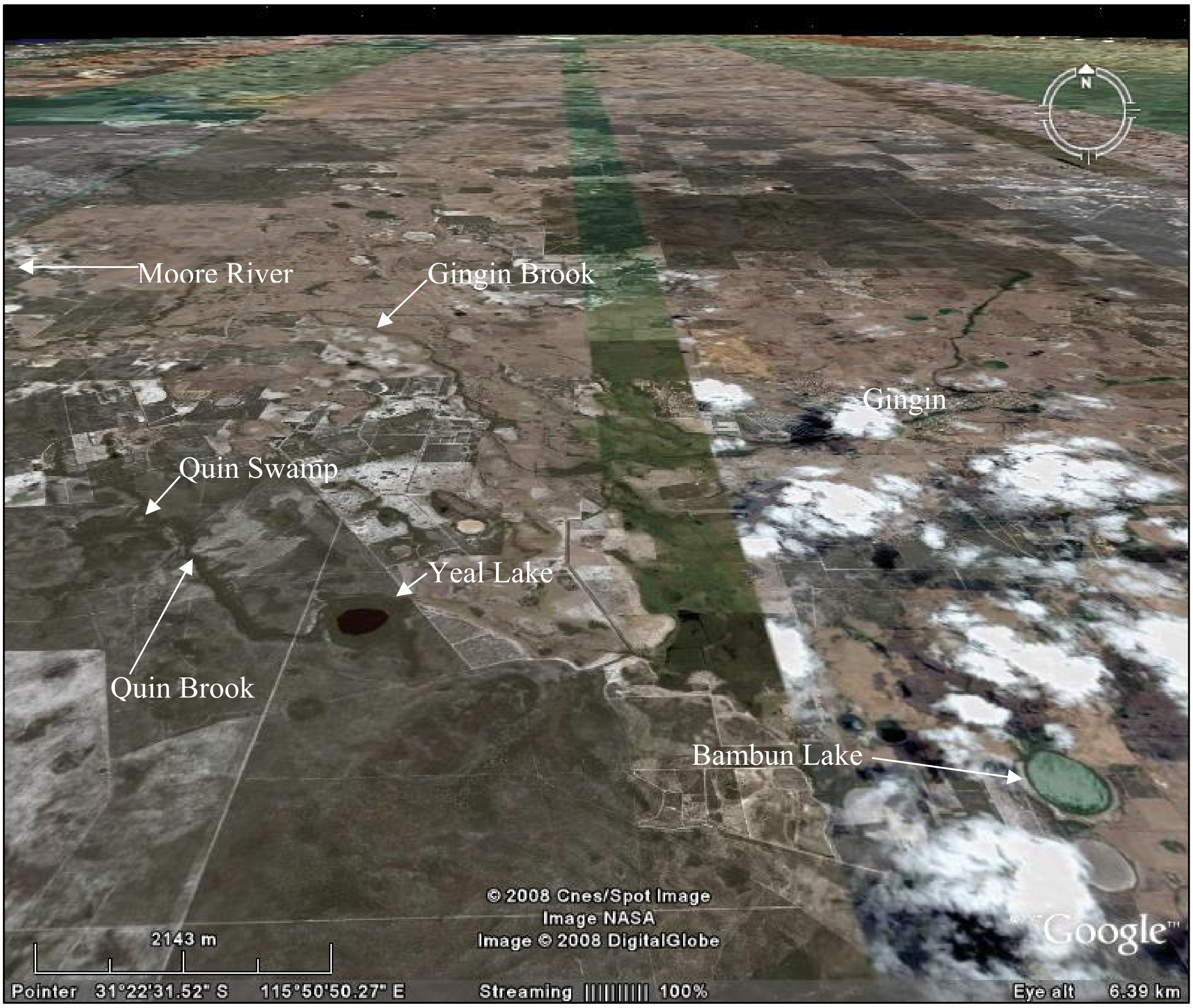


Figure 5.2: Location of the three wetlands, Bambun Lake, Yeal Lake and Quin Brook chosen for gap sampling.

endemic freshwater fish species (*Bostockia porosa, Galaxias oxidentalis and Pseudogobius olorum*), as well as the introduced mosquito fish (*Gambusia holbrooki*; see previous section). The locations of the study sites are shown in **Figure 5.3**.

The other two wetlands are vested within Yeal Nature Reserve (Reserve A31241), an area considered significant for containing eight of the nine landform/soil/vegetation types found on the Bassendean dune system which supports a rich diversity of habitats for birds, reptiles and amphibians (Australian Heritage Database online: http://www.environment.gov.au/ heritage/ahdb/). It also contains the northernmost stand of jarrah in the region. Yeal Nature Reserve is considered to be an area of high potential impact from groundwater extraction from the Gnangara mound. No information about these two wetlands could be found. Information on the WWW (http://maps.bonzle.com /c/a?a=p&p=199248&cmd=sp) suggests that Quin Brook drops around 35.3m over its 18.8km length. It flows from Yeal Lake in the south-east to Gingin Brook in the north. There is a large paperbark swamp west of the northern end of Quin Brook, which, from aerial photography, appears to have covered a much larger area in the past. The swamp was dry in August/September 2008, and the actual brook was sampled (**Figure 5.4**).

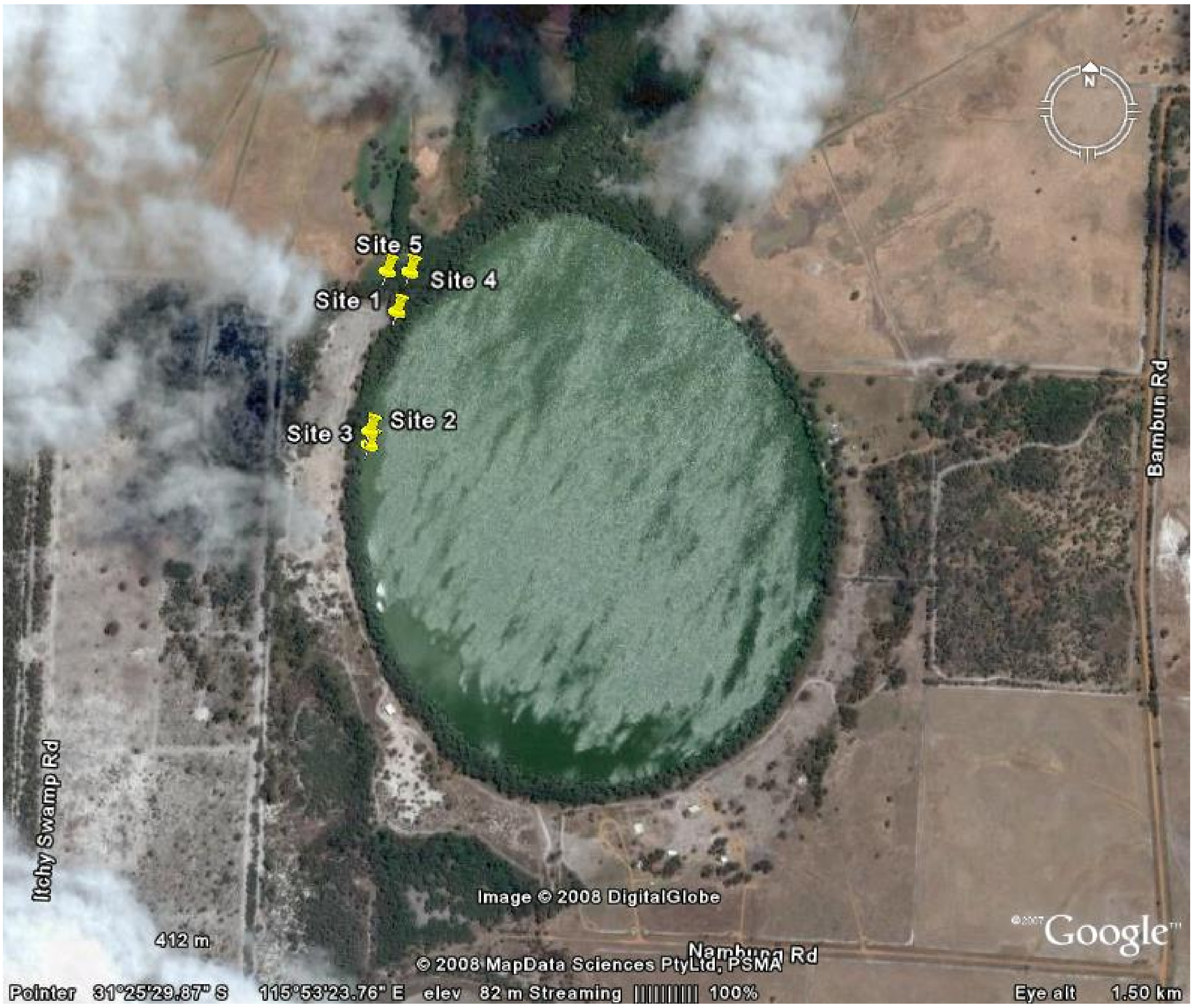


Figure 5.3: Lake Bambun, showing the location of five sites sampled in September 2008.

Figure 5.4: Quin Brook, showing the five sites sampled in September 2008.

5.2.2 Field methods

Five habitats were sampled at each wetland on 19^{th} and 20^{th} September 2008. Macroinvertebrate sampling was habitat-based and largely followed Chessman's (1995) 'rapid assessment' method. Taxonomic sensitivity is to family level (although the numbers of species per family were noted). GPS coordinates were taken at each site and habitat descriptions were made. Plant species were identified to species level wherever possible. In situ water quality measurements (temperature, dissolved oxygen concentration, electrical conductivity [EC] and pH) were taken at each habitat and water samples collected for the analysis of nutrients (PO_4^{3-}-P, total phosphorus [TP], nitrate+nitrite-N, NH_4^+-N, total Kjeldahl nitrogen [TKN]), $gilvin_{440}$, turbidity, major ions, and chlorophyll *a*. For these latter analyses, water samples from each habitat (i.e. site) were bulked so that one sample per wetland was analysed. All chemical analyses were carried out by the Chemistry Centre in Perth.

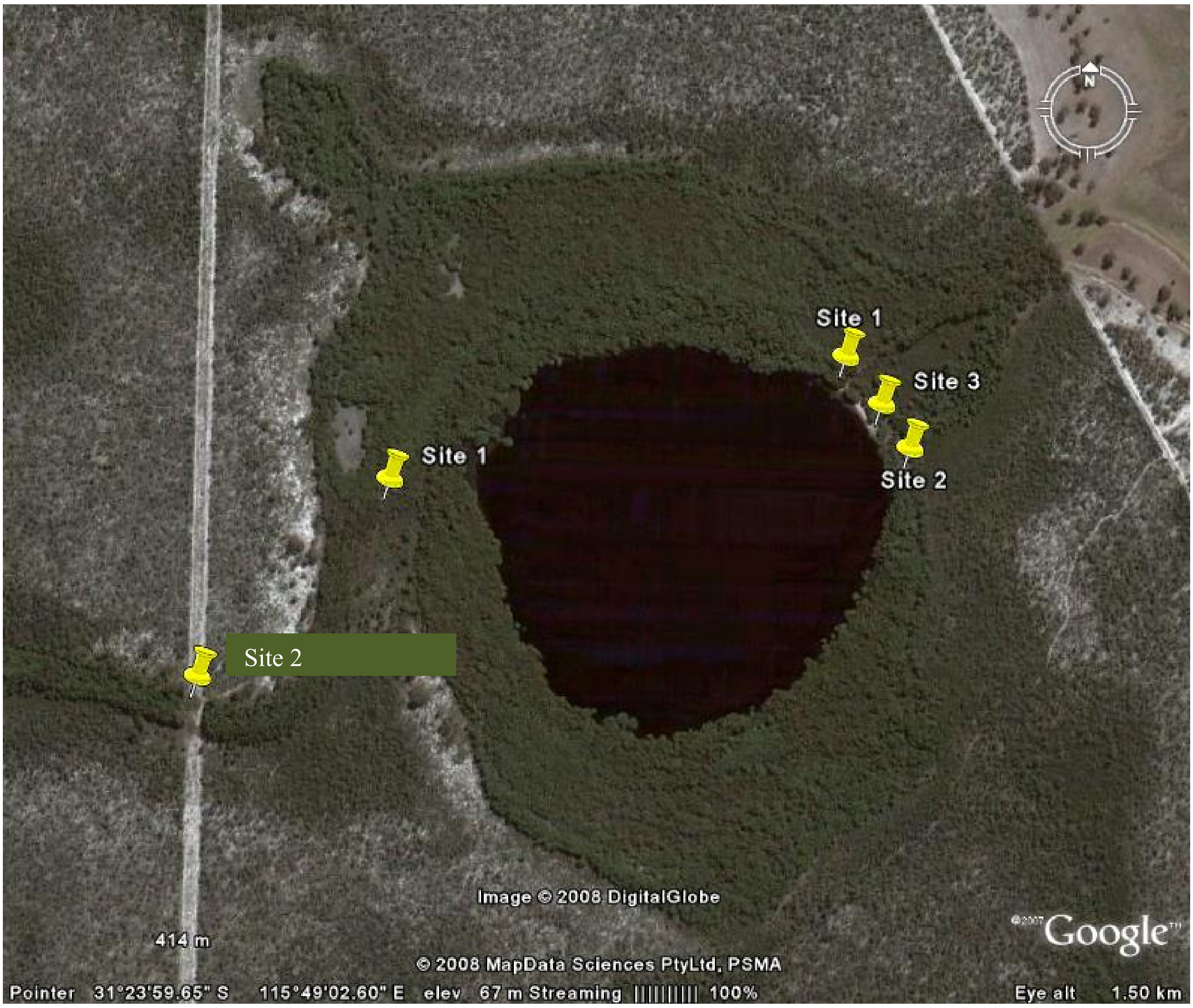


Figure 5.5: Yeal Lake, showing the five sites sampled in September 2008.

5.2.3 Data analyses

Multivariate techniques and pattern analyses in the Primer (v. 6.1.6) statistical package were used to detect spatial patterns in vegetation, water quality and aquatic macroinvertebrates. Vegetation, macroinvertebrate and water quality similarity matrices were computed using the Bray-Curtis coefficient, the Kulczynski (presence/absence) coefficient and Euclidean distance respectively. The RELATE function in Primer was used to test whether vegetation and water quality similarity matrices were correlated with the macroinvertebrate matrix. The BIOENV procedure was then used to select environmental variables (i.e. vegetation and water quality) best explaining macroinvertebrate patterns.

Regression analysis was used to estimate dissolved organic carbon (DOC) from $gilvin_{440}$ based on a CEM dataset from the Scott Coastal Plain. This dataset showed good correlation of $gilvin_{440}$ and DOC ($n= 28$, $r= 0.938$, $p<.0.001$). DOC and pH was then used to estimate organic anion charge (A^-) using the Oliver *et al.* (1983) model. Ion charge balances were calculated, and alkalinity was estimated from the difference between total base cations and strong anions (plus

A⁻). In addition, the chloride to sulphate ratios of the water samples were calculated in order to determine if any non-marine sulphate is present.

5.3 Results and discussion

The vegetation composition of each of the 15 sampled sites is shown in **Table 5.1**. There was a large number of herbaceous weed species, including *Zantedeschia aethipica* (Arum Lily) which was particularly dominant at Lake Bambum. All 3 wetlands are dominated by *Melaleuca* paperbarks (*raphiophylla* , *teretifolia* and *preisiana*). However, different vegetation communities (i.e. habitat types) were sampled (**Table 5.2**). Hierarchical clustering of the sites based on vegetation composition did not group the sites into wetland location (i.e. Bambun, Quin and Yeal; **Figure 5.6**). This reflects the fact that similar habitat types based on vegetation composition were present at each wetland (e.g. 'open water'). The 3 main clusters in terms of habitat type that can be identified from **Figure 5.6** are 'open water'-, '*Melaleuca*'-, and 'weed'-dominated.

Photographs of the sites sampled are given in **Appendix 3**. At Yeal Lake, fire damage was still evident although there were also signs of recovery and regrowth. Some of the flooded *Melaleuca* trees on the western side of the lake appeared to be dead and are unlikely to recover (e.g. Site 1, west; see Appendix 3). Vegetation on the western side of Yeal Lake, and particularly at and around Quin Brook appeared severely drought-stressed (as evidenced by numerous dead, leafless and bleached branches of trees and aquatic macrophytes; R. Froend, pers. comm.). On the north-western side of Lake Bambum also, there was a stand of flooded *Melaleuca raphiophylla* that had a drought-stressed appearance (see **Appendix 3**).

Future monitoring and management of the fringing and aquatic vegetation in these wetlands should focus on (1) reducing the amount of exotics and weeds; (2) control/prevention of wildfires; and (3) controlling groundwater decline.

The aquatic chemistry of the wetlands is shown in **Table 5.3**. Yeal East and West are shown separately in order to be able to detect differences in the quality of in- (the eastern side) and out- (the western side) flow water. Analysis of similarity of the aquatic chemistry based on Euclidian distances places Lake Bumbun at an outlying position. This is mainly due to lower gilvin440 and nutrients than the other two wetlands (graph not shown). Lake Bambun was ~6 times less coloured (as expressed by $gilvin_{440}$) than the other two wetlands. Humic wetlands are usually slightly to very acidic due to the prevalence of organic acids, however, the waters investigated all had circum-neutral pH (**Table 5.3**). All three wetlands are eutrophic in terms of P and N concentrations; Quin Brook and Yeal Lake fall into the hyper-eutrophic category (based on OECD boundary values; Ryding and Rast 1989). These are some of the highest recorded nutrient concentrations that we have seen in any of the monitored Gnangara Mound wetlands. At Yeal Lake nutrient concentration (especially phosphorus) was higher on the west side (i.e. the outflow) than the east, suggesting that the lake itself may be an additional source of nutrients. This could be partially related to the recent wildfire as fire does have the potential to increase nutrient concentrations in water bodies (see review in Horwitz and Sommer 2005). The most likely source of nutrients are the numerous agricultural drains that wash into the wetlands. Blue-green algal blooms were observed in September at Lake Bambun and Yeal Lake. Chlorophyll *a* analyses were unreliable, however, and hence are not shown here. It is most likely this high productivity that is contributing to the higher than would be expected pH. High productivity increases pH by consuming CO_2 in the water column.

Electrical conductivities were comparatively high for high-flow readings. Ionic charge balances show that this is primarily due to high sodium and chloride concentrations (**Table 5.4**). Na^+:Cl^- ratios were all more or less equivalent to that of average seawater, 0.859. Cation concentrations were in the order $Na^+ > Mg^{2+} > Ca^{2+} K^+ > NH_4^+$, and anions $Cl^- >$(est.)$HCO_3^- > SO_4^{2-} \cong$(est.)$A^-$. In terms of the potential for drought-induced acidification to occur in these wetlands, the fact that

Table 5.1: Plant species found at each of the north-eastern Gnangara mound sites. (*= weed species)

%-cover:	Bambun 1	Bambun 2	Bambun 3	Bambun 4	Bambun 5	Quin 1	Quin 2	Quin 3	Quin 4	Quin 5	Yeal East 1	Yeal East 2	Yeal East 3	Yeal West 1	Yeal West 2
Acacia pulchella							1								
Astartea							5		4.76	5					
Azolla				1.5											
Baumea articulata								70			35				
Baumea juncea											0.9				
Cassytha		1									30				
Elatine gratidoides						20		5							20
Eucalyptus rudis	30	10										3			
Filamentous algae								0.9							
Kunzea ericifolia						30		50	16.7						
Kunzea micrantha										50					
Hydrocotyle bonariensis		1													
Lemna				0.5	30										
Lepidosperma ericifolia														5	
Lepidosperma longditudinale		1					60	20	7	80					5
M. preisiana (overstorey only)															
M. preisiana							20								
M. raphiophylla	30	40		98			20		2	40		5			
M. raphiophylla (overstorey only)					60	45					30			45	80
M. teretifolia														15	
M. teretifolia (overstorey only)	30	5									5				
open water			100						5			90	100		
Triglochlin sp.		0.5				4									
Typha orientalis					80										
Villarsia albiflora								5							
*Alternanthera pungens**															15
*Arctotheca calendulum**											0.9				2
*Conyza bonariensis**										2					
*Cotula coronopifolia**											0.9				
*Cotula sp.**								30							5
*Cynodon dactylon**					5										
Lolium rigidum															1
*Osterospermum picroides**															
*Paspalum distichum**	4														1
*Pennisetum dandestinum**		10									2				
*Rumex brownii**		0.9									0.9				
*Rumex frutescens**					2										
*Senecio vulgaris**											0.9				
*Sonchus asper**															1
*Sonchus oleraceus**										2	0.9				
*Spergularia diandra**											0.9				
Stenotaphrum secundatum *		50													
Tridax procumbens															5
Other weeds									7.14						
*Zantedeschia aethiopica**		3			15										

Table 5.2: Categorization of north-eastern Gnangara mound sites based on vegetation community.

Site	Vegetation community
Bambun 1	*Melaleuca/ E. rudis*
Bambun 2	*Melaleuca* / submerged weeds (grasses)
Bambun 3	Open water
Bambun 4	*Melaleuca* / submerged macrophytes
Bambun 5	*Typha*
Quin 1	*Kunzea/* submerged macrophytes
Quin 2	*Lepidosperma/ Melaleuca*
Quin 3	*B. articulata/ Kunzea/ Astartea/ Lepidosperma*
Quin 4	Open water with *Kunzea/ Astartea/ Lepidosperma/ Melaleuca*
Quin 5	*Lepidosperma*
Yeal East 1	*B. articulata*
Yeal East 2	*Melaleuca sp.* / open water
Yeal East 3	Open water
Yeal West 1	*Melaleuca/ Lepidosperma*
Yeal West 2	Flowing water/ *Lepidosperma/ Melaleuca overstorey*

HCO_3^- (i.e. alkalinity) is higher than SO_4^{2-} is positive. However, as already mentioned, one of the possible reasons for the comparatively high HCO_3^- concentration is the consumption of CO_2 by in-lake primary production. **Table 5.4** also shows that alkalinity (HCO_3^-) is correlated with calcium ($r= 0.97$, $p< 0.05$) concentration, rather than with pH. pH in turn is inversely correlated with sulphate concentration ($r= -0.73$, non-significant due to the low number of samples). The organic anions themselves also appear to be contributing to alkalinity. In terms of monitoring purposes, one would not want the charge from sulphate to exceed the organic anion charge. This already appears to be the case at Quin Brook. Quin Brook also has the lowest $Cl^-:SO_4^{2-}$ ratio (8.9, which is slightly lower than that of average seawater, 9.663), while having the lowest pH (**Table 5.4**). This points to a non-marine source of sulphate (e.g. from the oxidation of Acid Sulphate Soils).

In conclusion then, two issues need to be the focus of on-going monitoring in terms of water quality: (1) control of nutrient enrichment; and in view of declining groundwater levels, (2) potential for drought-induced acidification.

Yeal Lake had the highest aquatic macroinvertebrate species richness (50), followed by Lake Bambun (40), and Quin Brook (31; **Table 5.5**). These richness values are roughly average compared to the SCP meta-database (see Section 2), however it must be appreciated that these values are from one visit only, so are likely to be an underestimation of the true richness. Palaemonidae (*Palaemonetes australis,* a freshwater shrimp), not found in other Bassendean dune wetlands on the Gnangara Mound (presumably because of their general requirement for alkaline conditions) was found at Lake Bambun and Yeal Lake, but not at Quin Brook. The invertebrate fauna of the western side of Yeal Lake had some characteristics associated with flowing waters, e.g. the presence of Simulidae (larval blackflies). Also of interest is the large number of Cnidaria (*Hydra* spp.) found on the western side of Lake Yeal. *Hydra* have so far been recorded from 26 out of 66 wetlands on the SCP (see Section 2). Perthidae (a freshwater amphipod), have so far only been recorded from Yanchep Caves and the Lexia wetlands on the

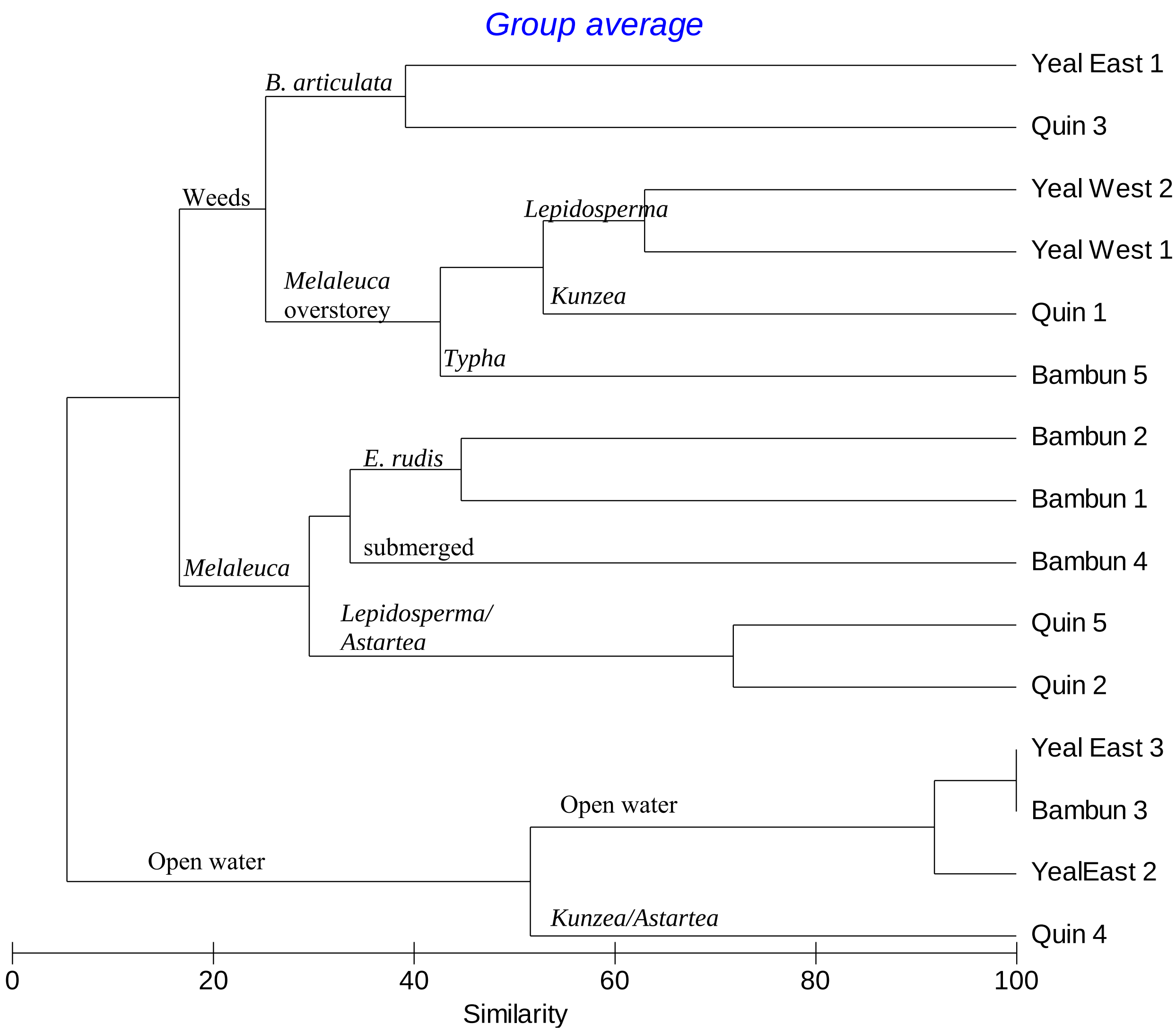


Figure 5.6: Hierarchical cluster analysis (group average mode) based on Bray-Curtis similarities of sites characterised by vegetation assemblages (standardised data, but not transformed) of the three north-eastern Gnangara mound wetlands. The habitat types upon which the groupings were based are overlayed.

Gnangara Mound, and only from 7 other wetlands on the Jandakot Mound. They were present at Lake Bambun. The acid-sensitive Ceinidae amphipod, *Austrochiltonia subtenuis*, was present in Lake Bambun and Yeal Lake, but also absent from Quin Brook. Of interest at Quin Brook and Yeal Lake were the abundant and very large calanoid copepods, (*Boeckella robusta*?), which are both an indicator of elevated nutrient levels and the absence of fish predation. They were also found at Lake Bambum, but in much lower numbers. All major taxonomic groups were present at the wetlands, with the exception of isopods. Isopods have also not been previously recorded from Gingin Brook and Gingin Pool (see Section 2). The reason for this is not known. It is possible that this area of the Mound is beyond the northern boundary of their distribution.

In contrast to the vegetation dendrogram (**Figure 5.6**), hierarchical clustering based on the aquatic invertebrate fauna groups the sites into wetland clusters (**Figure 5.7**). The only exception is Yeal East Site 1 which groups more closely with the Bambun sites because of the presence of Physidae. This wetland-based clustering suggests that, even though there were no evident

Table 5.3: Water chemistry at Lake Bambun, Quin Brook and Yeal Lake as at September 2008. The first 6 variables are means (Bambun and Quin, n= 5; Yeal East, n=3; Yeal West, n=2); standard deviations are shown in brackets. The remaining variables were analysed from bulked water samples from each wetland.

	Lake Bambum	Quin Brook	Yeal East	Yeal West
Temperature (°C)	17.56 (0.27)	14.28 (0.36)	18.87 (0.38)	20.45 (0.07)
Dissolved oxygen (%sat)	66 (3.73)	45 (23)	75 (5)	87 (0)
pH	7.49 (0.09)	7.06 (0.10)	7.24 (0.20)	7.5 (0.07)
EC (µS/cm)	1553 (13)	1973 (7)	1650 (56)	1604 (0)
$gilvin_{440}$ (/m)	9 (3)	55 (4)	58 (7)	57 (0.81)
turbidity (NTU)	3 (4)	15 (11)	19 (16)	14 (0.71)
FRP (ug/L)	140	460	520	1400
TP (ug/L)	180	690	930	1400
NOx-N (ug/L)	370	180	<0.10	300
NH_4 (ug/L)	1100	60	30	30
TKN (ug/L)	2500	3200	2900	2800
Na (mg/L)	220	288	263	225
K (mg/L)	8.4	11.9	8.7	11.5
Mg (mg/L)	30.7	41.3	30.6	32.2
Ca (mg/L)	17.7	29.5	19.9	32.4
Fe (mg/L)	0.041	0.23	0.49	0.25
Al (mg/L)	<0.005	0.35	0.34	0.19
Cl^- (mg/L)	419	511	476	408
SO_4^{2-} (mg/L)	25.7	77.8	30	43.1

groupings based on vegetation composition (**Figure 5.6**), each of the three wetlands appears to have a characteristic invertebrate fauna. Can the distribution of the invertebrate fauna then be explained by water chemistry? **Figure 5.7** shows that, as with the similarity analysis based on water chemistry, Lake Bambum is grouped separately from the other two wetlands. This would suggest that water chemistry is influencing the invertebrate assemblages, even though (because of having only 3 wetlands) the correlation between the two similarity matrices was not statistically significant ($r= 0.98$; $p> 0.10$). The BIOENV analysis in Primer indicates that the two sets of variables best explaining the invertebrate distribution are gilvin and sulphate on the one hand, and ammonium and sulphate on the other. The higher sulphate concentration measured at Quin Brook may at least partially explain the lower invertebrate richness found there.

In summary, the three wetlands have rich and diverse fringing and aquatic vegetation communities. However, they are showing signs of drought-stress. Besides declining groundwater levels, weed invasion and fire are likely to be the greatest threat to this biodiversity. Aquatic invertebrate distribution does not appear to be related to specific habitat type (i.e. dominant vegetation community), as has already been shown for the other monitored Gnangara Mound wetlands (Section 3). However, it does appear to be related to water quality, and therefore careful management of nutrient levels and potential drought-induced acidification is important

Table 5.4: Ionic charge balances for Lake Bambum, Quin Brook and Yeal Lake. 'Est. DOC' is dissolved organic carbon estimated from $gilvin_{440}$ measurements; 'Est. A^-' is the estimated organic anion charge (Oliver *et al.* 1983), and 'Est. HCO_3^-' is the difference between base cations and strong anions + Est. A^-. Na^+:Cl^- and Cl^-:SO_4^{2-} ratios are based on equivalent charges. Units are in meq/L unless otherwise noted.

	Lake Bambum	Quin Brook	Yeal East	Yeal West
Est. DOC (mg/L)	22	50	52	51
EC (µS/cm) (in situ)	1553	1973	1650	1604
EC (µS/cm) (Lab.)	1560	1970	1720	1550
pH (in situ)	7.49	7.06	7.24	7.5
NH_4^+	0.079	0.004	0.002	0.002
Na^+	9.607	12.576	11.485	9.825
K^+	0.215	0.304	0.223	0.294
Mg^{2+}	1.263	1.699	1.259	1.325
Ca^{2+}	0.442	0.736	0.497	0.808
Cations	**13.310**	**17.756**	**15.220**	**14.388**
Cl^-	11.818	14.413	13.426	11.508
SO_4^{2-}	0.268	0.810	0.312	0.449
Est. A^-	0.213	0.492	0.513	0.510
Anions	**12.566**	**16.526**	**14.564**	**12.915**
Est. HCO_3^- meq/L	0.74	1.23	0.66	1.47
Est. HCO_3^- (mg/L)	45	75	40	90
Na^+:Cl^-	0.813	0.873	0.855	0.854
Cl^-:SO_4^{2-}	22.1	8.9	21.5	12.8

for the maintenance, and perhaps, improvement of aquatic invertebrate diversity in these wetlands.

This snap-shot survey has partially filled in a gap in our general knowledge of aquatic invertebrate biodiversity on the Gnangara Mound. The wetlands have distinct aquatic vegetation communities. The wetlands are also unique in that they are the only of the monitored Gnangara Mound wetlands that are coloured and receive high volumes of agricultural drainage (and are hence highly eutrophic). Agricultural drainage is also more than likely affecting the hydrology of these wetlands which could constitute a challenge for managers trying to control both nutrient enrichment and acidification from declining water levels. A longer-term data set will be very useful in helping us to better understand the complexity of aquatic biodiversity in this little-studied area of the Mound. Hence future monitoring and pro-active management of these three, as well as other, wetlands on this north-eastern corner of the Gnangara Mound is warranted.

Table 5.5: Aquatic macroinvertebrates sampled from three wetlands on the north-eastern Gnangara mound (Bambun Lake, Quin Brook and Yeal Lake). '1' indicates presence. 'Total occurrence' indicates at how many of the three wetlands the species was found.

HIGHER TAXA	FAMILY/ SUBFAMILY	Species	Bambun 1	Bambun 2	Bambun 3	Bambun 4	Bambun 5	Total Bambun	Quin 1	Quin 2	Quin 3	Quin 4	Quin 5	Total Quin	Yeal East 1	Yeal East 2	Yeal East 3	Yeal West 1	Yeal West 2	Total Yeal	Total occurrence
CNIDARIA	(Hydra)							0						0					1	1	1
NEMATODA	Unidentified				1			1						0						0	1
ANNELIDA	Hirudinea			1	1			1						0						0	1
MOLLUSCA	Ancylidae (shell only)							0						0	1					1	1
	Hydrobiidae					1		1						0						0	1
	Lymnaeidae					1		1						0						0	1
	Physidae			1				1						0	1					1	2
ARANEAE	Lycosidae							0						0	1					1	1
	Pisauridae			1				1						0						0	1
	Unidentified						1	1						0						0	1
ACARINA	Arrenuridae	**1**						0						0				1		1	1
	Hydrachnidae							0				1		1			1			1	2
	Hydrodromidae							0						0			1			1	1
	Limnesiidae							0	1	1	1	1	1	1		1	1	1		1	2
	Pionidae							0	1					1						0	1
	Unioncolidae							0		1				1						0	1
AMPHIPODA	Ceinidae		1	1				1						0	1	1	1			1	2
	Perthidae			1				1						0						0	1
DECAPODA	Palaemonidae		1	1			1	1						0	1	1				1	2
	Parastacidae							0						0			1			1	1
ODONATA	Aeshnidae	**1**		1		1	1	1						0	1					1	2
		2	1					1						0						0	1
	Coenagrionidae			1				1						0						0	1
	Cordulidae					1	1	1						0	1		1			1	2
	Lestidae	**1**		1				1						0	1	1	1	1		1	2
		2						0						0	1					1	1
		3						0						0	1					1	1
	Libellulidae					1		1						0						0	1
	Megapodagrionidae							0						0		1				1	1
TRICHOPTERA	Leptoceridae		1					1						0						0	1
HEMIPTERA	Corixidae	**1**	1	1		1	1	1						0	1		1	1	1	1	2
		2	1	1	1	1		1		1	1	1		1		1				1	3
	Notonectidae		1	1			1	1						0	1			1		1	2
	Saldidae						1	1						0						0	1
	Veliidae						1	1						0						0	1
DIPTERA	Ceratopogonidae			1				1						0						0	1
	Chironominae	**1**					1	1	1			1		1		1	1			1	3
		2		1		1		1						0	1		1			1	2
		3				1		1		1				1						0	2
		4		1	1			1						0			1			1	2
		5		1	1			1						0	1			1	1	1	2
		6						0		1	1	1	1	1			1			1	2
	Culicidae	**1**					1	1		1	1	1	1	1				1		1	3
		2						0		1		1	1	1						0	1
		3						0	1	1		1	1	1						0	1
		4						0	1	1				1						0	1
	Orthocladiinae							0	1	1				1				1	1	1	2
	Simulidae							0						0					1	1	1
	Tanypodinae	**1**		1	1			1						0	1				1	1	2
		2						0						0			1	1		1	1
	Tipulidae							0				1		1						0	1
	Unidentified				1	1	1	1						0						0	1
COLEOPTERA	Dytiscidae	**1**						0				1		1		1				1	2
		2						0	1				1	1	1			1		1	2
		3						0	1	1	1	1	1	1	1			1		1	2
		4						0		1	1	1		1				1		1	2
		5						0						0				1		1	1
		6						0					1	1						0	1
		7						0		1				1	1					1	2
		8						0		1				1					1	1	2
		9						0						0	1					1	1
	Haliplidae			1				1						0						0	1
	Hydrophilidae							0	1	1	1	1	1	1	1	1	1			1	2
	Scirtidae							0						0		1				1	1
COPEPODA	Calanoida	**1**		1	1			1	1	1	1	1	1	1	1	1	1		1	1	3
		2						0		1	1	1		1		1	1	1		1	2
	Cyclopoida							0	1	1	1	1	1	1	1			1	1	1	2
OSTRACODA	Cyprididae	**1**			1			1						0	1	1	1	1	1	1	2
		2						0						0	1	1	1	1	1	1	1
		3						0		1		1		1	1	1	1	1	1	1	2
		4						0						0			1		1	1	1
	Darwinulidae					1	1	1						0						0	1
CLADOCERA	Chydoridae	**1**	1			1		1			1	1		1	1					1	3
		2			1			1						0						0	1
		3						0					1	1						0	1
	Daphniidae	**1**	1		1		1	1		1		1	1	1				1		1	3
		2				1		1	1	1	1		1	1						0	2
		3		1				1		1			1	1				1		1	3
Number of species per habitat			**9**	**20**	**11**	**13**	**13**		**12**	**22**	**12**	**19**	**15**		**26**	**15**	**20**	**20**	**13**		**78**
Total no of species								**40**						**31**						**50**	

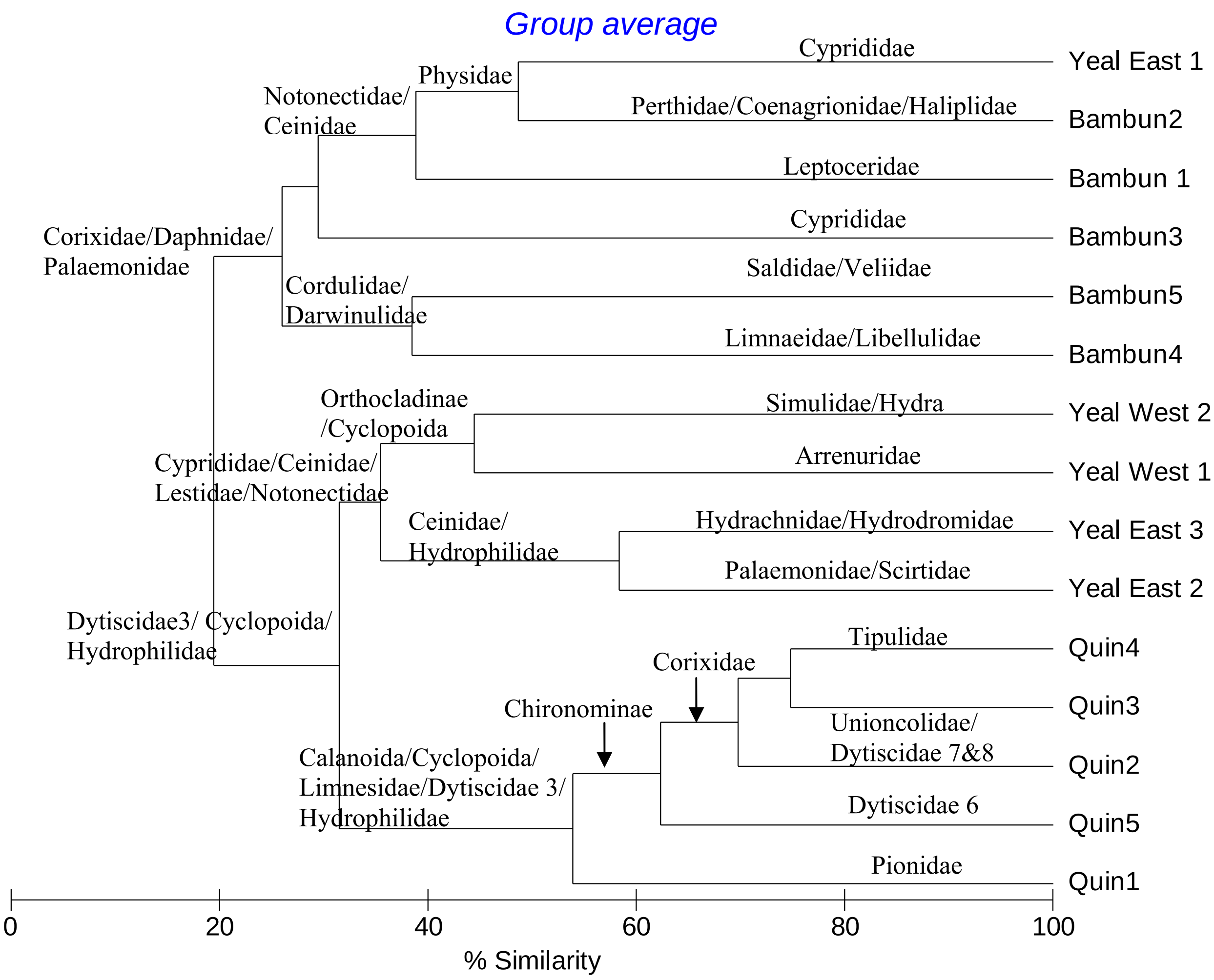


Figure 5.7: Hierarchical cluster analysis (group average mode) based on Kulczynski (presence/absence) similarities of sites characterised by aquatic macroinvertebrate assemblages of the three north-eastern Gnangara mound wetlands. The invertebrate groups upon which the groupings were based are overlayed.

6. GIS spatial layer of wetland invertebrate data (Objective 5)

This component of the project is being undertaken in collaboration with DEC GIS officers who will produce spatial models of invertebrate species (richness and endemism) in surveyed wetlands to allow overlay with other environmental parameters, such as remnant vegetation, time since fire, etc. CEM is providing relevant species compilations, including geographical locations with the help of the WIN dataset. We understand that spatial modellers from CSIRO are also involved.

Table 6.1 lists the wetlands in the GSS study area for which aquatic invertebrate data are available. A complete list of species, genera and families for each of the wetlands is available on request. Wherever possible the Unique Field Identifier (UFI) as listed in the WIN database is indicated in order to facilitate GIS mapping. For the monitored criteria wetlands, northings and eastings, and the WIN site identification numbers used by DoW (which is different from the UFI) are given. The northings and eastings indicated for the criteria wetlands refer to the location of the monitored staff gauges. The entire wetland (or the central point of the wetland) will have to be treated as the taxa locality because exact site positions are generally not available.

CEM will be happy to collaborate with DEC (GSS) in the further development of a GIS layer.

Table 6.1: Wetlands in the GSS study area for which aquatic invertebrate data is available. See text for explanation.

Easting	Northing	UFI (WIN)	WIN SITE ID	Wetland/Wetland System	Richness			No. named species	Rarity %	Endemism	
					Family	Genus	Species			%RE	LE
384260	6527891	9961		Gingin Brook Pool	30	48	53	34	6	5.9	0
376569	6535003	9961		Gingin Brook	32	32	32	0	19	0	0
375756	6509432	8010		Yanchep Caves	43	43	55	13	58	7.7	1
376024	6529875	10010		Tangletoe Swamp	26	34	38	20	0	10	0
374900	6508930	8010	14585	Loch McNess	76	87	89	28	13	25	0
375305	6508126	8011	14586	Lake Yonderup	68	88	92	36	11	5.6	0
375725	6505904	8022	10246057	Lake Wilgarup	26	28	28	3	0	0	0
375023	6505329	8012	10278971	Pipidinny Lake	56	58	58	3	10	0	0
377454	6504641	8015		Coogee Springs	59	86	98	46	9	4.3	0
378336	6502256	8009		Lake Carabooda	30	50	55	32	0	6.2	0
379746	6499839	8021	14588	Lake Nowergup	60	92	110	59	5	18.6	0
403242	6504577	8772		Muchea/Peter's Spring	43	61	62	24	42	8.3	1
398920	6497156	8367		Kings Spring	24	30	33	14	48	14.3	1
401428	6488972	13387		Bullsbrook Channel	13	14	14	4	36	50	0
403389	6493193			Bullsbrook Runnel	14	15	15	4	20	25	0
403389	6484444		23000099	Edgerton Spring	29	37	38	7	32	28.6	0
404835	6481778		23000098	Edgecombe Spring	11	13	13	0	8	0	0
405230	6482003	9099		Edgecombe Lake	22	27	27	10	15	30	0
401584	6491926	8646		Cooper Rd Swamp	12	17	17	5	18	0	0
403286	6493157	8784		Nursery Dam	21	27	28	15	36	6.7	0
407629	6486827			Ellen Brook Floodplain	25	32	33	18	21	16.7	0
408437	6486924			Ellen Brook Nature Reserve	33	59	67	30	54	23.3	0
408119	6490837			Ellen Brook Monitoring	33	33	33	0	18	0	0
406541	6489525	12266/7		Twin Swamps	49	108	135	75	44	22.7	0
381220	6495924	8019		Lake Neerabup	42	66	76	43	0	14	0
401754	6491898	8384	12865389	Melaleuca Park	47	75	84	37	6	16.2	0
401429	6486537		12282922	Lexia Wetland 86	34	34	34	0	3	0	0
401801	6487538		12282919	Lexia Wetland 186	19	19	19	0	11	0	0
387304	6489134	7953	14598	Lake Mariginiup	56	72	76	33	1	12.1	0
390818	6487087	15006	14599	Lake Jandabup	72	118	137	75	12	16	0
384239	6487399	7954	14593	Lake Joondalup	61	86	90	43	3	11.6	0
386269	6482629	8169		Beenyup Swamp	27	41	44	31	2	12.9	0
392389	6482374	8130	14612	Lake Gnangara	34	40	42	8	12	25	0
387838	6479242	8167	14538	Lake Goollelal	47	62	66	34	6	17.6	0
400510	6476409	8726		Mussel Pool	35	60	67	47	1	12.8	0
385243	6475222	8180		Big Carine Swamp	33	45	49	30	2	13.3	0
394242	6476523	15416		Malaga Wetlands (Emu Lake)	23	31	36	23	0	13	0
385702	6472425	8173		Lake Gwelup	33	53	55	35	4	5.7	0
400866	6514442	15168		Lake Chandala	34	64	72	38	6	10.5	0
389272	6466807	8183		Lake Monger	42	60	66	35	9	11.4	0
387170	6467696	8192		Herdsman Lake	38	60	63	37	8	13.5	0

7. Management considerations for the conservation of wetlands and wetland invertebrates on the Gnangara Mound (Objective 6)

This project component addresses the appropriateness of specific management actions, responses of the macroinvertebrate fauna, the potential cost of these interventions, and indicators and tolerance thresholds for aquatic macroinvertebrates in Gnangara mound wetlands. Strategies/options for the protection and retention of key wetlands are discussed, as are management options based on different hydrological scenarios.

The specific issues addressed in this section are:

- threats to wetland aquatic biodiversity
- management scenarios (factors influencing responses to declining water tables)
- aquatic macroinvertebrate response to management actions: case study of the acidic eastern Wanneroo wetlands
- indicators and tolerance thresholds (using the 13-year monitoring history of Gnangara mound criteria wetlands)
- cost of artificial augmentation of wetland water levels.

For this component of the project information has been drawn and compiled from various sources, including unpublished reports of CEM work funded by the Department of Water (the Acid Sulfate Soil Strategic Reserve Project; the Gnangara Mound Macroinvertebrate Monitoring Program), CEM published papers, and the unpublished PhD thesis of B. Sommer.

7.1 Threats to wetland aquatic biodiversity on the Gnangara mound

The threats that wetlands on the SCP are faced with have been alluded to in the introduction of this report (Section 1.2). In summary, they are:

- clearing of natural vegetation and insufficient buffer zones (mainly due to urban and rural expansion)
- planting of non-native vegetation, plantations etc.
- introduced aquatic weeds and pests
- altered fire regimes
- wetland drainage and infilling
- groundwater extraction
- pollution
- Nutrient enrichment
- climate change (declining rainfall)

With the exception of introduced aquatic weeds and pests, and to some degree perhaps pollution, all of these threats have the potential to alter the hydrological regime of wetlands. During the 1960's and 1970's large-scale clearing for the establishment of pine plantations and rural and urban development resulted in significant increases in surface water levels of most of the wetlands on the mound. This period was also characterised by higher rainfall than anytime since (**Figure 7.1**). The main impact of higher surface water levels is on aquatic macrophytes and fringing vegetation which will tend to move up-gradient if higher water levels are sustained

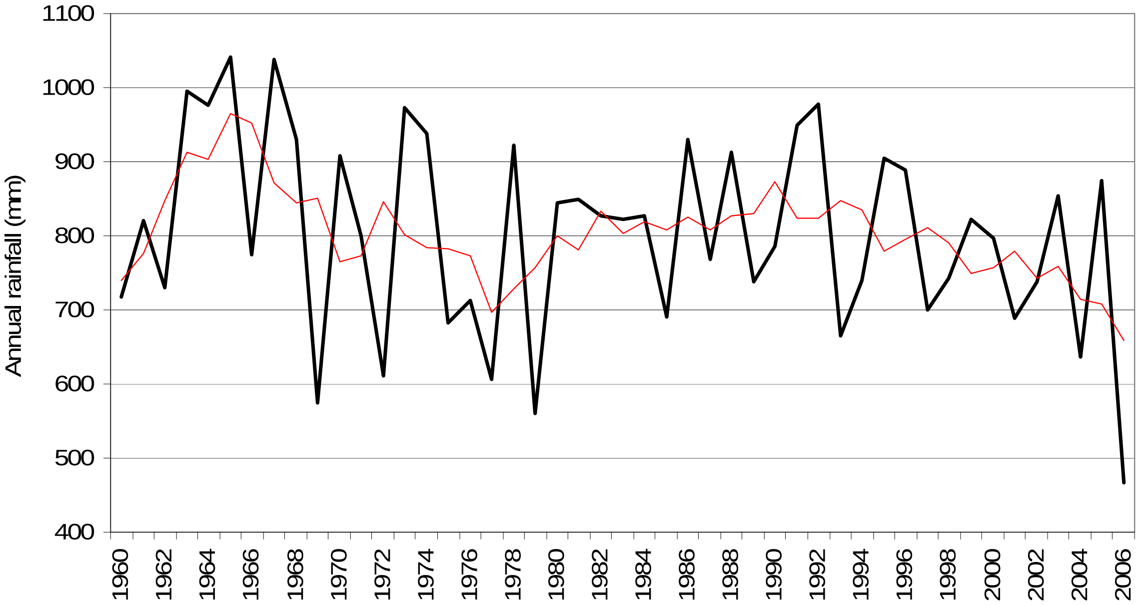


Figure 7.1: Perth Regional Office annual rainfall totals in mm 1960-2006, with 5 year moving averages. (Compiled from Bureau of Meteorology data)

(Froend *et al.* 1993). This will not necessarily have an adverse impact on the aquatic fauna, unless higher water levels are associated with changes in water quality (such as nutrient enrichment, pollution or increased salinity). For at least the past decade or so, Perth has been experiencing the opposite trend, namely decreasing rainfall, exacerbated by over-extraction of groundwater and maturing/mature pines. Consequently, the incidence of breeches of the set wetland water level criteria has been increasing for the monitored wetlands on the mound. It is probably fair to say that water allocation issues have become the principal business of wetland management agencies in Perth. Moreover, it is slowly being acknowledged that the biogeochemical impacts of these low water levels and drying may be more significant (ecologically and socially) and difficult to 'treat' than direct 'ecological impacts' *per se*. The two most common biogeochemical impacts of water table drawdown on the Gnangara mound wetlands are acidification and eutrophication. Of the two, acidification has received greater political attention recently because of the potential for downstream acid plumes which could be detrimental to human health. Furthermore, monitoring detected serious impacts on aquatic macroinvertebrate community structure (including local extinctions) at one of the wetlands (Lake Jandabup) following the prolonged summer drought of 1997/1998 (Sommer & Horwitz, 2001). However, eutrophication can also have serious health and ecological implications. The most publicised (locally) of these are nuisance midge (Chironomidae) swarms and unpleasant odours following drought and reinundation. These issues will be further discussed in terms of management scenarios in Section 7.2.

Declining water levels arguably constitute the most serious threat to the wetlands of the Gnangara mound, however the other threats mentioned at the beginning of this section remain. For example, the summer wildfires (particularly through arson) have become more frequent in Gnangara mound wetlands because of the dry conditions. The limited timeframe allocated for the aquatic biodiversity component of the project means that a detailed list of threats for Gnangara mound wetlands could only be compiled for the sixteen monitored wetlands (**Table 7.1**). However the sections of this report addressing Objective 1 have already dealt with threats and values in relation to specific aquatic invertebrate taxa.

Table 7.1: Summary of threats to the criteria wetlands of the Gnangara Mound (showing level of concern relative to threatening processes for wetland values; Adapted from: Sommer and Horwitz 2007).

Wetland	Overall Concern[1]	Water level[2]	Eutroph-ication	Acidi-fication	Susceptibility to fire[3]	Loss of vegetation	Loss of fauna	Terrestria-lisation	Introduced species
Coogee Spring	1	A	B	C	A	A	B	A	A
Gnangara	3	B	C	A	C	D	C	C	D
Goollelal	3	B	B	D	D	D	D	D	C
Jandabup *	2	A	C	A	B	C	B	D	B
Joondalup (N)	2	B	B	D	C	C	C	C	C
Joondalup (S)	2	B	A	D	D	C	C	A	B
Lexia 86	1	A	D	A	A	A	A	D	B
Lexia186a/b	1	A	D	A	A	A	A	C	B
Loch McNess (N)	1	A	B	D	B	B	C	A	A
Loch McNess (S)	3	A	B	D	C	D	C	D	B
Mariginiup	1	A	B	A	A	B	B	C	B
Melaleuca Park	1	A	C	A	A	C	A	C	B
Nowergup **	2	A	B	C	B	B	B	D	C
Pipidinny Swamp	3	A	B	D	D	D	C	B	C
Wilgarup	1	A	C	B	A	A	A	A	B
Yonderup	3	A	D	D	D	C	C	C	C

A: extreme concern. B: probable concern. C: possible concern. D: no immediate concern.

[1]Overall concern: Priority for management action as recommended to the DoW (based on level of concern across all issues, and need for new/extra response to alleviate significant risk);
1 = Urgent priority (immediate management action unavoidable)
2 = High priority (immediate management planning required)
3 = Management action required to address issues of concern (A or B);
4 = no management action required

[2] Level of concern *in the absence* of water level augmentation. "Extreme concern" includes where environmental water level criteria have breached.

[3] No evidence for immediate management action presented in this report

* Status determined providing augmentation continues
** Status determined *because* augmentation is continuing

Seven of the criteria wetlands have unavoidable management imperatives (which have been recommended to the DoW; see Sommer and Horwitz 2007) from the perspective of the impact of declining water levels, where the impacts are many and varied, depending on the wetland.

Commensurate with 2006 recording the lowest annual rainfall on record for Perth, all of the monitored, un-supplemented wetlands (with the exception of Lake Goollelal) had the lowest winter peak levels on record, and these water levels have continued to decline further in 2007/2008. Goollelal itself had the lowest winter peak since 1985, and of the supplemented wetlands, Jandabup had the lowest winter peak on record in winter 2006. Nowergup only reached the absolute preferred minimum in winter 2006, however increased artificial supplementation resulted in unusually high water levels in winter 2007. Coogee Springs, the Lexia wetlands and Lake Wilgarup have not contained surface water since winter 2005. Water levels at Loch McNess and Lake Yonderup (both high conservation value wetlands) are of grave concern. Since 2006 historically constant water levels have been severely declining. An investigation of the annual rainfall and peak spring water levels since records began revealed only a poor relationship for these two wetlands. It is speculated that this lack of correlation could be due to a number of inter-related factors over time, including extraction from nearby bore fields, increased evapo-transpiration by the prolific post fire vegetative growth around the wetland, and perhaps also to underlying sediments and lithology (e.g. peat, karst features) and localised pumping into Yanchep caves.

Lakes Jandabup, Pipidinny, Yonderup and Loch McNess remain the most macroinvertebrate family rich of the monitored wetlands, with Lake Jandabup recording both the highest richness in 2006/2007, as well has having the highest cumulative number of families. Permanently acidified Lake Gnangara always has the lowest number of invertebrate families, followed by Lake Goollelal. Analyses of the relationship between annual rainfall and invertebrate richness revealed that despite the low annual rainfall and the record low water levels, six of the wetlands had higher than average macroinvertebrate family richness in winter/spring 2006. In particular, in 2006/2007 lower water levels coincided with higher family richness in spring in a number of wetlands (Jandabup, Joondalup north, McNess south, Pipidinny and Yonderup). Explanations for these observations were given by Sommer and Horwitz (2007) as follows. When water levels are low, the wetlands may act as refuges for invertebrate fauna. Interestingly, the permanent of these wetlands (i.e. McNess south and Yonderup) showed the same inverse relationship between water level and family richness in summer, while the seasonal ones (Jandabup and Pipidinny) showed a more stronger, positive one in summer. The reason for this is probably that at the seasonal wetlands, although they may act as fauna refuges in spring when water levels are low, but most habitats are nevertheless inundated, in summer the low water levels result in reduced habitat availability, and hence lower family richness. For the majority of wetlands however associations between water level and family richness, or between annual rainfall and family richness, were weak to non-existent. These findings (once again) highlight the fact that conservation strategies based on the protection of wetlands that currently support a large number of species may not be reliable in the long term.

Two of the monitored wetlands consistently have pH values of less than 4; Lake Gnangara and Melaleuca Park, indicating that acidification remains a concern for wetlands on the Gnangara Mound. A number of other wetlands have shown signs of acidification in the past but have been dry for the past few years, as already mentioned (Wilgarup and the three wetlands in the Lexia wetland suite). At Lake Mariginiup where pH has been steadily declining over the past few years due to exposure of organic acid-sulfate sediments, the pH is currently also below 4. Aquatic macroinvertebrate response to acidification in the east Wanneroo acidic wetland suite (Lakes Mariginiup, Jandabup and Gnangara) is discussed in Section 7.3.

At Lake Nowergup, where artificial supplementation from the Leederville aquifer has been ongoing since 2002, a state change is hypothesized to have occurred: it is possible that the removal of seasonal fluctuations and the quality of the supplementation water, may have influenced macroinvertebrate assemblages and the ecology of the lake, rather than restoring it to some predetermined state.

In addition to the comments above, individual wetlands that warrant management action include:

- Coogee Springs, Lake Wilgarup, and the three Lexia wetlands all have organic rich sediments and are all currently dry, so their sediments are unable to resist a fire;
- Advancing terrestrialisation, elevated nutrient levels and algal blooms are symptomatic of the relationship between urbanisation and changed water regimes at Lake Joondalup (South). The management imperative here extends to catchment approaches;
- Loch McNess (north) where the spread of *Typha* continues unabated, possibly exacerbated by low water levels;
- Loch McNess (south) where the spring has decreased its discharge;
- Several wetlands continue to have elevated nutrient levels, principally Lake Joondalup. Low water levels in this lake may concentrate and warm waters, making algal blooms more likely.

It is to be expected that other (un-monitored) wetlands on the mound are experiencing similar threats to those listed above. In terms of water level decline, wetlands situated towards the top of the mound are experiencing even greater declines (Vogwill 2004). Unfortunately, it is precisely these wetlands that have been identified in this report as containing invertebrate (and fish) species with restricted distribution, as well as containing poorly-studied aquatic vegetation communities.

7.2 Scenarios for management of wetlands on the Gnangara mound threatened by declining water levels

The biota of wetlands are adapted to particular water regimes, including periods of drought. On the SCP, however, decreasing rainfall, over-extraction of groundwater and poor land management practices have resulted in <u>excessive and/or prolonged drying</u> in wetlands. When this occurs, the physical and biogeochemical processes initiated in the sediments when they dry will be more pronounced, the effects on water quality upon reflooding, more extreme, and potential recovery more difficult. As mentioned above, two specific problems commonly associated with drying wetland sediments are eutrophication (and associated algal blooms, malodours and nuisance insect swarms) and acidification (and associated problems such as heavy metal mobility, etc.). The severity of such impacts depends on a number of factors, sediment characteristics (particularly the type and amount of organic matter present) arguably being the most important of these (McComb and Qui 1998). Organic sediments (peat) are particularly susceptible to acidification upon exposure because they can contain large stores of pyrite. On the other hand, organic sediments are also a sink for nutrients, which are released into the water column (potentially causing eutrophication), after the re-inundation of dried sediments. Apart from distributional changes of flora and fauna (which can lead to habitat loss) caused by a potentially permanent change in hydrological regime, it is mainly the drought-induced changes in water quality that affect the biota of lacustrine systems. Hence, it is important to understand the geochemical processes involved when sediments dry and are re-inundated.

On the Gnangara mound (and elsewhere), the characteristics of sediments present in a wetland are good indicators of the change that can be expected in response to drying and rewetting

(Sommer 2006). The wetlands on the Gnangara mound support most of the known types of wetland sediments found elsewhere on the planet. These range from different sized particles of quartz grains and other mineral components to biogenic materials such as marl, peat, diatomite and various organic 'oozes' (see Semeniuk and Semeniuk 2004). Often an individual wetland will support a combination of a number of these sediment types. There is also considerable variation in the types and amounts of important elements (e.g. carbon, iron, phosphorus, nitrogen, etc.) present in the different wetland sediments (see Davis *et al.* 1993). Because of this it is to be expected that each individual wetland will respond somewhat differently to water level drawdown and drying. Hence, although it generally makes sense to manage wetlands from a watershed perspective, certain management objectives can only be met if wetlands are managed individually.

Four relevant generalized scenarios resulting from declining wetland water levels are considered: (1) eutrophication from the exposure of nutrient-rich floc; (2) acidification from the exposure of sulfidic sediments; (3) fire from excessive drying of catchment and wetland vegetation and organic sediments; and (4) loss of biodiversity due to decreased inundation of habitats.

Scenario 1: Eutrophication from floc exposure

A number of wetlands on the mound feature suspended detrital floc (colloquially referred to as 'false bottom' and sometimes as 'metaphyton'). Sommer (2006) characterized suspended floc from Lake Goollelal (the first time this common sediment type has been characterized for the SCP). Her work suggests that suspended detrital floc plays a very important, if not dominant, role not only in the biogeochemical cycling of elements and in the physical characteristics of the water body, but also in its ecological functioning. Suspended detrital floc at Lake Goollelal is sulfidic and exceptionally rich in nitrogen and phosphorus. In terms of declining water level, the floc also has an important function because it is the first part, and often the only part, of the wetland's sediments to become aerated and subsequently dry. The following scenarios (1a and 1b) apply to both floc overlying organic or peat sediments (e.g. Lakes Goollelal, Nowergup, Yonderup, Loch McNess), and floc overlying largely mineral sediments (e.g. Lake Joondalup, Pipidinny Swamp).

Scenario 1a: The initial scenario is where the water level falls to the surface of the floc layer, then refills. This is generally speaking an undesirable situation for the wetland to be in for any length of time. Concentration of nutrients in the surface- and porewater and increased solar irradiation will likely cause algal blooms, exacerbating anaerobic conditions below (by increasing oxygen demand of decaying algal biomass). However, incubation experiments carried out by Sommer (2006) imply that the increase in nutrient concentration (specifically phosphorus) will probably be solely from evapo-concentration and not from anaerobic release from the floc itself. Moreover, another study Wong (2003) suggests that at least some of the increase in phosphorus concentration may be sequestered by the floc. Once taken up by the floc, the phosphorus is unlikely to be released again, so long as the floc does not dry. In this respect then, reduction of the water level roughly to the surface of the floc might have a positive effect in lowering nutrient concentrations once the lake has refilled. This point has implications for artificial water level maintenance of eutrophic wetlands. For instance, much water could be saved if the summer water level were allowed to drop to the surface of the floc layer, rather than maintaining higher water levels.

Midge plagues during the low water stage (assuming water temperature does not exceed the tolerances of the midges) however could be an outcome, especially in the event that the water level should further decline. Concentration of nutrients, as well as of the floc, a suspected food of midge larvae, would spur this on. Aeration of some or all of the floc layer, e.g. in the event of strong winds, would be unlikely to have any significant effects, based on Sommer's (2006) incubation studies, in spite of the high iron sulfide content of the Gollelal floc. A small amount of sulfate may be released, however this would probably quickly be taken up by algae and microbes. In this scenario sediment bulk characteristics alone (e.g. high P and N concentrations, certain elemental ratios, etc.) would not be helpful in predicting 'expected change'. This is because the apparent structural characteristics of the floc (which are as yet poorly understood) play an overriding role in determining floc behaviour. It was found that the Lake Goollelal floc was relatively inert regardless of oxygen concentration, so long as it remained hydrated and its structure had not been destroyed by drying. It is quite possible that all types of organic detrital floc found in SCP wetlands behave in this manner, however, this is something that requires confirmation through further experimental work.

Expected outcomes of scenario 1a: the possibility of midge plagues during low water phase; unlikely deterioration of water quality after refilling and possibly even improved water quality upon refilling due to nutrient uptake by the floc during low water phase.

Potential management action for scenario 1a: None required.

Scenario 1b: The second part of this scenario is where the water level falls further and the floc actually dries. Once the floc dries, it is likely to become permanently part of the consolidated sediment (Childers *et al.* 2003; Sommer 2006). This has a number of significant consequences. For example, it will no longer be available as a sink for nutrients and other pollutants. Drying ruptures the floc structure, and substantially increases the bioavailability of phosphorus (Sommer 2006). Upon re-inundation there will be a huge pulse of phosphorus and nitrogen into the water column. This can be expected to spur on intense primary productivity (and associated problems) and probably quickly reinstate anaerobic conditions in the hypolimnion. **Figure 7.2** shows such an 'instant algal bloom' at Lake Joondalup following the first autumn rains after the long, dry summer of 1997/1998. In spite of the high pyrite content of the (Lake Goollelal) floc, acidification is unlikely for two reasons. Firstly, organic coatings formed during drying provide temporary protection from excessive oxidation, and secondly the quick re-instatement of anaerobic and eutrophic conditions would prevent this. The high productivity, reinstatement of anaerobic conditions, and the adequate supply of iron and calcium from the infill water create a

Figure 7.2: Instant algal bloom upon rewetting of a nutrient-enriched wetland (Lake Joondalup, summer 1998). (Photo: B. Sommer)

situation conducive to the (re-)formation of suspended detrital floc. However, it is not known how quickly these form. It may possibly require many decades to build up to the depths (~0.5 m) encountered at Lake Goollelal today. At Lake Joondalup though, suspended detrital floc appears to quickly redevelop after seasonal draw down on an annual basis. At this wetland though, there is no peat, and the mineral component of the sediment (including the floc) consists primarily of calcite.

Expected outcomes of scenario 1b: severe ongoing eutrophication (until the floc layer can be re-established).

Potential management action for scenario 1b: Prevent floc from drying (however the costs of achieving this, e.g. artificial pumping of groundwater, should be weighed up against the benefits of keeping some or all of the floc hydrated).

Scenario 2: Acidification from the exposure of sulfidic sediments

On the Gnangara mound this scenario relates primarily to wetlands with organic, sulfidic sediments. Again two sub-scenarios are presented: one where suspended detrital floc is present, and one where this is absent.

Scenario 2a: In this scenario the water level falls well below the peat surface (in a wetland that does not support floc), and the peat dries. A very intense drought, or long-term drawdown of the water table would be required to create this scenario. This is because peat has a very strong water-holding capacity (Fuchsman 1986). Drying causes some irreversible changes in the peat, in particular the susceptibility to mineralization is increased, and the peat's water holding capacity is decreased, so that it will dry more rapidly in future drawdown events. In this scenario, the wetland sediments are very susceptible to fire (see below). This scenario would be rare in the history of organic-rich wetlands because it is contra-indicative to the build-up and persistence of organic sediments.

Upon reinundation, the sediment will initially resist wetting due to the organic coatings formed during drying (leading to water repellency) and other physical changes in the peat. Eventually however, the oxidised peat will release H_2SO_4 into the water column, along with much of the sediment calcium, and acidification will result if the infill water does not contain enough buffering material to neutralize the acids formed. The large amounts of iron released from the oxidation of pyrite (plus perhaps iron provided by the infill water) would remove much of the phosphorus in the water column.

Expected outcomes of scenario 2a: High vulnerability to fire during the dry phase. Permanent physical changes in sediment properties. Acidification of the water column upon re-inundation, and erosion of pH buffering leading to future acidification if the drying/wetting is repetitive in well-buffered systems.

Potential management action for scenario 2a: Prevent peat from drying (however the costs of achieving this, e.g. artificial pumping of groundwater, should be weighed up against the benefits of keeping some or all of the peat hydrated).

Scenario 2b: In this scenario the water level also falls well below the peat surface in a wetland that supports floc, and both the floc and the peat dry. All of the processes during the dry phase described under scenario 2a will occur, but upon re-inundation, both the peat and ex-floc will initially resist wetting due to water repellency. Eventually the organic coatings dissolve and substantial amounts of phosphorus and nitrogen (primarily from the ex-floc) will immediately be released into the water column. Thus, anaerobic conditions may be reinstated before the peat (and ex-floc) can oxidize to any considerable degree. Some H_2SO_4 will be released though, along with calcium and other base elements.

Expected outcomes of scenario 2b: High vulnerability to fire during the dry phase. Permanent physical changes in sediment properties. Eutrophication of the water column. Acidification of the water column possible if drying/wetting is repetitive in well-buffered systems due to the loss of buffering materials.

Potential management action for scenario 2b: Prevent peat and/or floc from drying (however the costs of achieving this, e.g. artificial pumping of groundwater, should be weighed up against the benefits of keeping some or all of the peat and/or floc hydrated).

Scenario 3: Fire from excessive drying of catchment and wetland vegetation, and organic sediments

Scenario 3a: This scenario follows from scenario 2 above where drought has resulted in drawdown to below the peat surface. In this scenario, the wetland sediments are very susceptible to fire (a growing problem on the Gnangara mound). Some peat fires on the Gnangara mound have burnt underground for months (e.g. Pipidinny Swamp, Coogee Springs, Lake Wilgarup, and most recently Lake Neerabup) creating a human health hazard, and ecological problems associated with acidification of the water column. The loss of organic matter decreases the ability of the sediments to become reduced after re-inundation. Although water-repellency may provide some temporary protection, fire will cause the sediments to oxidize more severely than simple drying. The large amounts of iron released from the oxidation of pyrite (plus iron provided by the infill water) would remove much of the phosphorus in the water column, ultimately reducing the rate of organic matter additions to the sediments, exacerbating the problem. If the wetland contained a nutrient-rich suspended detrital floc, acidification may be abated to some degree (as described above), however, wetlands on the mound prone to burning tend not to support floc. This appears to be because wetlands with peaty sediments are comparatively deep (and hence only the wetland perimeters would burn), while the shallower ones (e.g. Lake Joondalup) have a calcareous floc overlying largely mineral sediments (which will not burn).

Expected outcomes of scenario 3a: Acidification of the water column after post-fire re-inundation.

Potential management action for scenario 3a: Prevent peat and/or floc from drying (however the costs of achieving this, e.g. artificial pumping of groundwater, should be weighed up against the benefits of keeping some or all of the peat and/or floc hydrated). Fuel reduction and other fire management techniques in the catchment.

Scenario 3b: Water quality, and hence biodiversity, can however also be affected if the actual wetland does not burn, but the surrounding vegetation does. The dissolvable and erodible residue of a fire will generally find its way into a wetland, changing water quality. Vegetation ash derived from the surrounding catchment is typically alkaline and rich in extractable Mg, Ca and K (Gimeno Garcia *et al.* 2000). Because of this, the pH of receiving water bodies tends to increase following a catchment fire (Ranalli 2004). It is also well known that, depending on the intensity, fire releases varying types and quantities of soil nutrients, which will also be washed into wetlands. Increased water yield due to the destruction of vegetation and litter cover, and reduced infiltration resulting from the development of water-repellency of catchment soils following fire, can be expected. Hence, wetlands whose sediments have not been directly impacted by the fire (including ones with pyritic organic sediments) may experience higher water levels following fire, possibly with increased pH and nutrient enrichment.

Fire can therefore have completely contrasting effects on aquatic ecology, depending on whether surface water following fire becomes acidic and low in nutrients, or alkaline and nutrient enriched. The effects of increased alkalinity and nutrient levels tend to be short-lived (see for instance Earl and Blinn 2000), however, recovery from acidification can be relatively slow, particularly if much organic matter were lost from the wetland (Sommer and Horwitz 2008, subm.). In addition to these water quality effects, in well-vegetated catchments, removal by fire of the shade and organic matter provided by riparian cover, and the removal of catchment leaf litter, may temporarily at least reduce organic matter input. Fire will expose the wetlands to more sunlight, elevated temperatures and greater levels of water column and overall wetland photosynthesis. Trophic dynamics in wetlands may therefore temporarily shift from heterotrophy to autotrophy (particularly if increased solar irradiation is combined with nutrient enrichment). However, there is a complication. Although increased light penetration may favour algal growth, Schindler *et al.* (1996) have shown that decreases in an enzyme (alkaline phosphatase) due to ultra-violet radiation could increase P-stress in low nutrient aquatic environments. Bothwell *et al.* (1994) further found that solar UV-B radiation can reduce the photosynthesis and growth of benthic diatom communities in shallow freshwater, while paradoxically the growth of other algae is increased. They also found that increased UV-B radiation inhibits algal consumers (especially Chironomidae) more than the algae they consume, thus contributing to counterintuitive increases in algae in habitats exposed to UV-B.

Expected outcomes of scenario 3b: Possible temporarily increased water level, alkalinity and nutrient enrichment. Changes in solar irradiation and temperature due to loss of shading. Temporarily decreased inputs from catchment dissolved and particulate organic matter.

Potential management action for scenario 3: Fuel reduction and other fire management techniques in the catchment.

Scenario 3c: A last, but common, scenario is where attempts are made to extinguish or suppress fire in the wetland or its catchment, or to prevent fire from spreading into a wetland. Fire suppression commonly uses retardant chemicals and fire suppressant foams that are toxic to aquatic organisms including algae, aquatic invertebrates and fish (Hamilton *et al.* 1996). Hence, fire-control managers need to consider protection of aquatic resources from toxic effects, especially if endangered species are present. Another technique employed for extinguishing fires is flooding with water extracted or diverted from a nearby source, which has the potential for translocation of unwanted aquatic species, the accidental removal of endangered species (Jimenez and Burton 2001) or deleterious water quality changes. Trenching has also been applied to attempt to arrest the progress of burning peat in organic-rich soils in south-western Australia. When the flooding or drenching involves any digging of organic soils, or construction of trenches, the possibility is raised of exposing acid sulfate soils to aeration and developing a localized acidification event.

Expected outcomes of scenario 3c: Water toxicity due to the use of chemical fire retardants. Risk of introduction of unwanted aquatic species, accidental removal of endangered species or deleterious water quality changes from suppression water diverted from an outside source. Possible increased acidification risk where trenching or digging of ASS has occurred.

Potential management action for scenario 3a: Fuel reduction and other fire management techniques in the catchment. Caution should be taken when using chemical fire retardants and/or extinguishers. Caution should be taken when translocating water from nearby sources. Caution should be taken when digging trenches in acid sulfate soil areas.

Scenarios 3a, 3b, and 3c can of course all occur simultaneously and interact in a given wetland, depending on the situation. An in-depth review of water quality responses to fire (with particular reference to organic-rich wetlands on the SCP) and effects on aquatic biota is given in Horwitz and Sommer (2005).

Scenario 4: Loss of biodiversity due to decreased inundation of habitats

Besides the various drought-induced changes in wetland water quality, the loss of habitat through decreased inundation can also lead to direct loss, or at least changes in aquatic biodiversity. For example, hydrological disconnectivity can prevent fish and other aquatic fauna from moving into certain reaches of streams, rivers or other wetlands. In the medium to long term, a change to a drier hydrological regime will result in the shrinkage of wetland area, as the more water dependent plants move downslope, while the outer boundaries are taken over by terrestrial plants (Froend *et al*. 1993). Ultimately, this can result in the loss of the wetland, and a changeover to a terrestrial system. The hydrologic regime has profound effects on the reproduction, growth and distribution of aquatic plants (Boon *et al*. 1996). This can be influenced by drought-induced changes in nutrient availability (as discussed above). Drying-induced changes in vegetation pattern can in turn themselves affect nutrient dynamics (Serrano *et al.* 2003). Competition can be a significant constraint on the successful re-establishment of wetland vegetation (Budelsky and Galatowitsch 2000). A wetting-drying regime can prevent the build-up and development of organic sediments in wetlands and therefore the redox environment at the sediment-water interphase. This in turn will also influence the type of vegetation growing there. Aquatic plants affect the introduction of oxygen and carbon substrates into sediments, and hence a change in their distribution will tend to impact on microbes (Boon *et al.* 1996), as well as nutrient availability (Serrano *et al.* 2003).

The distribution of aquatic vegetation and available habitat types determine the distribution and abundance of macroinvertebrates. It can be reasoned that wetlands with permanently, as well as seasonally inundated zones will support a wide range of vegetation hydrotypes. This diversity in habitat types will necessarily also support a rich aquatic macroinvertebrate fauna (assuming good water quality). The presence of different hydrozones would also provide refuges for aquatic fauna in times of drought that would not be available in the more shallow, seasonal wetlands (that regularly completely dry). This most likely explains why aquatic invertebrate taxa richness at Lake Jandabup (and some other Gnangara mound wetlands) is inversely correlated with wetland water level (and rainfall; see Section 3.6.1). Therefore, whilst aquatic biodiversity may be (temporarily) lost from dry wetlands, it may increase, perhaps also temporarily, in those wetlands that retain water and suitable habitats. Sommer and Horwitz (2008, subm.) also found that declining water levels do, also temporarily, reduce the total number of invertebrate families and those that remain are represented by very few individuals (i.e. become rare; see also below).

Potential management action for scenario 4: Prevent excessive decline in wetland water levels (however the costs of achieving this, e.g. artificial pumping of groundwater, should be weighed up against the benefits of keeping some or all of the aquatic habitats inundated).

7.3 Aquatic macroinvertebrate response to management actions and thresholds of tolerance issues: Case study of the acidic eastern Wanneroo wetlands

Management actions that have been employed for Gnangara mound wetlands include rehabilitation of fringing vegetation, clearing of *Typha orientalis* and other aquatic weeds, re-alignment or removal of stormwater drains, reduction and/or cessation of fertilization of parklands surrounding wetlands, and public education campaigns. These actions are mainly aimed at improving habitat conditions for aquatic biota and reducing nutrient concentrations, as well as enhancing the aesthetic values of the wetlands. In addition, a number of lakes (e.g. Lake Monger, Lake Joondalup, Lake Goollelal) are sprayed regularly (using Temephos© or Sumilarv©), and light traps have been installed, in an attempt to control chironomid midges.

These management actions are mainly employed in the urban wetlands of the mound, where urbanisation has caused huge increases in the amounts of nutrients flowing into the wetlands (and public pressure tends to entice agencies into action). Aquatic macroinvertebrate fauna respond to all of these management actions. However because the main concerns of the GSS are the effects of declining groundwater levels and biodiversity, this section of the report will focus on this aspect.

When regulation of public water supply and private abstraction fail to achieve the stipulated minimum water level criteria, the conventional management option for wetlands on the Gnangara mound is to artificially supplement affected wetlands with groundwater. This is done for two reasons: (1) to avoid loss of aquatic habitat (i.e., scenario 4 above; e.g. Coogee Springs and Lake Nowergup); and (2) to maintain or reinstate anaerobia in the sediments (in order to prevent or reverse acidification, i.e. scenario 2 above; e.g. lake Jandabup). A third reason could be to prevent fire from entering a wetland (i.e. scenario 3 above), however artificial supplementation of water levels has not been applied to any wetland on the mound so far for the purpose of keeping fire out. Whilst eutrophication and pollution issues are more relevant to urban wetlands, declining groundwater levels affect all of the wetlands on the mound. Due to limited resources (both financial and actual water) management agencies are faced with the dilemma of having to prioritise between wetlands considered to have ecological and/or social values ‘worthy’ of artificial supplementation and ones that are better ‘written off’ (i.e. left to dry). The Gnangara Mound macroinvertebrate monitoring program has now been running for some twelve years and Sommer and Horwitz (2008, subm.) recently used the resulting dataset to identify key biotic (aquatic macroinvertebrates) responses to episodic or permanent acidification, and assess how aquatic macroinvertebrate dynamics respond to the management strategies such as artificial supplementation. The study focussed on three wetlands: Lakes Jandabup, Mariginiup and Gnangara which resulted in an analytical design that enabled macroinvertebrate dynamics to be compared between the following ‘ecological state’ scenarios:

1. episodic/sudden acidification followed by intervention and recovery (Lake Jandabup);
2. gradual erosion of buffer capacity in the absence of intervention leading to either an alternative permanently acidified state (as in 3. below), or to recovery (as in 1. above), depending on the position of the water table; the wetland is in a transition state (Lake Mariginiup);
3. buffer capacity exhausted and in a permanently acidified steady state (Lake Gnangara).

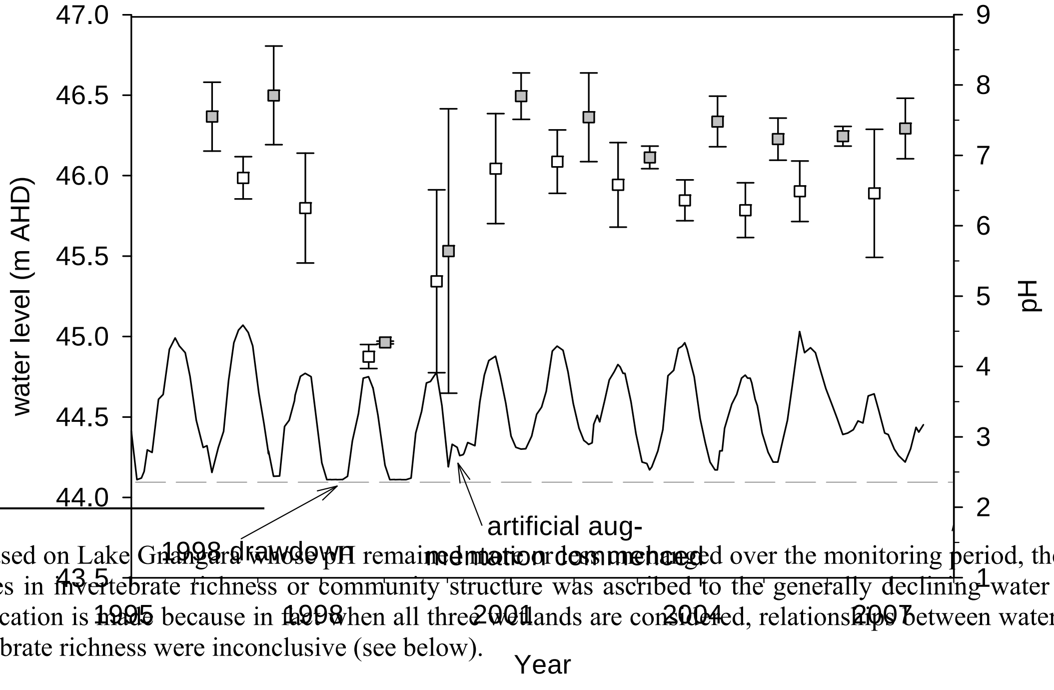
The research design also enabled some distinction to be made between the effects on macroinvertebrates of acidification, declining water levels and artificial supplementation. In short, it was found that acidification caused decreased summer invertebrate taxa (family or higher) richness in Lakes Jandabup and Mariginiup, but no change in spring richness. In terms of community structure, there were clearly identifiable groups of acid-sensitive taxa (Ceinidae, Planorbidae, Cyprididae, Amphisopidae, Sphaeridae, Caenidae, Daphnidae, Oligochaeta), which either became locally extinct, or decreased in abundance; and acid-tolerant taxa (mainly Ceratopogonidae, Macrothricidae, Corixidae, Dytiscidae, Chironomidae, Hydrophilidae, Notonectidae, Aeshnidae, Lestidae, Limnichidae), which increased in abundance. Lake Gnangara, the perpetually acidified ‘control’ is composed entirely of acid-tolerant taxa. Acidification furthermore resulted in a tendency towards rarity.

Water level decline* resulted in reduced taxa richness in both summer and spring, and there was also a tendency towards rarity. The effect of declining water levels on community structure could not be determined due to the lack of an un-acidified control. Functional feeding groups were also affected by both acidification and declining water levels, suggesting some impact on the ecological functioning of the wetlands. The main effects of acidification were decreases in filter feeder abundances (mainly ostracods, copepods and Sphaeridae) and gatherer-collector richness (e.g. aquatic snails, mayflies and amphipods). The main effects of declining water levels were decreases in both richness & abundances of predators, and decreases in gatherer-collector & mixed feeder abundances. Therefore both acidification and declining water levels, either on their own or synergistically, will impact on invertebrate community structure and trophic relationships within wetlands.

Aquatic invertebrate responses to artificial augmentation

Artificial augmentation at Lake Jandabup was successful at restoring pH to pre-acidification levels, almost immediately (**Figure 7.3**). It also reversed the effects of acidification (as described above) on the aquatic fauna, although this did not occur as soon as pH recovered **(Figure 7.4)**. The highly sensitive amphipod, *Austrochiltonia subtenuis*, for example reappeared in the wetland three years after commencement of augmentation. Today all of the invertebrates that have disappeared from Lake Jandabup have returned. However, abundances of the identified acid-sensitive have not entirely reached pre-acidification levels (**Figure 7.4**). This may be an artefact of the fact that only two years of pre-acidification data are available, or it may be due to the effects of artificial augmentation (see below).

The main and most apparent effects of artificial augmentation on the aquatic invertebrates were that there was a number of taxa that either increased in abundance or appeare d for the first time since augmentation ('augmentation beneficiaries': Cnidaria, Ancylidae, Caenidae, Baetidae, Turbellaria, Arrenuridae, Hydrachnidae Mesoveliidae, Stratiomydae, Calanoida), and there was a marked increase in summer family richness (**Figure 7.4**). The increase in summer richness most likely reflects increased inundation of habitats in summer due to artificial augmentation. It is also possible that the abundances of the acid-sensitive invertebrates have not yet entirely reached pre-acidification abundances due to competition with the augmentation beneficiaries. These observations imply that artificial augmentation can only be regarded as partially successful: it



* This is based on Lake Gnangara whose pH remained more or less unchanged over the monitoring period, therefore any changes in invertebrate richness or community structure was ascribed to the generally declining water levels. This clarification is made because in fact when all three wetlands are considered, relationships between water levels and invertebrate richness were inconclusive (see below).

Figure 7.3: Hydrograph of Lake Jandabup showing pH since commencement of the monitoring program. Shaded symbols represent summer, clear winter, pH. Error bars are standard errors. Peaks on the hydrographs are peak spring, and troughs lowest summer/autumn water levels. The grey dashed line shows the level at which the majority of the lakebed is dry. (Source: Sommer 2006)

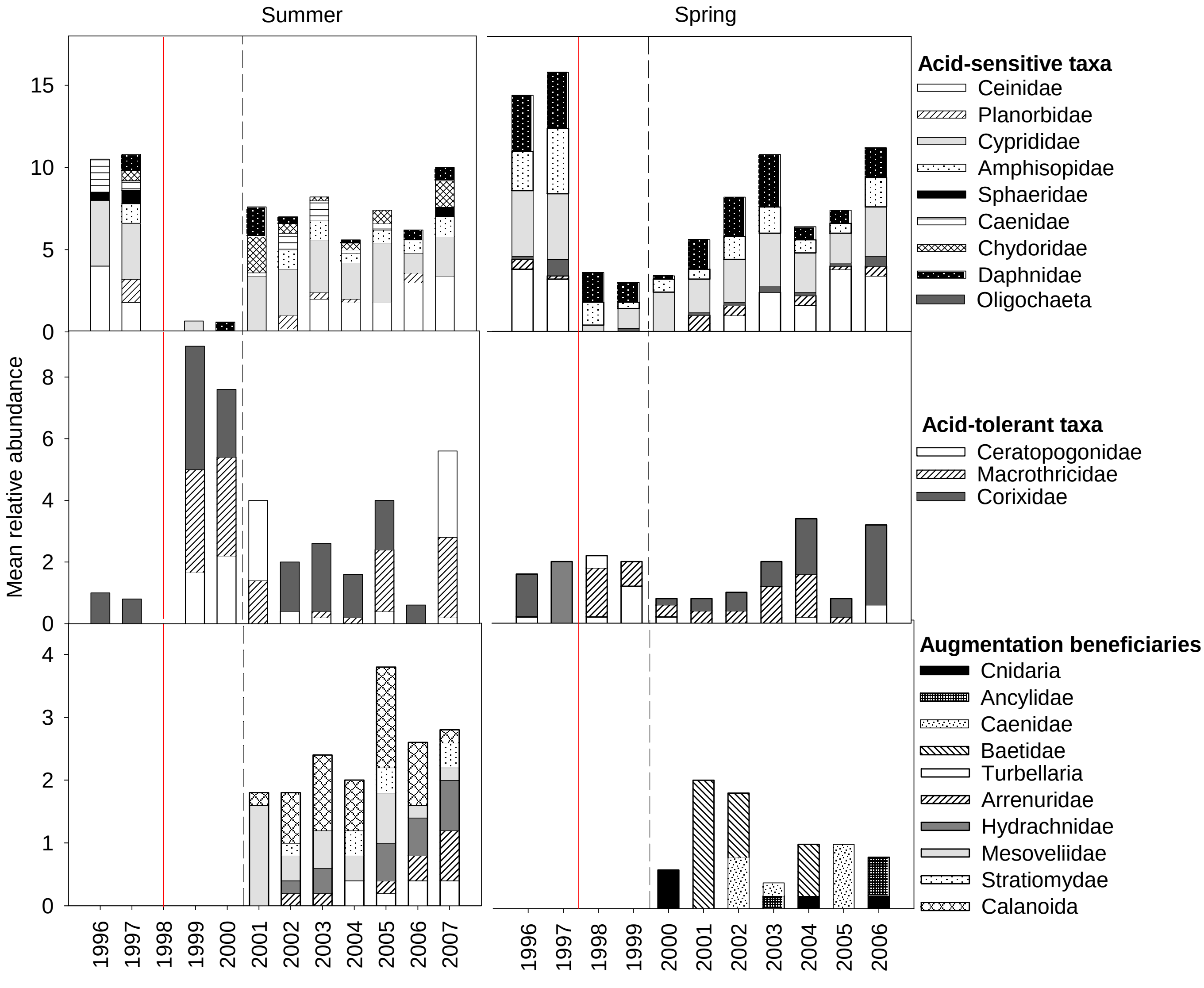


Figure 7.4: Macroinvertebrate taxa response groups at Lake Jandabup. The solid line denotes the 1998 draw-down, the dashed line commencement of artificial augmentation of water levels. (Source: Sommer and Horwitz 2008, subm.)

was successful at reinstating lost and reduced macroinvertebrate families, but the community structure is somewhat different than pre-augmentation. In addition, it must be noted that some of the structural changes observed at Lake Jandabup may have been partially caused by the elimination of *Gambusia holbrooki* after the draw-down of summer 1998 (and its failure to re-establish post-augmentation). Likewise, some of the observed changes are as much likely to be due to changes in competition and predator-prey relationships, as to the direct effects of acidification or low water levels (Ledger and Hildrew 2005).

The conclusion, however, is that artificial augmentation of surface water as a management tool (by reinstating anaerobia in the sediments) can indeed reverse the effects of drawdown-induced acidification and lead to recovery of macroinvertebrate community structure. Success will of course depend on a number of factors, such as whether enough buffer capacity remains in the sediments. The Jandabup case has further demonstrated that although successful at reversing the effects of acidification, artificial augmentation will inevitably change the system in another direction, i.e. the 'recovered' state will be slightly different to the original state. In addition, it will constitute an ongoing effort, will use a valuable resource relatively inefficiently (see Section 7.5), and will exacerbate, not address, the root causes of the problem, namely over-extraction of water and declining rainfall.

7.4 Indicators and thresholds of change

In order to assess the potential suitability of individual measured environmental variables as tolerance threshold criteria, Sommer and Horwitz (2008, subm.) performed various multivariate and correlation analyses. The most relevant of the monitored variables with regards to water level decline and acidification are water level and pH.

For flat, shallow wetlands it is reasonable to expect higher water levels to be associated with higher macroinvertebrate richness because of the increased availability of inundated habitat. Indeed invertebrate richness is higher in spring (when rainfall and surface water levels are higher) than in summer in all three acidic east Wanneroo wetlands. However, the relationship between invertebrate richness and water level <u>within the individual seasons</u> was weak to non-existent. There was however an inverse relationship between spring invertebrate richness and peak spring water levels at Lake Jandabup, contrary to the two un-supplemented wetlands (Lakes Gnangara and Mariginiup). As already discussed elsewhere in this report, one explanation for this could be that when water levels are low, the wetland may act as a refuge. Another may simply be that invertebrates are more concentrated in the restricted number of available habitats. Because water level readings (i.e. staff gauges) and depth measurements do not extend beyond the lakebed (i.e. do not reflect the severity of draw-down), correlations between rainfall and family richness were carried out. As before, the relationship between total annual rainfall and invertebrate richness was poor at Lakes Gnangara and Mariginiup. At the artificially augmented Lake Jandabup, however, there were inverse associations between both spring and summer family richness and total annual rainfall ($r = -0.678$, $p<0.02$, and $r = -0.572$, $p<0.100$ respectively). In general, the relative inconclusiveness of these analyses (which were also carried out for the remainder of the 16 monitored wetlands with similar results) is most likely due to extrinsic factors such as artificial supplementation in the case of Jandabup, groundwater extraction, and differences in evaporation rates. Multivariate analyses (non-metric multi-dimensional scaling and principal component analysis) also failed to find any significant relationships between these variables and invertebrate dynamics (Sommer and Horwitz 2008, subm.). These analyses lead to the conclusion that neither water depth, water level, or even annual rainfall would make good threshold criteria.

When all three wetlands were considered together, there were significant positive relationships between family richness and pH overall ($r = 0.559$, $p<0.001$), in summer ($r = 0.559$, $p<0.01$), and in spring ($r = 0.746$, $p<0.001$). However, <u>within individual wetlands</u> this was not the case. The only significant relationship was at Lake Mariginiup, where higher summer family richness was actually associated with lower pH (r= -0.775, $p<0.05$). At the other two wetlands relationships between pH and family richness were weak and inconclusive. The lack of convincing relationships between pH and invertebrate richness within the individual wetlands suggests that pH may not be the ideal ‘master parameter’ upon which to base management decisions for wetlands threatened by acidification. pH *per se* gives no indication of a system’s capacity to buffer acid inputs and thus reveals little about the acid sensitivity of a site. In the case of Lakes Jandabup and Mariginiup, for example, organic anions (these wetlands being slightly to moderately humic-stained) may also contribute to low pH. The organic anions in turn will not necessarily lower acid neutralising capacity (ANC; Sullivan *et al.* 1989), and moreover, may ameliorate the potential toxicity of dissolved metals such as Al^{3+}. In this regard the data set of the monitoring program to-date still lacks many chemical variables that would be useful for assessing the acid sensitivity of the resident aquatic macroinvertebrate fauna.

The monitoring program was originally designed to monitor the effects of groundwater extraction (i.e. the direct effects of water levels) on vegetation and aquatic fauna; the prospect of drawdown-induced acidification was not considered at the time (Balla and Davis 1993; Water Authority of W.A. 1995). Given that today many wetlands (in addition to the three investigated here) on the Gnangara mound are threatened by acidification, it would be advisable to include in the chemical data set at least ANC, titratable alkalinity/acidity, the full set of major anions and cations, and potentially toxic metals (especially aluminium). As a monitoring tool, ANC (determined as the difference in equivalent concentrations between base cations and acid anions) is particularly useful because it can provide an early warning sign in the form of eroding buffer capacity, and management intervention can take place before all of the alkalinity is consumed. Time to depletion of ANC, which can take decades, can easily be estimated (Stumm and Morgan 1996).

For the three investigated wetlands, the monitoring program was able to detect biological indicators of change (i.e. the ‘acid-sensitive’, ‘acid-tolerant’ and ‘augmentation beneficiary’ invertebrates), but only after the changes had occurred; it was not able to pick up early warning physico-chemical indicators which, if acted upon, may have prevented some of the biological changes from occurring. The long-term goal of identifying site-specific thresholds of change, can only be achieved once environmental parameters are available that can be better linked to the macroinvertebrate fauna.

7.5 Cost of artificial augmentation of wetland water levels (Lake Jandabup)

For this component of the project, historical pumping data were obtained from the Water Corporation who are responsible for maintaining water levels at Lake Jandabup. Water is sourced from the superficial aquifer. Two decommissioned production bores are used for pumping (W220 and W210). They are located some 2 km east of the lake in the Gnangara pine plantation. The recharge scheme originally commenced in April 1989 and water was pumped sporadically into the lake between then and 1995 (however no data could be obtained for this early stage of the scheme). Between February 1995 and May 1996, 808,833 kl were pumped into

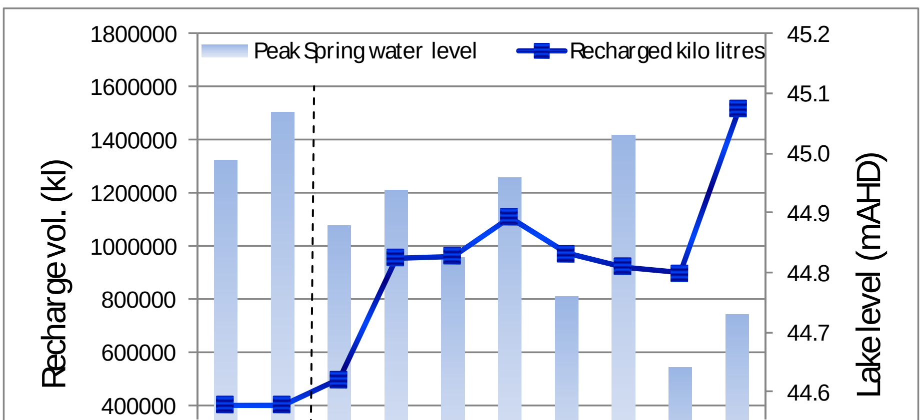


Figure 7.5: Volumes of groundwater recharged into Lake Jandabup and peak spring water levels from 1995 to 2007. The dashed line signifies the break between 1996 and 2000 (see text).

the lake. Supplementation ceased in May 1996 and recommenced in January 2000 and has been ongoing to this day. Between January 2000 and December 2007, 7,843,391 kl were pumped into the lake. There is no set pumping schedule, that is, water is pumped into the lake in summer as well as in winter (Brendan Bradley, pers. comm.). No significant correlations were found between the amount of water pumped and rainfall, nor between the amount pumped and peak spring water levels. One might think that when rainfall is higher, comparatively less water would have to be pumped into the lake. Or, that the more water is pumped into the lake, the higher the water levels should be. The dilemma of course is that whilst one is pumping during the year, one does not know what the total annual rainfall for that particular year will be. It is a little discomforting, nevertheless, that in 2007 the historically highest volume of water pumped into the lake coincided with the second lowest spring peak in the time series displayed (**Figure 7.5**). This may due to the well below average rainfall experienced in Perth in 2006 and 2007. There may, however, also be hydrological reasons (e.g. changes in hydraulic gradients due to the combined effects of pumping, which can cause localised mounding under the lake, and the regional drawdown of the groundwater table).

In terms of the actual costs associated with the scheme, 'real' figures were obtained from the Water Corporation (Joe Miotti, pers. comm.). These include initial installation costs of infrastructure and annual costs of maintenance, monitoring, etc. (**Table 7. 2**). These costs however do not include the value of the groundwater. A more detailed study would be required to work this out. As an indication though one could take, e.g., the domestic water charge of \$1.66/kl for volume usage >950 kl/a. This is the price for treated water. However, were one to deduct the cost of treatment, one would most likely arrive at a negative figure. The fact is that the price of water in Perth does not reflect the costs of providing it, let alone the environmental costs. The charge for non-residential water use is somewhat lower, namely \$1.03/kl. If, for the purpose of this exercise, one takes \$1/kl, this would amount to a total of:

8,652,224 kl x \$1.00 = **\$ 8,652,224**

for the period between 1995-2007. This equates to an average yearly 'cost' of \$865,222. One could then add to this the yearly maintenance costs of \$25,000, and say the annual costs of replenishing the lake is ~\$890,222. The total 'value' of the scheme since commencement, (\$8,652,224 (water) + \$250,000 (\$25000 x 10 years) + \$550,000 (installation costs)), would equate to \$9,452,224.

Is the aquatic biodiversity of Lake Jandabup worth nearly \$10m? Because the price of \$1/kl is hypothetical, the answer to this question will probably depend on two things: how we use the dwindling water in the mound, and whether we as a society can afford to use for this purpose, not only a scarce resource, but one that is thought to be essential for the maintenance of human wellbeing. Of course not all of the water pumped into the lake is lost from the aquifer. Some of it does inevitably find its way back. Nevertheless, with Perth's high evaporation rates, much of it will end up in the atmosphere.

The calculations presented here could be similarly done for the replenishment scheme of Lake Nowergup, which receives water from the Leederville aquifer. The Coogee Springs supplementation scheme was abandoned because the wetland was no longer able to hold pumped water. A cynical conclusion could be that eventually we may have to top up all 16 of the criteria wetlands. Using the calculations and arguments presented above, this would 'cost' the tax payer ~$16m/year. This is indeed cynical because artificial supplementation can be appropriate under certain circumstances (as the successful example of Lake Jandabup has shown). However, one must be very aware, as mentioned elsewhere in this report, that such a management strategy is trying to solve one problem whilst exacerbating another. Because of this, wetland supplementation schemes in Perth should be supported by somewhat more rigorous scientific backing than they appear to be at the present time.

Table 7.2: Actual and hypothetical costs associated with the Lake Jandabup artificial supplementation scheme.

Items	Details	Establishment costs	Annual costs
Installation costs	Bore installation Pump Pipelines Overhead power line installation	$ 550,000	
Ongoing costs	Sampling/monitoring Salaries Maintenance		$ 25,000
'Value' of water	Based on an arbitrary cost of $1/kl	($1 x 865,222 kl)	$ 865,222
Total annual 'costs'			**$ 890,222**

8. Conclusions and recommendations

This contract has allowed the completion of work commenced three years ago in which all records for aquatic macroinvertebrate taxa collected from wetlands on the Swan Coastal Plain in the general Perth metropolitan area were compiled in order to determine patterns of macroinvertebrate richness in wetlands, and the contribution that restricted or local endemism, or taxon rarity, make to this richness. In addition, thirteen years of monitoring Gnangara Mound wetlands as part of the "Wetland Macroinvertebrate Monitoring Program of the Gnangara Mound Environmental Monitoring Project" (Department of Water) has provided the opportunity to assess long-term trends and other issues, not normally within the scope of the yearly reporting. The main aim of this research was to identify wetlands that can be regarded as being particularly rich or otherwise significant for their invertebrate components. We trust that this investigation will help focus management objectives for wetlands on the Swan Coastal Plain in general, and Gnangara Sustainability Strategy area in particular, particularly where they can be shown to have significance based on their invertebrate faunal assemblage.

The main conclusions and recommendations that emerge from this report, as they relate to the contracted six objectives, are summarized below.

1) Regional/local endemism and rarity do not, in general, markedly contribute to taxa richness in wetlands of the SCP, and this appears to contrast with other bioregions of south-western Australia. For SCP wetlands, levels of richness and endemism have been attributed to geologically recent colonizing forces associated with the geological formation of the plain, which have allowed invertebrate colonization from multiple directions: the cooler southern, the warmer northern, and from Darling Scarp wetlands. Rare invertebrate taxa, on the other hand, appear to be associated with rare wetland types harbouring very specific (and perhaps unusual) microhabitats (and often also other rare biota). High priority wetlands with 'significant' invertebrate fauna in terms of aquatic invertebrate richness, endemism and/or rarity include:

- aquatic habitats in a cave system in karstic areas around Yanchep;
- permanent deeper surface waters in northern linear chain wetlands of the Spearwood interdunal system;
- tumulus springs (organic mound springs) in the Ellen Brook region of the eastern Gnangara mound;
- surface waters in the Ellen Brook region of the eastern Gnangara mound; and
- habitat complexes in large shallow wetland systems on the Bassendean Dune system.

The greatest threat to wetlands on the SCP at the current time are declining surface water levels (and associated water quality problems) brought about by a combination of climate change, groundwater extraction and changes in land use. It would be unrealistic to allocate the same amount of management resources to all of these threatened wetlands. Equipped with the information presented in this report, wetland management can be more wetland-specific, focusing on wetlands identified as being 'significant' in terms of aquatic invertebrates, rather than on other common criteria such as wetland type (e.g. *sensu* Semeniuk 1987). This is all the more pertinent since it is precisely these significant or unusual wetlands that are currently under the greatest threat from declining groundwater levels.

2) In terms of habitat specificity, the emerging overall pattern is that the eastern Bassendean wetlands (i.e. Melaleuca Park and the Lexia wetlands) formed outliers both in terms of vegetation communities as well as in invertebrate assemblages. The fact that these wetlands were also 'under-sampled' compared to the other monitored wetlands suggests that management

efforts should be intensified in these areas in order to be able to properly compare their biodiversity values with the more intensively monitored wetlands. Unfortunately it is also these eastern Gnangara mound wetlands that are suffering most from declining water levels.

3) The review of fish biodiversity on the mound suggests that fish populations occurring towards their northern distribution limits (some areas of which fall just north of the GSS study area), or in roadside pools or other 'unfashionable' habitats, are only rarely sampled. Past and/or future sampling regimes may fail to record these northern, possibly relict populations before they become extinct. In terms of the GSS, and for the Swan Coastal Plain in general, there is a case for conducting a systematic survey of freshwater fish, using proven, rigid methods designed for fish surveys (and not simply relying on incidentally-caught fish whilst targeting aquatic invertebrates). In doing so, attention should also be devoted to the endemic freshwater fish of the northern/northeastern area of the mound (ideally including the area just north of Moore River). In the meantime, management efforts should continue to focus on the conservation of the known threatened communities on the mound such as Bennett and Ellen Brook.

4) The review of the status of aquatic invertebrates, habitat specificity of the invertebrates, and also the review of the status of freshwater fish on the Gnangara mound (Objectives 1, 2 and 3 of this report) all point to aquatic biodiversity data lacking from

- the more or less permanent black-water wetlands in the north-eastern section of the mound (including the area just north of Moore River; and
- portions of the Pinjarra Plain.

CEM has conducted strategic sampling of Lake Bambun, Yeal lake and Quin Brook in September 2008. The snap-shot survey has partially filled in a gap in our general knowledge of aquatic invertebrate biodiversity on the Gnangara Mound. However, a longer-term data set is required if we are to better understand the complexity of aquatic biodiversity in this little-studied area of the Mound.

5) For the GIS aquatic biodiversity layer, CEM has so far provided relevant species compilations, including geographical locations with the help of the WIN dataset. We understand that this component of the research is ongoing and CEM will be happy to assist with the further development of a GIS layer for the GSS biodiversity component.

6) Threats to Gnangara mound wetlands are manifold, the most pressing, as has often been repeated, being declining water levels. Wetlands situated towards the top of the mound are experiencing the greatest declines. Unfortunately, it is precisely these wetlands that have been identified in this report as containing invertebrate (and fish) species with restricted distribution, as well as containing poorly-studied aquatic vegetation communities.

Wetland management scenarios with regards to declining water levels often depend on the types of sediments present. Wetlands supporting nutrient-rich detrital floc will tend to become eutrophic if they dry, wetlands with pyrtic peat will tend to acidify. Where both sediment types coexist, the buffering properties of the floc will tend to override, at least temporarily (and especially where the floc is a calcareous one), the oxidative effects of the peat.

Dry wetlands will be susceptible to fire. Fire can have completely contrasting effects on aquatic ecology, depending on whether surface water following fire becomes acidic and low in nutrients, or alkaline and nutrient enriched. The effects of increased alkalinity and nutrient levels tend to be short-lived while recovery from acidification can be relatively slow. Catchment effects (e.g. the removal of shade) have the potential to shift trophic dynamics from heterotrophy to autotrophy. Fire suppressant chemicals, digging trenches in ASS areas, and translocating water for the purpose of extinguishing fires in wetland can have adverse affects on aquatic biota.

The loss of habitat through decreased inundation can lead to direct loss, or at least changes in aquatic biodiversity. Processes are complicated though, because wetlands retaining aquatic habitats during times of drought may act as refuges, and show increased invertebrate richness, in spite of low water levels. Invertebrate richness as an indicator for environmental health must therefore always be regarded with caution.

Artificial augmentation of surface water as a management tool (by reinstating anaerobia in the sediments) can reverse the effects of drawdown-induced acidification and lead to recovery of macroinvertebrate community structure. Success will depend on a number of factors, such as whether enough buffer capacity remains in the sediments. The Lake Jandabup case has demonstrated that although successful at reversing the effects of acidification, artificial augmentation will inevitably change the system in another direction, i.e. the 'recovered' state will be slightly different to the original state. In addition, it will constitute an ongoing effort, will use a valuable resource relatively inefficiently, and will exacerbate, not address, the root causes of the problem, namely over-extraction of water and declining rainfall.

The 'Wetland Macroinvertebrate Monitoring Program of the Gnangara Mound Environmental Monitoring Project' which has been running since 1996, was able to detect biological indicators of change in three wetlands affected by drought-induced acidification, but only <u>after</u> the changes had occurred; it was not able to pick up early warning physico-chemical indicators which, if acted upon, may have prevented some of the biological changes from occurring. The long-term goal of identifying site-specific thresholds of change, can only be achieved once environmental parameters are available that can be better linked to the macroinvertebrate fauna.

Artificial supplementation can be appropriate under certain circumstances (as the successful example of Lake Jandabup has shown). However, one must be very aware that such a management strategy is trying to solve one problem whilst exacerbating another. Because of this, wetland supplementation schemes in Perth should be supported by somewhat more rigorous scientific backing than they appear to be at the present time.

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Appendix 1: Reference materials sourced for the establishment of the database of all known aquatic invertebrates recorded in wetlands of the SCP

The reference materials sourced for the establishment of the database of all known aquatic invertebrates recorded in wetlands of the SCP are outlined below. For each source, an abbreviation is used, plus a brief comment on the nature of the database, and the sampling protocol used to obtain the invertebrate information (which was subsequently used to calculate the effort index).

<u>AusRivAS</u>: the Australia-wide Monitoring River Health Initiative using a standardized rapid bioassessment sampling protocol (Smith, Kay *et al.* 1999) included data from two sites in the study area (Gin Gin Broook and Ellenbrook). These data, collected between August 1994 and May 1996, are under the custodianship of the Western Australian Department of Environment and Conservation. Flowing wetlands were sampled twice yearly for three years, using a 250 μm mesh net over 10 m length of habitat, in 3 different types of habitat in a 100 m section of wetland. Invertebrate samples were sorted live and picked for 60 minutes. Taxa were usually identified to family level.

<u>B&D</u>: Balla and Davis (1993) reports on Shirley Balla's PhD work undertaken in 1988 and 1989 and subsequently published as a Volume of the Wetlands of the Swan Coastal Plain series. Five wetlands were sampled intensively (every three weeks over a 13 month period). Samples were collected over one 50-m section of wetland in 1 m units with a 250μm mesh net. Samples were preserved and sorted with the aid of a microscope, with identification to species level.

<u>B&H</u>: the Western Australian Water and Rivers Commission (today the Department of Water) have funded rapid bioassessment of 16 selected iconic and important wetlands on the Gnangara Mound, documented in annual reports (Benier and Horwitz 2003). Monitoring took place biannually (spring and late summer/early autumn) for nine years up to and including summer 2003. Sampling was done by sweeping with a 250μm mesh net for two minutes in 3, 4 or 5 habitats (depending on habitat heterogeneity). Samples were live-picked for 30 minutes and identified to family level. Some taxa (e.g. oligochaetes) were not differentiated beyond Class level identification.

<u>D&C</u>: Davis and Christidis (1997) have compiled previously known records of invertebrates, bringing together the work undertaken by Balla and Davis (1993), Davis et al (1993) and other work (see below). The book includes Pinder's Oligochaeta identifications of material held at Murdoch University. This source was not used to calculate the effort index.

<u>Detal</u>: probably the most systematic attempt to survey the macroinvertebrate fauna of wetlands on the Swan Coastal Plain was undertaken by Davis et al. (1993), commonly referred to as "the 40 wetland study". Wetlands were sampled three times in two years (1989 and 1990) in spring and summer. Six samples from randomly selected areas, usually in open water, were sampled with a 250μm mesh net; samples were preserved and picked in the laboratory with the aid of a microscope. Identification was to species level where appropriate.

<u>DHNC</u>: Davis et al.(2006) conducted an *in situ* test of methods used to collect invertebrates and monitor wetlands by comparing sampling and sorting techniques used by Davis et al. (1993), and the rapid bioassessment techniques (i.e. Benier and Horwitz 2003; Wild, Davis *et al.* 2003).

<u>English</u>: English et al. (2003) and Knott and Storey (2004) report the fauna collected from five caves with aquatic root mat habitats and a surface stream in Yanchep National Park. Aquatic root mat communities were sampled by taking a small portion of the root map,

keeping it cool and aerated and transporting to the laboratory where it was sorted and live-picked. The authors report the fauna collected by Jasinska (1997). The taxonomic list provided by Knott and Storey (2004) is used as the verified data, which consolidates uncertain taxa into higher level categories.

Hpc: Halse pers. comm., unpublished data. For the purposes of analyses in this paper the sampling for invertebrates was taken to be similar to Halse and Storey (1996) below.

H&G: Hembree and George (1978) and members of the Western Australian Museum give the earliest record of a systematic attempt to document fauna of wetlands on the Swan Coastal Plain. Sampling occurred every two months (monthly for Lake Jandabup) over one year 1977-8, in the dominant habitats. Macroinvertebrates were collected by sweep net (500μm mesh pore size) and by benthic corer. Zooplankton were collected with a 50 μm mesh. Samples were preserved and sorted by microscope, and identified to species where possible.

H&S: Halse and Storey (1996) undertook aquatic invertebrate surveys of the Perth Airport swamps. One site per wetland was sampled. Because all wetlands were part of a local suite they are considered together for this study. Two samples were collected in 1995, one in early spring, one in late spring, using a 110 μm mesh net swept over a 50 m stretch of mixed habitat. Samples were preserved and sorted under a microscope, and taxa were identified to species level wherever possible.

Jas: Jasinska (1998) reports on the monitoring of tumulus springs. Macroinvertebrates were sampled from water flowing out of the springs, and from surface waters receiving flowing waters (wetland areas), using techniques as per J&K below.

J&K: The work of Jasinska & Knott (1994) records the aquatic fauna in Gnangara Mound discharge areas of the Ellen Brook catchment. These discharge areas included tumulus mound springs and their receiving surface wetland areas. Sweep nets were used for surface waters, and plastic tubing was used to siphon water out of the mouth of the spring. Samples were sieved, retaining material above 50 μm in size, and live-sorted in the laboratory under a microscope.

Ketal: Kinnear et al.(1997) collected monthly samples over 15 months in 1992 and 1993 from Lakes Joondalup and Goolellal, and Beenyup Swamp from randomised sites within each wetland. A net (70 μm mesh) was used to sweep the water column for 1 minute Samples were preserved, sorted in the laboratory and identified to species level where possible (except Oligochaete and Hirudinea taxa).

KJ&S: Knott et al. (2002) document the invertebrate fauna collected from Melaleuca Park Wetland EPP 173 during spring 1995 and spring 1997.

L92: Lund (1992) sampled six sites at Lake Monger monthly. Samples were taken by sweeping a net (250 μm mesh) throughout the water column within an area of $0.5m^2$ over 20 seconds. Samples were preserved then sorted in the laboratory, and invertebrates were identified to species where possible.

L&O: Lund and Ogden (2003) report on work carried out in 2002-2003 at Mary Carroll Park Wetlands. Up to seven sites per wetland were sampled each season, depending on the extent of the water. Samples were taken by sweeping a net (500 μm mesh) throughout water column, over 5 m transects for 20 seconds. Samples were preserved then sorted in the laboratory, and invertebrates were identified to species where possible.

P02: Pinder (2002) reported on the fauna of three springs of the Gnangara Mound, sampled once in 2002.

WDS: : the Western Australian Water and Rivers Commission (today the Department of Water) have funded rapid bioassessment of selected iconic and important wetlands on the Jandakot Mound, documented in annual reports (Wild, Davis *et al.* 2003). Monitoring took place biannually (spring and late summer/early autumn) for nine years up to and including summer 2003. Sampling was done by sweeping a 250μm mesh net for two minutes in 3, 4 or 5 habitats (depending on habitat heterogeneity). Samples were live-picked for 30 minutes and identified to family level. Some taxa (e.g. oligochaetes) were not differentiated beyond Class level identification.

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*Typha orientalis*					*Baumea articulata*					*T. orientalis/B. articulata*					Mixed Cyper		
	total visits	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*	*times found*	*Percent*
(Hydra)	139	2	1.4	1.3	2.5	99	1.00	1.01	0.48	1.06	59	1	1.7	2.08	4.2	59	6	10.2
NEMATODA	139	1	0.7	0.8	2.4	99	3.00	3.03	1.43	3.19	59	2	3.4	4.17	8.3	59	0	0.0
NEMERTINI	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
PORIFERA	139	3	2.2	2.0	2.8	99	3.00	3.03	2.48	4.33	59	1	1.7	1.92	3.8	59	1	1.7
TURBELLARIA	139	39	28.1	18.2	23.9	99	5.00	5.05	2.96	4.32	59	8	13.6	20.83	25.0	59	5	8.5
TEMNOCEPHALIDEA	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Hirudinea	139	38	27.3	25.4	22.2	99	15.00	15.15	14.93	17.79	59	5	8.5	12.26	17.1	59	7	11.9
Oligochaeta	139	60	43.2	39.5	30.1	99	40.00	40.40	24.27	30.05	59	27	45.8	52.56	18.7	59	20	33.9
Ancylidae	139	4	2.9	2.9	5.5	99	3.00	3.03	2.01	2.75	59	0	0.0	0.00	0.0	59	2	3.4
Lymnaeidae	139	6	4.3	4.0	8.8	99	4.00	4.04	3.53	4.22	59	2	3.4	4.17	8.3	59	4	6.8
Physidae	139	62	44.6	42.4	29.9	99	20.00	20.20	17.90	34.96	59	16	27.1	25.24	17.9	59	0	0.0
Planorbidae	139	18	12.9	10.0	12.2	99	9.00	9.09	7.06	6.90	59	18	30.5	27.00	17.9	59	9	15.3
Hydriella	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Sphaeriidae	139	5	3.6	1.7	4.9	99	1.00	1.01	1.05	2.35	59	5	8.5	5.77	7.4	59	1	1.7
Lycosidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Tetragnathidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Pisauridae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Unidentified	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Arrenuridae	139	12	8.6	12.5	14.2	99	2.00	2.02	2.00	4.47	59	3	5.1	2.88	5.8	59	9	15.3
Astigmata	139	1	0.7	1.0	2.7	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Eylaidae	139	3	2.2	2.0	3.9	99	0.00	0.00	0.00	0.00	59	3	5.1	5.05	6.2	59	0	0.0
Halacoroidea	139	0	0.0	0.0	0.0	99	3.00	3.03	3.16	7.06	59	0	0.0	0.00	0.0	59	0	0.0
Hydrachnidae	139	12	8.6	10.2	13.0	99	3.00	3.03	2.48	4.33	59	2	3.4	4.09	5.9	59	3	5.1
Hydrodromidae	139	5	3.6	4.5	6.3	99	3.00	3.03	3.29	3.84	59	0	0.0	0.00	0.0	59	2	3.4
Limnocharidae	139	1	0.7	0.3	1.0	99	3.00	3.03	3.00	6.71	59	1	1.7	0.96	1.9	59	0	0.0
Limnesiidae	139	29	20.9	23.1	25.2	99	14.00	14.14	15.50	6.31	59	8	13.6	13.06	4.0	59	2	3.4
Oribatida	139	6	4.3	4.7	4.9	99	10.00	10.10	12.41	8.86	59	1	1.7	1.92	3.8	59	7	11.9
Oxidae	139	6	4.3	3.5	5.2	99	5.00	5.05	2.38	5.32	59	3	5.1	6.25	12.5	59	3	5.1
Pionidae	139	45	32.4	35.5	27.0	99	17.00	17.17	13.96	18.47	59	7	11.9	16.51	22.6	59	7	11.9
Unidentified	139	18	12.9	12.4	10.5	99	8.00	8.08	5.96	6.44	59	8	13.6	15.30	12.2	59	5	8.5
Unioncolidae	139	7	5.0	5.5	6.9	99	15.00	15.15	16.54	27.59	59	10	16.9	18.91	19.8	59	11	18.6
Ceinidae	139	56	40.3	32.2	27.8	99	37.00	37.37	33.44	38.68	59	31	52.5	46.31	20.2	59	35	59.3
Perthidae	139	0	0.0	0.0	0.0	99	3.00	3.03	5.45	12.20	59	0	0.0	0.00	0.0	59	0	0.0
Amphisopidae	139	66	47.5	49.3	33.4	99	15.00	15.15	14.95	20.96	59	7	11.9	8.89	11.1	59	29	49.2
Janiridae	139	1	0.7	1.6	4.4	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Palaemonidae	139	38	27.3	19.9	32.6	99	41.00	41.41	26.62	32.15	59	30	50.8	55.85	46.4	59	21	35.6
Parastacidae	139	4	2.9	2.7	4.5	99	14.00	14.14	20.69	24.54	59	3	5.1	3.85	4.4	59	4	6.8
Caenidae	139	8	5.8	4.9	4.9	99	16.00	16.16	12.13	13.46	59	5	8.5	9.05	2.3	59	11	18.6
Baetidae	139	17	12.2	9.9	9.5	99	30.00	30.30	20.82	24.63	59	12	20.3	25.16	15.3	59	19	32.2
COLLEMBOLA	139	2	1.4	1.3	2.5	99	2.00	2.02	0.95	2.13	59	2	3.4	5.05	6.2	59	0	0.0
MECOPTERA	139	1	0.7	1.6	4.4	99	13.00	13.13	6.19	13.84	59	0	0.0	0.00	0.0	59	0	0.0
Sisyridae	139	0	0.0	0.0	0.0	99	15.00	15.15	7.14	15.97	59	0	0.0	0.00	0.0	59	0	0.0
Aeshnidae	139	50	36.0	40.6	20.5	99	31.00	31.31	38.98	23.71	59	16	27.1	26.12	8.0	59	26	44.1
Coenagrionidae	139	27	19.4	18.1	7.9	99	14.00	14.14	16.98	22.90	59	24	40.7	36.22	24.1	59	18	30.5
Cordulidae	139	19	13.7	15.7	10.2	99	19.00	19.19	17.61	15.24	59	8	13.6	14.34	13.9	59	11	18.6
Gomphidae	139	3	2.2	3.8	8.8	99	8.00	8.08	3.81	8.52	59	6	10.2	6.73	9.1	59	1	1.7
Lestidae	139	54	38.8	39.9	20.3	99	27.00	27.27	36.36	28.44	59	19	32.2	23.72	27.3	59	30	50.8

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	***Typha orientalis***					***Baumea articulata***					*T. orientalis/B. articulata*					Mixed Cyper		
	total visits	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***
Libellulidae	139	18	12.9	11.4	11.6	99	12.00	12.12	14.28	17.19	59	14	23.7	22.20	17.4	59	21	35.6
Macrodiplactidae	139	0	0.0	0.0	0.0	99	1.00	1.01	1.82	4.07	59	0	0.0	0.00	0.0	59	0	0.0
Megapodagrionidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	1	1.7
Synthemidae	139	0	0.0	0.0	0.0	99	1.00	1.01	0.48	1.06	59	1	1.7	0.96	1.9	59	0	0.0
Ecnomidae	139	10	7.2	5.2	6.5	99	12.00	12.12	17.41	27.30	59	2	3.4	5.21	6.3	59	5	8.5
Hydroptilidae	139	22	15.8	10.2	13.1	99	20.00	20.20	10.05	19.79	59	12	20.3	25.08	22.4	59	15	25.4
Leptoceridae	139	70	50.4	51.4	27.4	99	61.00	61.62	46.09	35.69	59	38	64.4	61.06	31.0	59	39	66.1
Corixidae	139	90	64.7	62.6	31.3	99	55.00	55.56	55.51	22.92	59	23	39.0	40.63	37.3	59	18	30.5
Gerridae	139	5	3.6	7.2	17.5	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	9	15.3
Hebridae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Hydrometridae	139	1	0.7	1.0	2.7	99	1.00	1.01	0.48	1.06	59	0	0.0	0.00	0.0	59	1	1.7
Mesoveliidae	139	9	6.5	8.1	8.2	99	13.00	13.13	11.46	9.49	59	3	5.1	7.29	8.6	59	12	20.3
Nepidae	139	0	0.0	0.0	0.0	99	4.00	4.04	4.35	3.41	59	1	1.7	2.08	4.2	59	5	8.5
Notonectidae	139	68	48.9	54.5	26.9	99	32.00	32.32	33.32	31.05	59	17	28.8	24.92	19.8	59	32	54.2
Pleidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Naucoridae	139	1	0.7	0.8	2.2	99	1.00	1.01	1.05	2.35	59	0	0.0	0.00	0.0	59	4	6.8
Saldidae	139	1	0.7	0.8	2.2	99	1.00	1.01	0.48	1.06	59	0	0.0	0.00	0.0	59	0	0.0
Veliidae	139	11	7.9	9.1	11.4	99	12.00	12.12	17.82	20.91	59	4	6.8	6.97	5.2	59	6	10.2
Ceratopogonidae	139	40	28.8	30.4	35.4	99	31.00	31.31	27.59	24.67	59	13	22.0	23.32	12.2	59	13	22.0
Chaoborinae	139	0	0.0	0.0	0.0	99	2.00	2.02	3.64	8.13	59	0	0.0	22.92	45.8	59	0	0.0
Chironominae	139	117	84.2	86.7	11.4	99	74.00	74.75	66.47	24.14	59	47	79.7	60.10	28.1	59	42	71.2
Culicidae	139	24	17.3	19.7	21.0	99	17.00	17.17	18.62	10.24	59	13	22.0	17.79	13.5	59	5	8.5
Empididae	139	1	0.7	0.8	2.4	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	1	1.7
Ephydridae	139	2	1.4	2.2	4.5	99	0.00	0.00	0.00	0.00	59	1	1.7	0.96	1.9	59	0	0.0
Orthocladiinae	139	40	28.8	28.4	16.4	99	31.00	31.31	27.29	13.39	59	17	28.8	32.29	9.8	59	15	25.4
Sciomyzidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	1	1.7	3.13	6.3	59	0	0.0
Simulidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Stratiomyidae	139	21	15.1	12.6	9.5	99	10.00	10.10	7.90	13.02	59	7	11.9	12.10	3.7	59	1	1.7
Tabanidae	139	1	0.7	0.6	1.8	99	3.00	3.03	1.95	2.67	59	3	5.1	6.17	5.4	59	0	0.0
Tanypodinae	139	79	56.8	59.5	11.5	99	64.00	64.65	54.57	19.17	59	37	62.7	59.78	24.9	59	29	49.2
Tipulidae	139	0	0.0	0.0	0.0	99	6.00	6.06	3.96	4.03	59	0	0.0	0.00	0.0	59	0	0.0
Pyralidae	139	8	5.8	6.4	7.3	99	5.00	5.05	4.25	4.14	59	1	1.7	3.13	6.3	59	1	1.7
Carabidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Chyrsomelidae	139	0	0.0	0.0	0.0	99	1.00	1.01	1.00	2.24	59	0	0.0	0.00	0.0	59	3	5.1
Curculionidae	139	3	2.2	3.1	5.8	99	5.00	5.05	9.36	11.59	59	1	1.7	3.13	6.3	59	5	8.5
Dryopidae	139	0	0.0	0.0	0.0	99	1.00	1.01	1.82	4.07	59	0	0.0	0.00	0.0	59	0	0.0
Dytiscidae	139	79	56.8	65.9	29.9	99	62.00	62.63	71.59	17.93	59	37	62.7	52.48	30.9	59	33	55.9
Elmidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Gyrinidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Haliplidae	139	5	3.6	3.4	6.4	99	3.00	3.03	3.82	5.24	59	0	0.0	0.00	0.0	59	1	1.7
Helminthidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Hydraenidae	139	3	2.2	1.6	3.5	99	3.00	3.03	2.77	4.09	59	2	3.4	1.92	3.8	59	1	1.7
Hydrochidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Hydrophilidae	139	63	45.3	54.5	25.2	99	42.00	42.42	50.08	21.40	59	21	35.6	37.50	16.4	59	25	42.4
Limnichidae	139	2	1.4	1.7	3.2	99	7.00	7.07	14.31	17.70	59	0	0.0	0.00	0.0	59	8	13.6
Noteridae	139	1	0.7	0.5	1.5	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Ptilodactilidae	139	1	0.7	0.6	1.8	99	1.00	1.01	2.86	6.39	59	0	0.0	0.00	0.0	59	0	0.0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	***Typha orientalis***					***Baumea articulata***					*T. orientalis/B. articulata*					Mixed Cyper		
	total visits	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***
Scirtidae	139	12	8.6	7.6	8.8	99	14.00	14.14	23.02	24.66	59	0	0.0	0.00	0.0	59	11	18.6
Staphylinidae	139	1	0.7	1.6	4.4	99	1.00	1.01	1.82	4.07	59	1	1.7	2.08	4.2	59	0	0.0
Unidentified	139	0	0.0	0.0	0.0	99	1.00	1.01	1.82	4.07	59	0	0.0	0.00	0.0	59	2	3.4
Calanoida	139	48	34.5	26.1	26.2	99	31.00	31.31	35.47	35.29	59	20	33.9	33.33	18.4	59	31	52.5
Cyclopoida	139	71	51.1	55.6	24.5	99	51.00	51.52	47.93	22.11	59	21	35.6	34.29	18.6	59	21	35.6
Harpacticoida	139	5	3.6	3.6	7.1	99	5.00	5.05	2.96	4.32	59	1	1.7	0.96	1.9	59	4	6.8
CONCHOSTRACA	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0
Cyprididae	139	95	68.3	64.8	37.7	99	67.00	67.68	51.56	36.74	59	40	67.8	71.63	22.4	59	40	67.8
Gomphodellidae	139	1	0.7	0.6	1.8	99	1.00	1.01	0.48	1.06	59	1	1.7	2.08	4.2	59	0	0.0
Ilyocyprididae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	1	1.7	0.96	1.9	59	0	0.0
Limnocytheridae	139	1	0.7	0.8	2.2	99	1.00	1.01	1.05	2.35	59	0	0.0	0.00	0.0	59	0	0.0
Notodromadidae	139	18	12.9	11.1	12.1	99	3.00	3.03	1.95	2.67	59	5	8.5	5.77	7.4	59	0	0.0
Unidentified Ostracoda	139	1	0.7	0.8	2.2	99	0.00	0.00	0.00	0.00	59	5	8.5	9.62	19.2	59	4	6.8
Chydoridae	139	53	38.1	37.1	26.9	99	35.00	35.35	32.93	29.40	59	18	30.5	32.45	14.8	59	29	49.2
Daphniidae	139	54	38.8	40.6	24.8	99	21.00	21.21	20.92	14.22	59	11	18.6	13.86	14.8	59	27	45.8
Macrothricidae	139	8	5.8	6.8	13.3	99	21.00	21.21	29.97	27.01	59	3	5.1	5.93	7.4	59	18	30.5
Moinidae	139	1	0.7	0.3	1.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	2	3.4
Habitat richness																		
Total richness per wetland																		
Percentage of habitat																		

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	aceae		Mixed Cyperaceae with submerged herbaceous					Mixed Restionaceae					Mixed Cyperaceae/Restionaceae					
	Mean percentage	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***
(Hydra)	8.3	11.8	70	2	2.9	2.7	6.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
NEMATODA	0.0	0.0	70	0	0.0	0.0	0.0	34	2.00	5.88	5.16	4.51	12	0	0.0	0.0	0	42
NEMERTINI	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
PORIFERA	2.2	3.1	70	0	0.0	0.0	0.0	34	1.00	2.94	2.38	4.12	12	0	0.0	0.0	0	42
TURBELLARIA	8.5	0.3	70	5	7.1	10.0	14.1	34	1.00	2.94	2.78	4.81	12	1	8.3	8.3	0	42
TEMNOCEPHALIDEA	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42
Hirudinea	10.5	8.7	70	3	4.3	8.1	8.4	34	3.00	8.82	8.33	14.43	12	1	8.3	8.3	0	42
Oligochaeta	38.0	26.2	70	28	40.0	41.2	24.2	34	4.00	11.76	10.71	12.88	12	0	0.0	0.0	0	42
Ancylidae	3.6	1.1	70	2	2.9	1.4	3.1	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Lymnaeidae	7.1	2.2	70	3	4.3	6.0	8.3	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Physidae	0.0	0.0	70	25	35.7	27.8	38.1	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Planorbidae	13.3	12.6	70	15	21.4	20.9	13.1	34	4.00	11.76	11.11	19.25	12	0	0.0	0.0	0	42
Hydriella	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Sphaeriidae	1.4	2.0	70	4	5.7	2.8	6.2	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Lycosidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Tetragnathidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Pisauridae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Unidentified	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Arrenuridae	14.1	7.6	70	10	14.3	27.4	33.6	34	2.00	5.88	5.56	9.62	12	0	0.0	0.0	0	42
Astigmata	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Eylaidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Halacoroidea	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Hydrachnidae	4.2	5.9	70	9	12.9	9.5	11.2	34	4.00	11.76	9.92	10.80	12	0	0.0	0.0	0	42
Hydrodromidae	2.8	3.9	70	5	7.1	4.7	6.6	34	1.00	2.94	2.78	4.81	12	3	25.0	25.0	0	42
Limnocharidae	0.0	0.0	70	1	1.4	3.3	7.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Limnesiidae	2.8	3.9	70	8	11.4	13.7	13.5	34	2.00	5.88	4.76	8.25	12	7	58.3	58.3	0	42
Oribatida	9.7	13.7	70	10	14.3	12.4	14.2	34	6.00	17.65	17.26	6.76	12	1	8.3	8.3	0	42
Oxidae	6.5	9.2	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Pionidae	10.5	8.7	70	17	24.3	33.2	21.3	34	1.00	2.94	2.78	4.81	12	0	0.0	0.0	0	42
Unidentified	9.3	5.3	70	9	12.9	11.0	7.4	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Unioncolidae	22.3	23.7	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	12	100.0	100.0	0	42
Ceinidae	62.0	16.9	70	29	41.4	29.3	26.9	34	8.00	23.53	21.83	31.82	12	0	0.0	0.0	0	42
Perthidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Amphisopidae	43.4	36.8	70	30	42.9	55.7	26.7	34	6.00	17.65	16.67	28.87	12	0	0.0	0.0	0	42
Janiridae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Palaemonidae	45.7	64.6	70	12	17.1	8.3	18.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Parastacidae	5.6	7.9	70	9	12.9	14.8	12.6	34	6.00	17.65	15.48	13.52	12	10	83.3	83.3	0	42
Caenidae	19.2	3.6	70	8	11.4	10.7	11.4	34	3.00	8.82	8.33	14.43	12	0	0.0	0.0	0	42
Baetidae	30.3	12.1	70	11	15.7	10.8	15.5	34	4.00	11.76	11.11	19.25	12	0	0.0	0.0	0	42
COLLEMBOLA	0.0	0.0	70	3	4.3	4.3	9.6	34	5.00	14.71	12.30	14.69	12	0	0.0	0.0	0	42
MECOPTERA	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Sisyridae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Aeshnidae	36.1	51.1	70	27	38.6	37.5	31.7	34	11.00	32.35	29.37	34.03	12	2	16.7	16.7	0	42
Coenagrionidae	26.6	25.3	70	32	45.7	33.8	37.3	34	6.00	17.65	16.67	28.87	12	4	33.3	33.3	0	42
Cordulidae	15.3	21.6	70	15	21.4	16.6	16.1	34	4.00	11.76	12.10	4.77	12	0	0.0	0.0	0	42
Gomphidae	2.2	3.1	70	2	2.9	1.4	3.1	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Lestidae	42.5	53.9	70	42	60.0	56.7	27.6	34	17.00	50.00	45.44	28.92	12	7	58.3	58.3	0	42

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	aceae		Mixed Cyperaceae with submerged herbaceous					Mixed Restionaceae					Mixed Cyperaceae/Restionaceae					
	Mean percentage	*SD*	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*
Libellulidae	30.7	31.2	70	33	47.1	37.4	26.5	34	8.00	23.53	23.61	30.71	12	0	0.0	0.0	0	42
Macrodiplactidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Megapodagrionidae	1.4	2.0	70	1	1.4	0.7	1.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Synthemidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Ecnomidae	6.9	9.8	70	2	2.9	2.7	6.0	34	4.00	11.76	10.71	12.88	12	0	0.0	0.0	0	42
Hydroptilidae	30.3	31.0	70	6	8.6	8.9	6.7	34	4.00	11.76	11.11	19.25	12	0	0.0	0.0	0	42
Leptoceridae	66.7	4.0	70	42	60.0	51.9	21.1	34	12.00	35.29	32.54	44.56	12	12	100.0	100.0	0	42
Corixidae	27.4	20.2	70	45	64.3	51.9	32.6	34	11.00	32.35	31.75	8.78	12	6	50.0	50.0	0	42
Gerridae	12.5	17.7	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Hebridae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Hydrometridae	1.4	2.0	70	1	1.4	0.7	1.5	34	1.00	2.94	2.78	4.81	12	1	8.3	8.3	0	42
Mesoveliidae	17.5	18.5	70	15	21.4	18.9	20.5	34	5.00	14.71	14.88	9.16	12	3	25.0	25.0	0	42
Nepidae	6.9	9.8	70	5	7.1	4.8	4.6	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42
Notonectidae	44.4	62.9	70	44	62.9	53.4	38.9	34	14.00	41.18	38.69	32.46	12	7	58.3	58.3	0	42
Pleidae	0.0	0.0	70	1	1.4	0.7	1.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Naucoridae	5.6	7.9	70	1	1.4	1.3	3.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Saldidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Veliidae	9.1	6.7	70	10	14.3	11.1	11.9	34	5.00	14.71	12.70	11.25	12	5	41.7	41.7	0	42
Ceratopogonidae	21.2	5.4	70	17	24.3	23.5	19.1	34	14.00	41.18	49.60	46.93	12	0	0.0	0.0	0	42
Chaoborinae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42
Chironominae	71.7	3.2	70	52	74.3	64.9	27.7	34	17.00	50.00	51.39	10.49	12	7	58.3	58.3	0	42
Culicidae	6.9	9.8	70	23	32.9	42.6	25.6	34	11.00	32.35	28.77	24.66	12	5	41.7	41.7	0	42
Empididae	2.2	3.1	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Ephydridae	0.0	0.0	70	1	1.4	3.3	7.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Orthocladiinae	27.1	10.8	70	13	18.6	17.0	12.5	34	6.00	17.65	19.05	10.31	12	10	83.3	83.3	0	42
Sciomyzidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Simulidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Stratiomyidae	1.4	2.0	70	9	12.9	13.4	7.8	34	1.00	2.94	2.78	4.81	12	0	0.0	0.0	0	42
Tabanidae	0.0	0.0	70	2	2.9	4.0	7.2	34	3.00	8.82	7.54	7.18	12	0	0.0	0.0	0	42
Tanypodinae	52.8	23.7	70	41	58.6	51.5	23.3	34	17.00	50.00	45.04	28.34	12	4	33.3	33.3	0	42
Tipulidae	0.0	0.0	70	1	1.4	3.3	7.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Pyralidae	1.4	2.0	70	2	2.9	2.9	6.4	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42
Carabidae	0.0	0.0	70	0	0.0	0.0	0.0	34	1.00	2.94	4.17	7.22	12	0	0.0	0.0	0	42
Chyrsomelidae	4.2	5.9	70	1	1.4	1.4	3.2	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Curculionidae	6.9	9.8	70	1	1.4	3.3	7.5	34	7.00	20.59	19.25	8.34	12	3	25.0	25.0	0	42
Dryopidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Dytiscidae	51.3	29.5	70	52	74.3	70.7	14.0	34	25.00	73.53	78.17	30.87	12	11	91.7	91.7	0	42
Elmidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Gyrinidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Haliplidae	1.4	2.0	70	5	7.1	5.6	5.9	34	1.00	2.94	2.78	4.81	12	0	0.0	0.0	0	42
Helminthidae	0.0	0.0	70	1	1.4	1.4	3.2	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Hydraenidae	1.4	2.0	70	2	2.9	4.0	7.2	34	1.00	2.94	2.78	4.81	12	1	8.3	8.3	0	42
Hydrochidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42
Hydrophilidae	37.1	34.0	70	40	57.1	49.5	31.1	34	21.00	61.76	63.49	9.98	12	5	41.7	41.7	0	42
Limnichidae	11.1	15.7	70	1	1.4	1.4	3.2	34	8.00	23.53	26.39	22.95	12	3	25.0	25.0	0	42
Noteridae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Ptilodactilidae	0.0	0.0	70	3	4.3	6.2	8.5	34	1.00	2.94	4.17	7.22	12	0	0.0	0.0	0	42

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	aceae		Mixed Cyperaceae with submerged herbaceous					Mixed Restionaceae					Mixed Cyperaceae/Restionaceae					
	Mean percentage	SD	total visits	times found	Percent	Mean percentage	SD	total visits	times found	Percent	Mean percentage	SD	total visits	times found	Percent	Mean percentage	SD	total visits
Scirtidae	15.3	21.6	70	17	24.3	38.6	37.7	34	3.00	8.82	7.54	7.18	12	7	58.3	58.3	0	42
Staphylinidae	0.0	0.0	70	2	2.9	6.7	14.9	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42
Unidentified	3.6	1.1	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Calanoida	47.0	35.7	70	30	42.9	40.9	24.8	34	10.00	29.41	26.98	35.10	12	11	91.7	91.7	0	42
Cyclopoida	35.4	0.9	70	30	42.9	38.7	9.9	34	12.00	35.29	30.16	28.70	12	6	50.0	50.0	0	42
Harpacticoida	6.3	2.8	70	3	4.3	3.4	5.8	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
CONCHOSTRACA	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Cyprididae	65.0	18.1	70	44	62.9	70.4	20.3	34	16.00	47.06	42.06	41.67	12	1	8.3	8.3	0	42
Gomphodellidae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Ilyocyprididae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Limnocytheridae	0.0	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Notodromadidae	0.0	0.0	70	14	20.0	19.1	13.6	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Unidentified Ostracoda	8.7	12.3	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Chydoridae	47.3	11.6	70	21	30.0	33.5	27.6	34	10.00	29.41	27.38	41.39	12	1	8.3	8.3	0	42
Daphniidae	41.4	27.8	70	22	31.4	34.7	24.3	34	8.00	23.53	21.83	31.82	12	6	50.0	50.0	0	42
Macrothricidae	27.4	20.2	70	11	15.7	15.1	20.8	34	10.00	29.41	32.14	15.57	12	1	8.3	8.3	0	42
Moinidae	2.8	3.9	70	1	1.4	1.3	3.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42
Habitat richness																		
Total richness per wetlan																		
Percentage of habitat																		

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*Lepidosperma longitudinale*				*Mixed Restionaceae/ Lepidosperma*									*B. articualta/Lepidosperma*					*M. rapl*	
	times found	***Percent***	***Mean percentage***	***SD***	***Gnangara***			***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***
					Times found	***Times habitat***	***Percen-tage***												
(Hydra)	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
NEMATODA	3	7.1	3.6	7.1		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	1
NEMERTINI	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
PORIFERA	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	4
TURBELLARIA	10	23.8	12.6	20.5		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	13
TEMNOCEPHALIDEA	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Hirudinea	7	16.7	13.5	9.7		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	25
Oligochaeta	20	47.6	28.2	33.6	1	9	11.11	9	1	11.11	11.11	0	15	8	53.33	53.33	0	93	29
Ancylidae	2	4.8	3.1	3.8		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	3
Lymnaeidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	3
Physidae	14	33.3	24.1	20.8		9	0.00	9	0	0.00	0.00	0	15	5	33.33	33.33	0	93	38
Planorbidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	8
Hydriella	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Sphaeriidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Lycosidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Tetragnathidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Pisauridae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Unidentified	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Arrenuridae	2	4.8	5.4	7.9		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	15
Astigmata	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Eylaidae	1	2.4	4.2	8.3		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Halacoroidea	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Hydrachnidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	4
Hydrodromidae	1	2.4	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Limnocharidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	5
Limnesiidae	5	11.9	6.7	9.0	1	9	11.11	9	1	11.11	11.11	0	15	2	13.33	13.33	0	93	11
Oribatida	2	4.8	8.3	16.7		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	3
Oxidae	5	11.9	7.4	8.6		9	0.00	9	0	0.00	0.00	0	15	4	26.67	26.67	0	93	5
Pionidae	6	14.3	16.8	22.5		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	17
Unidentified	2	4.8	2.4	4.8	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	8
Unioncolidae	8	19.0	11.7	13.5	1	9	11.11	9	1	11.11	11.11	0	15	7	46.67	46.67	0	93	13
Ceinidae	18	42.9	43.6	42.6		9	0.00	9	0	0.00	0.00	0	15	3	20.00	20.00	0	93	51
Perthidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Amphisopidae	3	7.1	12.5	25.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	33
Janiridae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Palaemonidae	34	81.0	53.0	52.0		9	0.00	9	0	0.00	0.00	0	15	12	80.00	80.00	0	93	61
Parastacidae	4	9.5	9.2	8.1	1	9	11.11	9	1	11.11	11.11	0	15	2	13.33	13.33	0	93	3
Caenidae	8	19.0	13.9	22.0		9	0.00	9	0	0.00	0.00	0	15	4	26.67	26.67	0	93	7
Baetidae	15	35.7	28.2	19.8		9	0.00	9	0	0.00	0.00	0	15	8	53.33	53.33	0	93	12
COLLEMBOLA	1	2.4	1.2	2.4		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	4
MECOPTERA	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Sisyridae	1	2.4	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Aeshnidae	18	42.9	49.8	15.8	3	9	33.33	9	3	33.33	33.33	0	15	2	13.33	13.33	0	93	15
Coenagrionidae	21	50.0	33.9	29.3	2	9	22.22	9	2	22.22	22.22	0	15	7	46.67	46.67	0	93	24
Cordulidae	3	7.1	5.0	7.3	3	9	33.33	9	3	33.33	33.33	0	15	4	26.67	26.67	0	93	4
Gomphidae	1	2.4	5.5	6.9		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Lestidae	10	23.8	39.0	23.6	2	9	22.22	9	2	22.22	22.22	0	15	5	33.33	33.33	0	93	15

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*Lepidosperma longitudinale*				*Mixed Restionaceae/ Lepidosperma*								*B. articualta/Lepidosperma*					*M. rapl*	
	times found	*Percent*	*Mean percentage*	*SD*	*Gnangara*			*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*	*total visits*	*times found*
					Times found	*Times habitat*	*Percen-tage*												
Libellulidae	7	16.7	9.5	16.0	1	9	11.11	9	1	11.11	11.11	0	15	1	6.67	6.67	0	93	4
Macrodiplactidae	1	2.4	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Megapodagrionidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Synthemidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Ecnomidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	3
Hydroptilidae	16	38.1	30.1	22.3		9	0.00	9	0	0.00	0.00	0	15	11	73.33	73.33	0	93	18
Leptoceridae	29	69.0	55.2	39.2		9	0.00	9	0	0.00	0.00	0	15	13	86.67	86.67	0	93	60
Corixidae	17	40.5	39.6	44.0	4	9	44.44	9	4	44.44	44.44	0	15	8	53.33	53.33	0	93	41
Gerridae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Hebridae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Hydrometridae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Mesoveliidae	6	14.3	7.1	14.3	1	9	11.11	9	1	11.11	11.11	0	15	2	13.33	13.33	0	93	5
Nepidae	1	2.4	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	3
Notonectidae	5	11.9	15.6	23.1	3	9	33.33	9	3	33.33	33.33	0	15	2	13.33	13.33	0	93	26
Pleidae	1	2.4	12.5	25.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Naucoridae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Saldidae	0	0.0	0.0	0.0	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	0
Veliidae	4	9.5	22.0	23.8		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	3
Ceratopogonidae	14	33.3	43.0	41.7	7	9	77.78	9	7	77.78	77.78	0	15	7	46.67	46.67	0	93	10
Chaoborinae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Chironominae	30	71.4	72.2	21.6	5	9	55.56	9	5	55.56	55.56	0	15	13	86.67	86.67	0	93	64
Culicidae	10	23.8	35.9	27.2	2	9	22.22	9	2	22.22	22.22	0	15	0	0.00	0.00	0	93	17
Empididae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Ephydridae	1	2.4	1.2	2.4		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Orthocladiinae	15	35.7	39.5	10.2	1	9	11.11	9	1	11.11	11.11	0	15	7	46.67	46.67	0	93	23
Sciomyzidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Simulidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Stratiomyidae	5	11.9	9.7	7.5		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	8
Tabanidae	1	2.4	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	3
Tanypodinae	22	52.4	55.3	21.7	4	9	44.44	9	4	44.44	44.44	0	15	10	66.67	66.67	0	93	40
Tipulidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	2
Pyralidae	1	2.4	1.9	3.8	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	7
Carabidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Chyrsomelidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Curculionidae	3	7.1	5.0	7.3	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	0
Dryopidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Dytiscidae	32	76.2	85.9	16.8	8	9	88.89	9	8	88.89	88.89	0	15	7	46.67	46.67	0	93	47
Elmidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Gyrinidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Haliplidae	1	2.4	4.2	8.3		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Helminthidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Hydraenidae	2	4.8	2.4	4.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Hydrochidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Hydrophilidae	16	38.1	55.0	36.6	7	9	77.78	9	7	77.78	77.78	0	15	5	33.33	33.33	0	93	22
Limnichidae	0	0.0	0.0	0.0	4	9	44.44	9	4	44.44	44.44	0	15	0	0.00	0.00	0	93	1
Noteridae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Ptilodactilidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	2

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*Lepidosperma longitudinale*				*Mixed Restionaceae/ Lepidosperma*								*B. articualta/Lepidosperma*					*M. rapl*	
	times found	***Percent***	***Mean percentage***	***SD***	***Gnangara***			***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***
					Times found	***Times habitat***	***Percen-tage***												
Scirtidae	1	2.4	1.9	3.8	3	9	33.33	9	3	33.33	33.33	0	15	0	0.00	0.00	0	93	14
Staphylinidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Unidentified	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Calanoida	13	31.0	30.3	27.6		9	0.00	9	0	0.00	0.00	0	15	8	53.33	53.33	0	93	26
Cyclopoida	18	42.9	43.1	18.8	2	9	22.22	9	2	22.22	22.22	0	15	8	53.33	53.33	0	93	37
Harpacticoida	3	7.1	8.0	9.3		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	3
CONCHOSTRACA	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Cyprididae	30	71.4	54.3	43.7	1	9	11.11	9	1	11.11	11.11	0	15	12	80.00	80.00	0	93	52
Gomphodellidae	3	7.1	3.6	7.1		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	2
Ilyocyprididae	1	2.4	4.2	8.3		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Limnocytheridae	1	2.4	1.2	2.4		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0
Notodromadidae	7	16.7	21.0	30.7		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	9
Unidentified Ostracoda	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	5
Chydoridae	16	38.1	27.9	20.0		9	0.00	9	0	0.00	0.00	0	15	8	53.33	53.33	0	93	21
Daphniidae	8	19.0	19.9	21.2		9	0.00	9	0	0.00	0.00	0	15	3	20.00	20.00	0	93	16
Macrothricidae	3	7.1	15.6	23.1	5	9	55.56	9	5	55.56	55.56	0	15	1	6.67	6.67	0	93	6
Moinidae	0	0.0	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1
Habitat richness					**28**														
Total richness per wetlan					50														
Percentage of habitat					56.0														

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*iophylla/B. articulata*			M. raphiophylla/submerged herbaceous					*Astartea fascicularis*					Submerged herbaceous				
	Percent	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***
		i.e. how common is																
(Hydra)	0.0	0.0	0.0	48	1.00	2.08	1.45	2.51	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
NEMATODA	1.1	1.7	3.7	48	2.00	4.17	2.90	5.02	39	1.00	2.56	3.57	7.14	115	1	0.9	1.0	3.0
NEMERTINI	0.0	0.0	0.0	48	1.00	2.08	1.45	2.51	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
PORIFERA	4.3	3.7	4.1	48	2.00	4.17	3.53	3.20	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
TURBELLARIA	14.0	16.9	20.8	48	3.00	6.25	7.87	6.85	39	0.00	0.00	0.00	0.00	115	8	7.0	10.5	17.2
TEMNOCEPHALIDEA	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	2.00	5.13	2.50	5.00	115	0	0.0	0.0	0.0
Hirudinea	26.9	25.2	25.0	48	17.00	35.42	34.85	18.63	39	3.00	7.69	8.39	13.66	115	28	24.3	17.9	18.5
Oligochaeta	31.2	28.9	18.6	48	16.00	33.33	32.84	23.09	39	2.00	5.13	9.58	16.01	115	41	35.7	45.1	34.1
Ancylidae	3.2	2.5	3.6	48	3.00	6.25	5.62	6.35	39	0.00	0.00	0.00	0.00	115	1	0.9	0.5	1.6
Lymnaeidae	3.2	2.9	4.4	48	1.00	2.08	3.70	6.42	39	0.00	0.00	0.00	0.00	115	4	3.5	2.3	4.8
Physidae	40.9	40.7	34.4	48	33.00	68.75	73.12	23.31	39	0.00	0.00	0.00	0.00	115	53	46.1	39.9	36.2
Planorbidae	8.6	9.5	6.3	48	17.00	35.42	28.16	28.34	39	0.00	0.00	0.00	0.00	115	11	9.6	9.3	13.6
Hydriella	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Sphaeriidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	1.5	3.0
Lycosidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Tetragnathidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Pisauridae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Arrenuridae	16.1	21.2	26.7	48	11.00	22.92	29.40	25.46	39	0.00	0.00	0.00	0.00	115	9	7.8	9.2	8.4
Astigmata	0.0	0.0	0.0	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Eylaidae	0.0	0.0	0.0	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	10	8.7	8.4	11.0
Halacoroidea	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.2
Hydrachnidae	4.3	3.9	6.5	48	8.00	16.67	19.91	18.86	39	2.00	5.13	11.11	15.71	115	14	12.2	12.0	9.5
Hydrodromidae	1.1	1.0	2.2	48	2.00	4.17	5.79	5.57	39	5.00	12.82	7.78	9.69	115	3	2.6	2.4	4.9
Limnocharidae	5.4	5.0	11.2	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	8	7.0	10.6	19.5
Limnesiidae	11.8	10.9	14.4	48	16.00	33.33	41.44	36.49	39	12.00	30.77	17.32	26.01	115	28	24.3	19.7	19.8
Oribatida	3.2	3.0	6.7	48	2.00	4.17	2.90	5.02	39	1.00	2.56	1.25	2.50	115	9	7.8	6.3	9.4
Oxidae	5.4	4.1	6.9	48	2.00	4.17	5.15	5.60	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Pionidae	18.3	19.9	12.8	48	19.00	39.58	48.04	34.09	39	3.00	7.69	6.07	7.23	115	37	32.2	28.1	14.5
Unidentified	8.6	11.1	13.0	48	6.00	12.50	14.47	6.98	39	1.00	2.56	2.78	5.56	115	20	17.4	19.1	12.6
Unioncolidae	14.0	11.5	16.2	48	4.00	8.33	8.33	14.43	39	16.00	41.03	23.85	31.37	115	3	2.6	2.8	4.6
Ceinidae	54.8	52.2	16.4	48	17.00	35.42	25.27	38.49	39	0.00	0.00	0.00	0.00	115	46	40.0	34.1	37.7
Perthidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	2.00	5.13	7.14	14.29	115	0	0.0	0.0	0.0
Amphisopidae	35.5	38.1	27.9	48	33.00	68.75	64.10	30.22	39	0.00	0.00	0.00	0.00	115	49	42.6	37.8	28.8
Janiridae	0.0	0.0	0.0	48	1.00	2.08	3.70	6.42	39	0.00	0.00	0.00	0.00	115	2	1.7	3.2	9.5
Palaemonidae	65.6	56.5	36.1	48	24.00	50.00	36.68	48.22	39	1.00	2.56	1.25	2.50	115	32	27.8	22.6	32.1
Parastacidae	3.2	3.4	4.7	48	1.00	2.08	1.45	2.51	39	19.00	48.72	37.56	29.68	115	6	5.2	5.9	8.9
Caenidae	7.5	6.5	8.2	48	7.00	14.58	10.14	17.57	39	0.00	0.00	0.00	0.00	115	5	4.3	5.3	12.3
Baetidae	12.9	10.7	14.8	48	4.00	8.33	8.33	14.43	39	0.00	0.00	0.00	0.00	115	9	7.8	10.3	10.9
COLLEMBOLA	4.3	4.8	7.0	48	3.00	6.25	7.24	3.49	39	5.00	12.82	10.10	6.94	115	4	3.5	3.6	5.0
MECOPTERA	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Sisyridae	0.0	0.0	0.0	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Aeshnidae	16.1	15.8	10.9	48	12.00	25.00	32.47	25.97	39	7.00	17.95	10.28	14.15	115	31	27.0	28.0	24.3
Coenagrionidae	25.8	23.6	15.5	48	16.00	33.33	32.49	7.10	39	5.00	12.82	7.78	9.69	115	23	20.0	23.6	18.5
Cordulidae	4.3	4.7	6.3	48	6.00	12.50	15.46	16.80	39	2.00	5.13	6.35	7.45	115	18	15.7	17.3	9.5
Gomphidae	1.1	0.8	1.8	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.0
Lestidae	16.1	17.7	19.7	48	11.00	22.92	23.27	23.18	39	20.00	51.28	44.42	20.01	115	50	43.5	37.3	24.0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*hiophylla/B. articulata*			M. raphiophylla/submerged herbaceous					*Astartea fascicularis*					Submerged herbaceous				
	Percent	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***
		i.e. how common is																
Libellulidae	4.3	4.9	6.3	48	6.00	12.50	16.09	14.98	39	1.00	2.56	1.25	2.50	115	30	26.1	26.4	19.3
Macrodiplactidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	3.00	7.69	3.75	7.50	115	0	0.0	0.0	0.0
Megapodagrionidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Synthemidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Ecnomidae	3.2	2.6	3.7	48	1.00	2.08	2.08	3.61	39	3.00	7.69	3.75	7.50	115	10	8.7	13.1	24.8
Hydroptilidae	19.4	15.4	21.7	48	5.00	10.42	7.25	12.55	39	0.00	0.00	0.00	0.00	115	17	14.8	19.2	23.4
Leptoceridae	64.5	60.5	15.8	48	34.00	70.83	66.54	19.48	39	16.00	41.03	22.32	35.76	115	59	51.3	49.3	26.7
Corixidae	44.1	45.8	43.4	48	33.00	68.75	71.50	26.42	39	13.00	33.33	31.03	7.51	115	90	78.3	73.3	21.9
Gerridae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Hebridae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Hydrometridae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	1	0.9	1.4	4.2
Mesoveliidae	5.4	5.1	3.4	48	5.00	10.42	11.40	7.21	39	3.00	7.69	5.28	6.11	115	1	0.9	0.7	2.2
Nepidae	3.2	3.0	6.7	48	2.00	4.17	5.79	5.57	39	3.00	7.69	6.07	7.23	115	2	1.7	2.8	8.3
Notonectidae	28.0	28.8	28.9	48	28.00	58.33	66.15	52.86	39	11.00	28.21	20.65	16.67	115	60	52.2	46.8	30.7
Pleidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Naucoridae	1.1	1.0	2.2	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	2	1.7	2.8	8.3
Saldidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	3.6	8.4
Veliidae	3.2	2.9	4.4	48	4.00	8.33	7.70	9.81	39	21.00	53.85	40.85	28.71	115	3	2.6	2.0	4.5
Ceratopogonidae	10.8	11.0	13.8	48	4.00	8.33	6.43	6.52	39	3.00	7.69	13.15	14.70	115	24	20.9	25.4	24.3
Chaoborinae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	2.00	5.13	2.50	5.00	115	0	0.0	0.0	0.0
Chironominae	68.8	66.8	14.6	48	45.00	93.75	92.76	3.49	39	17.00	43.59	46.96	14.08	115	101	87.8	85.2	14.4
Culicidae	18.3	24.8	33.6	48	5.00	10.42	18.52	32.08	39	14.00	35.90	47.18	37.30	115	23	20.0	21.2	24.0
Empididae	1.1	0.8	1.8	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Ephydridae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	1.6	4.8
Orthocladiinae	24.7	27.5	23.9	48	10.00	20.83	20.55	14.71	39	10.00	25.64	21.11	18.72	115	25	21.7	24.4	20.4
Sciomyzidae	0.0	0.0	0.0	48	2.00	4.17	7.41	12.83	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Simulidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Stratiomyidae	8.6	8.1	7.5	48	10.00	20.83	20.27	7.00	39	0.00	0.00	0.00	0.00	115	8	7.0	6.9	8.8
Tabanidae	3.2	2.8	4.4	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	1.1	2.3
Tanypodinae	43.0	41.6	13.5	48	34.00	70.83	70.41	4.23	39	16.00	41.03	30.02	24.16	115	87	75.7	67.9	23.2
Tipulidae	2.2	1.9	2.6	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.5	1.4
Pyralidae	7.5	6.9	5.1	48	3.00	6.25	7.24	3.49	39	1.00	2.56	1.25	2.50	115	10	8.7	7.9	13.2
Carabidae	1.1	1.7	3.7	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.0
Chyrsomelidae	1.1	1.0	2.2	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	1	0.9	0.9	2.6
Curculionidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	6.00	15.38	16.90	13.81	115	6	5.2	4.4	13.3
Dryopidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Dytiscidae	50.5	55.9	24.7	48	27.00	56.25	63.22	32.68	39	33.00	84.62	83.27	16.67	115	73	63.5	66.5	30.7
Elmidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	0	0.0	0.0	0.0
Gyrinidae	1.1	0.9	1.9	48	2.00	4.17	2.90	5.02	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Haliplidae	1.1	1.7	3.7	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	12	10.4	9.0	11.0
Helminthidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.2
Hydraenidae	1.1	0.8	1.8	48	1.00	2.08	3.70	6.42	39	1.00	2.56	1.25	2.50	115	5	4.3	4.2	8.7
Hydrochidae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	2	1.7	1.5	4.4
Hydrophilidae	23.7	26.4	16.5	48	17.00	35.42	40.98	20.62	39	14.00	35.90	40.16	22.76	115	60	52.2	51.8	27.0
Limnichidae	1.1	0.8	1.8	48	0.00	0.00	0.00	0.00	39	5.00	12.82	6.25	12.50	115	0	0.0	0.0	0.0
Noteridae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Ptilodactilidae	2.2	3.3	7.5	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*iophylla/B. articulata*			M. raphiophylla/submerged herbaceous					*Astartea fascicularis*					Submerged herbaceous				
	Percent	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***
		i.e. how common is																
Scirtidae	15.1	20.0	26.8	48	2.00	4.17	2.90	5.02	39	11.00	28.21	17.60	19.27	115	4	3.5	2.7	6.6
Staphylinidae	1.1	1.7	3.7	48	1.00	2.08	2.08	3.61	39	1.00	2.56	1.25	2.50	115	0	0.0	0.0	0.0
Unidentified	1.1	1.7	3.7	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	1.4	2.8
Calanoida	28.0	28.7	26.6	48	23.00	47.92	40.94	37.97	39	27.00	69.23	56.17	29.33	115	44	38.3	38.7	20.1
Cyclopoida	39.8	38.5	11.1	48	26.00	54.17	48.18	35.24	39	25.00	64.10	48.17	34.00	115	64	55.7	55.6	19.8
Harpacticoida	3.2	2.5	3.6	48	9.00	18.75	28.82	42.62	39	0.00	0.00	0.00	0.00	115	3	2.6	2.2	4.4
CONCHOSTRACA	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	2.78	5.56	115	0	0.0	0.0	0.0
Cyprididae	55.9	58.2	25.6	48	37.00	77.08	81.80	22.59	39	11.00	28.21	30.85	9.29	115	102	88.7	86.5	17.8
Gomphodellidae	2.2	1.8	2.5	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Ilyocyprididae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.0
Limnocytheridae	0.0	0.0	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Notodromadidae	9.7	11.0	13.8	48	1.00	2.08	1.45	2.51	39	0.00	0.00	0.00	0.00	115	16	13.9	15.9	18.1
Unidentified Ostracoda	5.4	4.0	8.9	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0
Chydoridae	22.6	22.8	16.1	48	21.00	43.75	46.78	10.75	39	9.00	23.08	13.57	18.86	115	45	39.1	40.5	22.0
Daphniidae	17.2	18.3	12.3	48	20.00	41.67	47.58	20.40	39	13.00	33.33	25.48	17.62	115	54	47.0	46.5	20.4
Macrothricidae	6.5	5.5	8.7	48	1.00	2.08	3.70	6.42	39	8.00	20.51	14.58	17.18	115	4	3.5	3.9	6.1
Moinidae	1.1	0.8	1.8	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	116	4	3.4	2.9	5.3
Habitat richness																		
Total richness per wetlan																		
Percentage of habitat																		

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	Open water					Spring				
	total visits	times found	Percent	Mean percentage	SD	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*
				i.e. how common is the		*i.e. how common is the taxa in this*				
(Hydra)	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
NEMATODA	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
NEMERTINI	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
PORIFERA	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
TURBELLARIA	65	7	10.8	6.8	11.2	23	0	0.00	0.00	0
TEMNOCEPHALIDEA	65	0	0.0	0.0	0.0	23	1	4.35	4.35	0
Hirudinea	65	6	9.2	5.8	7.4	23	4	17.39	17.39	0
Oligochaeta	65	18	27.7	22.5	23.1	23	10	43.48	43.48	0
Ancylidae	65	1	1.5	1.2	2.9	23	0	0.00	0.00	0
Lymnaeidae	65	1	1.5	1.2	2.9	23	3	13.04	13.04	0
Physidae	65	9	13.8	28.5	38.6	23	2	8.70	8.70	0
Planorbidae	65	6	9.2	6.2	9.8	23	1	4.35	4.35	0
Hydriella	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Sphaeriidae	65	10	15.4	9.7	15.8	23	4	17.39	17.39	0
Lycosidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Tetragnathidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Pisauridae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Unidentified	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Arrenuridae	65	1	1.5	1.2	2.9	23	0	0.00	0.00	0
Astigmata	65	1	1.5	0.9	2.1	23	0	0.00	0.00	0
Eylaidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Halacoroidea	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Hydrachnidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Hydrodromidae	65	1	1.5	3.3	8.2	23	1	4.35	4.35	0
Limnocharidae	65	1	1.5	0.8	1.9	23	0	0.00	0.00	0
Limnesiidae	65	2	3.1	1.6	3.9	23	6	26.09	26.09	0
Oribatida	65	2	3.1	1.7	2.6	23	2	8.70	8.70	0
Oxidae	65	0	0.0	0.0	0.0	23	11	47.83	47.83	0
Pionidae	65	5	7.7	4.3	8.4	23	5	21.74	21.74	0
Unidentified	65	7	10.8	8.8	9.5	23	4	17.39	17.39	0
Unioncolidae	65	0	0.0	0.0	0.0	23	4	17.39	17.39	0
Ceinidae	65	22	33.8	40.1	40.1	23	18	78.26	78.26	0
Perthidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Amphisopidae	65	20	30.8	32.3	40.9	23	9	39.13	39.13	0
Janiridae	65	0	0.0	0.0	0.0	23	2	8.70	8.70	0
Palaemonidae	65	2	3.1	17.5	40.4	23	20	86.96	86.96	0
Parastacidae	65	9	13.8	20.6	39.3	23	10	43.48	43.48	0
Caenidae	65	7	10.8	12.0	16.2	23	10	43.48	43.48	0
Baetidae	65	5	7.7	7.2	8.9	23	10	43.48	43.48	0
COLLEMBOLA	65	2	3.1	6.7	16.3	23	1	4.35	4.35	0
MECOPTERA	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Sisyridae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Aeshnidae	65	6	9.2	10.7	15.3	23	2	8.70	8.70	0
Coenagrionidae	65	9	13.8	16.1	23.0	23	1	4.35	4.35	0
Cordulidae	65	9	13.8	12.1	16.7	23	7	30.43	30.43	0
Gomphidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Lestidae	65	18	27.7	28.2	27.1	23	1	4.35	4.35	0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	Open water					Spring				
	total visits	times found	Percent	Mean percentage	SD	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*
				i.e. how common is the		*i.e. how common is the taxa in this*				
Libellulidae	65	20	30.8	48.9	48.9	23	3	13.04	13.04	0
Macrodiplactidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Megapodagrionidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Synthemidae	65	0	0.0	0.0	0.0	23	1	4.35	4.35	0
Ecnomidae	65	5	7.7	5.3	8.9	23	2	8.70	8.70	0
Hydroptilidae	65	2	3.1	1.7	2.6	23	12	52.17	52.17	0
Leptoceridae	65	16	24.6	51.0	43.3	23	17	73.91	73.91	0
Corixidae	65	47	72.3	69.0	27.5	23	3	13.04	13.04	0
Gerridae	65	0	0.0	0.0	0.0	23	2	8.70	8.70	0
Hebridae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Hydrometridae	65	0	0.0	0.0	0.0	23	1	4.35	4.35	0
Mesoveliidae	65	2	3.1	6.7	10.3	23	5	21.74	21.74	0
Nepidae	65	0	0.0	0.0	0.0	23	1	4.35	4.35	0
Notonectidae	65	21	32.3	34.3	34.3	23	7	30.43	30.43	0
Pleidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Naucoridae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Saldidae	65	3	4.6	5.3	7.8	23	0	0.00	0.00	0
Veliidae	65	4	6.2	13.3	24.2	23	3	13.04	13.04	0
Ceratopogonidae	65	15	23.1	12.7	24.8	23	5	21.74	21.74	0
Chaoborinae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Chironominae	65	46	70.8	68.4	41.7	23	15	65.22	65.22	0
Culicidae	65	9	13.8	15.8	22.7	23	4	17.39	17.39	0
Empididae	65	0	0.0	0.0	0.0	23	3	13.04	13.04	0
Ephydridae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Orthocladiinae	65	14	21.5	25.2	37.8	23	9	39.13	39.13	0
Sciomyzidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Simulidae	65	0	0.0	0.0	0.0	23	6	26.09	26.09	0
Stratiomyidae	65	2	3.1	4.2	8.0	23	2	8.70	8.70	0
Tabanidae	65	1	1.5	0.9	2.1	23	3	13.04	13.04	0
Tanypodinae	65	35	53.8	65.9	28.7	23	16	69.57	69.57	0
Tipulidae	65	0	0.0	0.0	0.0	23	1	4.35	4.35	0
Pyralidae	65	1	1.5	3.3	8.2	23	0	0.00	0.00	0
Carabidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Chyrsomelidae	65	1	1.5	1.2	2.9	23	0	0.00	0.00	0
Curculionidae	65	2	3.1	4.5	8.1	23	1	4.35	4.35	0
Dryopidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Dytiscidae	65	40	61.5	74.9	35.4	23	10	43.48	43.48	0
Elmidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Gyrinidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Haliplidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Helminthidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Hydraenidae	65	0	0.0	0.0	0.0	23	1	4.35	4.35	0
Hydrochidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Hydrophilidae	65	17	26.2	38.4	45.9	23	6	26.09	26.09	0
Limnichidae	65	2	3.1	6.7	16.3	23	0	0.00	0.00	0
Noteridae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Ptilodactilidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	Open water					Spring				
	total visits	times found	Percent	Mean percentage	SD	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*
				i.e. how common is the		*i.e. how common is the taxa in this*				
Scirtidae	65	2	3.1	6.7	16.3	23	1	4.35	4.35	0
Staphylinidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Unidentified	65	0	0.0	0.0	0.0	23	2	8.70	8.70	0
Calanoida	65	25	38.5	48.8	36.9	23	3	13.04	13.04	0
Cyclopoida	65	23	35.4	44.2	29.8	23	15	65.22	65.22	0
Harpacticoida	65	1	1.5	0.9	2.1	23	2	8.70	8.70	0
CONCHOSTRACA	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Cyprididae	65	35	53.8	49.5	40.5	23	11	47.83	47.83	0
Gomphodellidae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Ilyocyprididae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Limnocytheridae	65	0	0.0	0.0	0.0	23	0	0.00	0.00	0
Notodromadidae	65	1	1.5	0.8	1.9	23	0	0.00	0.00	0
Unidentified Ostracoda	65	0	0.0	0.0	0.0	23	2	8.70	8.70	0
Chydoridae	65	7	10.8	10.5	17.8	23	10	43.48	43.48	0
Daphniidae	65	16	24.6	18.1	22.3	23	2	8.70	8.70	0
Macrothricidae	65	14	21.5	19.5	25.9	23	3	13.04	13.04	0
Moinidae	65	0	0.0	0.0	0.0	23	1	4.35	4.35	0
Habitat richness										
Total richness per wetlan										
Percentage of habitat										

Appendix 1: The reference materials sourced for the establishment of the database of all known aquatic invertebrates recorded in wetlands of the SCP

The reference materials sourced for the establishment of the database of all known aquatic invertebrates recorded in wetlands of the SCP are outlined below. For each source, an abbreviation is used, plus a brief comment on the nature of the database, and the sampling protocol used to obtain the invertebrate information (which was subsequently used to calculate the effort index).

AusRivAS: the Australia-wide Monitoring River Health Initiative using a standardized rapid bioassessment sampling protocol (Smith, Kay *et al.* 1999) included data from two sites in the study area (Gin Gin Broook and Ellenbrook). These data, collected between August 1994 and May 1996, are under the custodianship of the Western Australian Department of Environment and Conservation. Flowing wetlands were sampled twice yearly for three years, using a 250 µm mesh net over 10 m length of habitat, in 3 different types of habitat in a 100 m section of wetland. Invertebrate samples were sorted live and picked for 60 minutes. Taxa were usually identified to family level.

B&D: Balla and Davis (1993) reports on Shirley Balla's PhD work undertaken in 1988 and 1989 and subsequently published as a Volume of the Wetlands of the Swan Coastal Plain series. Five wetlands were sampled intensively (every three weeks over a 13 month period). Samples were collected over one 50-m section of wetland in 1 m units with a 250µm mesh net. Samples were preserved and sorted with the aid of a microscope, with identification to species level.

B&H: the Western Australian Water and Rivers Commission (today the Department of Water) have funded rapid bioassessment of 16 selected iconic and important wetlands on the Gnangara Mound, documented in annual reports (Benier and Horwitz 2003). Monitoring took place biannually (spring and late summer/early autumn) for nine years up to and including summer 2003. Sampling was done by sweeping with a 250µm mesh net for two minutes in 3, 4 or 5 habitats (depending on habitat heterogeneity). Samples were live-picked for 30 minutes and identified to family level. Some taxa (e.g. oligochaetes) were not differentiated beyond Class level identification.

D&C: Davis and Christidis (1997) have compiled previously known records of invertebrates, bringing together the work undertaken by Balla and Davis (1993), Davis et al (1993) and other work (see below). The book includes Pinder's Oligochaeta identifications of material held at Murdoch University. This source was not used to calculate the effort index.

Detal: probably the most systematic attempt to survey the macroinvertebrate fauna of wetlands on the Swan Coastal Plain was undertaken by Davis et al. (1993), commonly referred to as "the 40 wetland study". Wetlands were sampled three times in two years (1989 and 1990) in spring and summer. Six samples from randomly selected areas, usually in open water, were sampled with a 250µm mesh net; samples were preserved and picked in the laboratory with the aid of a microscope. Identification was to species level where appropriate.

DHNC: Davis et al.(2006) conducted an *in situ* test of methods used to collect invertebrates and monitor wetlands by comparing sampling and sorting techniques used by Davis et al. (1993), and the rapid bioassessment techniques (i.e. Benier and Horwitz 2003; Wild, Davis *et al.* 2003).

English: English et al. (2003) and Knott and Storey (2004) report the fauna collected from five caves with aquatic root mat habitats and a surface stream in Yanchep National Park. Aquatic root mat communities were sampled by taking a small portion of the root map, keeping it cool and aerated and transporting to the laboratory where it was sorted and live-picked. The authors report the fauna collected by Jasinska (1997). The taxonomic list provided by Knott and Storey (2004) is used as the verified data, which consolidates uncertain taxa into higher level categories.

Hpc: Halse pers. comm., unpublished data. For the purposes of analyses in this paper the sampling for invertebrates was taken to be similar to Halse and Storey (1996) below.

H&G: Hembree and George (1978) and members of the Western Australian Museum give the earliest record of a systematic attempt to document fauna of wetlands on the Swan Coastal Plain. Sampling occurred every two months (monthly for Lake Jandabup) over one year 1977-8, in the dominant habitats. Macroinvertebrates were collected by sweep net (500µm mesh pore size) and by benthic corer. Zooplankton were collected with a 50 µm mesh. Samples were preserved and sorted by microscope, and identified to species where possible.

H&S: Halse and Storey (1996) undertook aquatic invertebrate surveys of the Perth Airport swamps. One site per wetland was sampled. Because all wetlands were part of a local suite they are considered together for this study. Two samples were collected in 1995, one in early spring, one in late spring, using a 110 µm mesh net swept over a 50 m stretch of mixed habitat. Samples were preserved and sorted under a microscope, and taxa were identified to species level wherever possible.

Jas: Jasinska (1998) reports on the monitoring of tumulus springs. Macroinvertebrates were sampled from water flowing out of the springs, and from surface waters receiving flowing waters (wetland areas), using techniques as per J&K below.

J&K: The work of Jasinska & Knott (1994) records the aquatic fauna in Gnangara Mound discharge areas of the Ellen Brook catchment. These discharge areas included tumulus mound springs and their receiving surface wetland areas. Sweep nets were used for surface waters, and plastic tubing was used to siphon water out of the mouth of the spring. Samples were sieved, retaining material above 50 µm in size, and live-sorted in the laboratory under a microscope.

Ketal: Kinnear et al.(1997) collected monthly samples over 15 months in 1992 and 1993 from Lakes Joondalup and Goolellal, and Beenyup Swamp from randomised sites within each wetland. A net (70 µm mesh) was used to sweep the water column for 1 minute Samples were preserved, sorted in the laboratory and identified to species level where possible (except Oligochaete and Hirudinea taxa).

KJ&S: Knott et al. (2002) document the invertebrate fauna collected from Melaleuca Park Wetland EPP 173 during spring 1995 and spring 1997.

L92: Lund (1992) sampled six sites at Lake Monger monthly. Samples were taken by sweeping a net (250 µm mesh) throughout the water column within an area of $0.5m^2$ over 20 seconds. Samples were preserved then sorted in the laboratory, and invertebrates were identified to species where possible.

L&O: Lund and Ogden (2003) report on work carried out in 2002-2003 at Mary Carroll Park Wetlands. Up to seven sites per wetland were sampled each season, depending on the extent of the water. Samples were taken by sweeping a net (500 µm mesh) throughout water column, over 5 m transects for 20 seconds. Samples were preserved then sorted in the laboratory, and invertebrates were identified to species where possible.

P02: Pinder (2002) reported on the fauna of three springs of the Gnangara Mound, sampled once in 2002.

WDS: : the Western Australian Water and Rivers Commission (today the Department of Water) have funded rapid bioassessment of selected iconic and important wetlands on the Jandakot Mound, documented in annual reports (Wild, Davis *et al.* 2003). Monitoring took place biannually (spring and late summer/early autumn) for nine years up to and including summer 2003. Sampling was done by sweeping a 250µm mesh net for two minutes in 3, 4 or 5 habitats (depending on habitat heterogeneity). Samples were live-picked for 30 minutes and identified to family level. Some taxa (e.g. oligochaetes) were not differentiated beyond Class level identification.

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	***Typha orientalis***					***Baumea articulata***					*T. orientalis/B. articulata*					Mixed Cyperaceae			
	total visits	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***
				i.e. how common					***i.e. how common***					***i.e. how common***					***i.e. how common***
(Hydra)	139	2	1.4	1.3	2.5	99	1.00	1.01	0.48	1.06	59	1	1.7	2.08	4.2	59	6	10.2	8.3
NEMATODA	139	1	0.7	0.8	2.4	99	3.00	3.03	1.43	3.19	59	2	3.4	4.17	8.3	59	0	0.0	0.0
NEMERTINI	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
PORIFERA	139	3	2.2	2.0	2.8	99	3.00	3.03	2.48	4.33	59	1	1.7	1.92	3.8	59	1	1.7	2.2
TURBELLARIA	139	39	28.1	18.2	23.9	99	5.00	5.05	2.96	4.32	59	8	13.6	20.83	25.0	59	5	8.5	8.5
TEMNOCEPHALIDEA	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Hirudinea	139	38	27.3	25.4	22.2	99	15.00	15.15	14.93	17.79	59	5	8.5	12.26	17.1	59	7	11.9	10.5
Oligochaeta	139	60	43.2	39.5	30.1	99	40.00	40.40	24.27	30.05	59	27	45.8	52.56	18.7	59	20	33.9	38.0
Ancylidae	139	4	2.9	2.9	5.5	99	3.00	3.03	2.01	2.75	59	0	0.0	0.00	0.0	59	2	3.4	3.6
Lymnaeidae	139	6	4.3	4.0	8.8	99	4.00	4.04	3.53	4.22	59	2	3.4	4.17	8.3	59	4	6.8	7.1
Physidae	139	62	44.6	42.4	29.9	99	20.00	20.20	17.90	34.96	59	16	27.1	25.24	17.9	59	0	0.0	0.0
Planorbidae	139	18	12.9	10.0	12.2	99	9.00	9.09	7.06	6.90	59	18	30.5	27.00	17.9	59	9	15.3	13.3
Hydriella	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Sphaeriidae	139	5	3.6	1.7	4.9	99	1.00	1.01	1.05	2.35	59	5	8.5	5.77	7.4	59	1	1.7	1.4
Lycosidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Tetragnathidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Pisauridae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Unidentified	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Arrenuridae	139	12	8.6	12.5	14.2	99	2.00	2.02	2.00	4.47	59	3	5.1	2.88	5.8	59	9	15.3	14.1
Astigmata	139	1	0.7	1.0	2.7	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Eylaidae	139	3	2.2	2.0	3.9	99	0.00	0.00	0.00	0.00	59	3	5.1	5.05	6.2	59	0	0.0	0.0
Halacoroidea	139	0	0.0	0.0	0.0	99	3.00	3.03	3.16	7.06	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Hydrachnidae	139	12	8.6	10.2	13.0	99	3.00	3.03	2.48	4.33	59	2	3.4	4.09	5.9	59	3	5.1	4.2
Hydrodromidae	139	5	3.6	4.5	6.3	99	3.00	3.03	3.29	3.84	59	0	0.0	0.00	0.0	59	2	3.4	2.8
Limnocharidae	139	1	0.7	0.3	1.0	99	3.00	3.03	3.00	6.71	59	1	1.7	0.96	1.9	59	0	0.0	0.0
Limnesiidae	139	29	20.9	23.1	25.2	99	14.00	14.14	15.50	6.31	59	8	13.6	13.06	4.0	59	2	3.4	2.8
Oribatida	139	6	4.3	4.7	4.9	99	10.00	10.10	12.41	8.86	59	1	1.7	1.92	3.8	59	7	11.9	9.7
Oxidae	139	6	4.3	3.5	5.2	99	5.00	5.05	2.38	5.32	59	3	5.1	6.25	12.5	59	3	5.1	6.5
Pionidae	139	45	32.4	35.5	27.0	99	17.00	17.17	13.96	18.47	59	7	11.9	16.51	22.6	59	7	11.9	10.5
Unidentified	139	18	12.9	12.4	10.5	99	8.00	8.08	5.96	6.44	59	8	13.6	15.30	12.2	59	5	8.5	9.3
Unioncolidae	139	7	5.0	5.5	6.9	99	15.00	15.15	16.54	27.59	59	10	16.9	18.91	19.8	59	11	18.6	22.3
Ceinidae	139	56	40.3	32.2	27.8	99	37.00	37.37	33.44	38.68	59	31	52.5	46.31	20.2	59	35	59.3	62.0
Perthidae	139	0	0.0	0.0	0.0	99	3.00	3.03	5.45	12.20	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Amphisopidae	139	66	47.5	49.3	33.4	99	15.00	15.15	14.95	20.96	59	7	11.9	8.89	11.1	59	29	49.2	43.4
Janiridae	139	1	0.7	1.6	4.4	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Palaemonidae	139	38	27.3	19.9	32.6	99	41.00	41.41	26.62	32.15	59	30	50.8	55.85	46.4	59	21	35.6	45.7
Parastacidae	139	4	2.9	2.7	4.5	99	14.00	14.14	20.69	24.54	59	3	5.1	3.85	4.4	59	4	6.8	5.6
Caenidae	139	8	5.8	4.9	4.9	99	16.00	16.16	12.13	13.46	59	5	8.5	9.05	2.3	59	11	18.6	19.2
Baetidae	139	17	12.2	9.9	9.5	99	30.00	30.30	20.82	24.63	59	12	20.3	25.16	15.3	59	19	32.2	30.3
COLLEMBOLA	139	2	1.4	1.3	2.5	99	2.00	2.02	0.95	2.13	59	2	3.4	5.05	6.2	59	0	0.0	0.0
MECOPTERA	139	1	0.7	1.6	4.4	99	13.00	13.13	6.19	13.84	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Sisyridae	139	0	0.0	0.0	0.0	99	15.00	15.15	7.14	15.97	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Aeshnidae	139	50	36.0	40.6	20.5	99	31.00	31.31	38.98	23.71	59	16	27.1	26.12	8.0	59	26	44.1	36.1
Coenagrionidae	139	27	19.4	18.1	7.9	99	14.00	14.14	16.98	22.90	59	24	40.7	36.22	24.1	59	18	30.5	26.6
Cordulidae	139	19	13.7	15.7	10.2	99	19.00	19.19	17.61	15.24	59	8	13.6	14.34	13.9	59	11	18.6	15.3
Gomphidae	139	3	2.2	3.8	8.8	99	8.00	8.08	3.81	8.52	59	6	10.2	6.73	9.1	59	1	1.7	2.2
Lestidae	139	54	38.8	39.9	20.3	99	27.00	27.27	36.36	28.44	59	19	32.2	23.72	27.3	59	30	50.8	42.5

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	***Typha orientalis***					***Baumea articulata***					*T. orientalis/B. articulata*					Mixed Cyperaceae			
	total visits	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***
				i.e. how common					***i.e. how common***					***i.e. how common***					***i.e. how common***
Libellulidae	139	18	12.9	11.4	11.6	99	12.00	12.12	14.28	17.19	59	14	23.7	22.20	17.4	59	21	35.6	30.7
Macrodiplactidae	139	0	0.0	0.0	0.0	99	1.00	1.01	1.82	4.07	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Megapodagrionidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	1	1.7	1.4
Synthemidae	139	0	0.0	0.0	0.0	99	1.00	1.01	0.48	1.06	59	1	1.7	0.96	1.9	59	0	0.0	0.0
Ecnomidae	139	10	7.2	5.2	6.5	99	12.00	12.12	17.41	27.30	59	2	3.4	5.21	6.3	59	5	8.5	6.9
Hydroptilidae	139	22	15.8	10.2	13.1	99	20.00	20.20	10.05	19.79	59	12	20.3	25.08	22.4	59	15	25.4	30.3
Leptoceridae	139	70	50.4	51.4	27.4	99	61.00	61.62	46.09	35.69	59	38	64.4	61.06	31.0	59	39	66.1	66.7
Corixidae	139	90	64.7	62.6	31.3	99	55.00	55.56	55.51	22.92	59	23	39.0	40.63	37.3	59	18	30.5	27.4
Gerridae	139	5	3.6	7.2	17.5	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	9	15.3	12.5
Hebridae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Hydrometridae	139	1	0.7	1.0	2.7	99	1.00	1.01	0.48	1.06	59	0	0.0	0.00	0.0	59	1	1.7	1.4
Mesoveliidae	139	9	6.5	8.1	8.2	99	13.00	13.13	11.46	9.49	59	3	5.1	7.29	8.6	59	12	20.3	17.5
Nepidae	139	0	0.0	0.0	0.0	99	4.00	4.04	4.35	3.41	59	1	1.7	2.08	4.2	59	5	8.5	6.9
Notonectidae	139	68	48.9	54.5	26.9	99	32.00	32.32	33.32	31.05	59	17	28.8	24.92	19.8	59	32	54.2	44.4
Pleidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Naucoridae	139	1	0.7	0.8	2.2	99	1.00	1.01	1.05	2.35	59	0	0.0	0.00	0.0	59	4	6.8	5.6
Saldidae	139	1	0.7	0.8	2.2	99	1.00	1.01	0.48	1.06	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Veliidae	139	11	7.9	9.1	11.4	99	12.00	12.12	17.82	20.91	59	4	6.8	6.97	5.2	59	6	10.2	9.1
Ceratopogonidae	139	40	28.8	30.4	35.4	99	31.00	31.31	27.59	24.67	59	13	22.0	23.32	12.2	59	13	22.0	21.2
Chaoborinae	139	0	0.0	0.0	0.0	99	2.00	2.02	3.64	8.13	59	0	0.0	22.92	45.8	59	0	0.0	0.0
Chironominae	139	117	84.2	86.7	11.4	99	74.00	74.75	66.47	24.14	59	47	79.7	60.10	28.1	59	42	71.2	71.7
Culicidae	139	24	17.3	19.7	21.0	99	17.00	17.17	18.62	10.24	59	13	22.0	17.79	13.5	59	5	8.5	6.9
Empididae	139	1	0.7	0.8	2.4	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	1	1.7	2.2
Ephydridae	139	2	1.4	2.2	4.5	99	0.00	0.00	0.00	0.00	59	1	1.7	0.96	1.9	59	0	0.0	0.0
Orthocladiinae	139	40	28.8	28.4	16.4	99	31.00	31.31	27.29	13.39	59	17	28.8	32.29	9.8	59	15	25.4	27.1
Sciomyzidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	1	1.7	3.13	6.3	59	0	0.0	0.0
Simulidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Stratiomyidae	139	21	15.1	12.6	9.5	99	10.00	10.10	7.90	13.02	59	7	11.9	12.10	3.7	59	1	1.7	1.4
Tabanidae	139	1	0.7	0.6	1.8	99	3.00	3.03	1.95	2.67	59	3	5.1	6.17	5.4	59	0	0.0	0.0
Tanypodinae	139	79	56.8	59.5	11.5	99	64.00	64.65	54.57	19.17	59	37	62.7	59.78	24.9	59	29	49.2	52.8
Tipulidae	139	0	0.0	0.0	0.0	99	6.00	6.06	3.96	4.03	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Pyralidae	139	8	5.8	6.4	7.3	99	5.00	5.05	4.25	4.14	59	1	1.7	3.13	6.3	59	1	1.7	1.4
Carabidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Chyrsomelidae	139	0	0.0	0.0	0.0	99	1.00	1.01	1.00	2.24	59	0	0.0	0.00	0.0	59	3	5.1	4.2
Curculionidae	139	3	2.2	3.1	5.8	99	5.00	5.05	9.36	11.59	59	1	1.7	3.13	6.3	59	5	8.5	6.9
Dryopidae	139	0	0.0	0.0	0.0	99	1.00	1.01	1.82	4.07	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Dytiscidae	139	79	56.8	65.9	29.9	99	62.00	62.63	71.59	17.93	59	37	62.7	52.48	30.9	59	33	55.9	51.3
Elmidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Gyrinidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Haliplidae	139	5	3.6	3.4	6.4	99	3.00	3.03	3.82	5.24	59	0	0.0	0.00	0.0	59	1	1.7	1.4
Helminthidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Hydraenidae	139	3	2.2	1.6	3.5	99	3.00	3.03	2.77	4.09	59	2	3.4	1.92	3.8	59	1	1.7	1.4
Hydrochidae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Hydrophilidae	139	63	45.3	54.5	25.2	99	42.00	42.42	50.08	21.40	59	21	35.6	37.50	16.4	59	25	42.4	37.1
Limnichidae	139	2	1.4	1.7	3.2	99	7.00	7.07	14.31	17.70	59	0	0.0	0.00	0.0	59	8	13.6	11.1
Noteridae	139	1	0.7	0.5	1.5	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Ptilodactilidae	139	1	0.7	0.6	1.8	99	1.00	1.01	2.86	6.39	59	0	0.0	0.00	0.0	59	0	0.0	0.0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	***Typha orientalis***					***Baumea articulata***					*T. orientalis/B. articulata*					Mixed Cyperaceae			
	total visits	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***
				i.e. how common					***i.e. how common***					***i.e. how common***					***i.e. how common***
Scirtidae	139	12	8.6	7.6	8.8	99	14.00	14.14	23.02	24.66	59	0	0.0	0.00	0.0	59	11	18.6	15.3
Staphylinidae	139	1	0.7	1.6	4.4	99	1.00	1.01	1.82	4.07	59	1	1.7	2.08	4.2	59	0	0.0	0.0
Unidentified	139	0	0.0	0.0	0.0	99	1.00	1.01	1.82	4.07	59	0	0.0	0.00	0.0	59	2	3.4	3.6
Calanoida	139	48	34.5	26.1	26.2	99	31.00	31.31	35.47	35.29	59	20	33.9	33.33	18.4	59	31	52.5	47.0
Cyclopoida	139	71	51.1	55.6	24.5	99	51.00	51.52	47.93	22.11	59	21	35.6	34.29	18.6	59	21	35.6	35.4
Harpacticoida	139	5	3.6	3.6	7.1	99	5.00	5.05	2.96	4.32	59	1	1.7	0.96	1.9	59	4	6.8	6.3
CONCHOSTRACA	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Cyprididae	139	95	68.3	64.8	37.7	99	67.00	67.68	51.56	36.74	59	40	67.8	71.63	22.4	59	40	67.8	65.0
Gomphodellidae	139	1	0.7	0.6	1.8	99	1.00	1.01	0.48	1.06	59	1	1.7	2.08	4.2	59	0	0.0	0.0
Ilyocyprididae	139	0	0.0	0.0	0.0	99	0.00	0.00	0.00	0.00	59	1	1.7	0.96	1.9	59	0	0.0	0.0
Limnocytheridae	139	1	0.7	0.8	2.2	99	1.00	1.01	1.05	2.35	59	0	0.0	0.00	0.0	59	0	0.0	0.0
Notodromadidae	139	18	12.9	11.1	12.1	99	3.00	3.03	1.95	2.67	59	5	8.5	5.77	7.4	59	0	0.0	0.0
Unidentified Ostracoda	139	1	0.7	0.8	2.2	99	0.00	0.00	0.00	0.00	59	5	8.5	9.62	19.2	59	4	6.8	8.7
Chydoridae	139	53	38.1	37.1	26.9	99	35.00	35.35	32.93	29.40	59	18	30.5	32.45	14.8	59	29	49.2	47.3
Daphniidae	139	54	38.8	40.6	24.8	99	21.00	21.21	20.92	14.22	59	11	18.6	13.86	14.8	59	27	45.8	41.4
Macrothricidae	139	8	5.8	6.8	13.3	99	21.00	21.21	29.97	27.01	59	3	5.1	5.93	7.4	59	18	30.5	27.4
Moinidae	139	1	0.7	0.3	1.0	99	0.00	0.00	0.00	0.00	59	0	0.0	0.00	0.0	59	2	3.4	2.8
Habitat richness																			
Total richness per wetland																			
Percentage of habitat																			

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community		Mixed Cyperaceae with submerged herbaceous					Mixed Restionaceae					Mixed Cyperaceae/Restionaceae					*Lepidosperma long*		
	SD	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***
					i.e. how common					***i.e. how common***					***i.e. how common***				
(Hydra)	11.8	70	2	2.9	2.7	6.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
NEMATODA	0.0	70	0	0.0	0.0	0.0	34	2.00	5.88	5.16	4.51	12	0	0.0	0.0	0	42	3	7.1
NEMERTINI	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
PORIFERA	3.1	70	0	0.0	0.0	0.0	34	1.00	2.94	2.38	4.12	12	0	0.0	0.0	0	42	0	0.0
TURBELLARIA	0.3	70	5	7.1	10.0	14.1	34	1.00	2.94	2.78	4.81	12	1	8.3	8.3	0	42	10	23.8
TEMNOCEPHALIDEA	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42	0	0.0
Hirudinea	8.7	70	3	4.3	8.1	8.4	34	3.00	8.82	8.33	14.43	12	1	8.3	8.3	0	42	7	16.7
Oligochaeta	26.2	70	28	40.0	41.2	24.2	34	4.00	11.76	10.71	12.88	12	0	0.0	0.0	0	42	20	47.6
Ancylidae	1.1	70	2	2.9	1.4	3.1	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	2	4.8
Lymnaeidae	2.2	70	3	4.3	6.0	8.3	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Physidae	0.0	70	25	35.7	27.8	38.1	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	14	33.3
Planorbidae	12.6	70	15	21.4	20.9	13.1	34	4.00	11.76	11.11	19.25	12	0	0.0	0.0	0	42	0	0.0
Hydriella	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Sphaeriidae	2.0	70	4	5.7	2.8	6.2	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Lycosidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Tetragnathidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Pisauridae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Unidentified	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Arrenuridae	7.6	70	10	14.3	27.4	33.6	34	2.00	5.88	5.56	9.62	12	0	0.0	0.0	0	42	2	4.8
Astigmata	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Eylaidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Halacoroidea	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Hydrachnidae	5.9	70	9	12.9	9.5	11.2	34	4.00	11.76	9.92	10.80	12	0	0.0	0.0	0	42	0	0.0
Hydrodromidae	3.9	70	5	7.1	4.7	6.6	34	1.00	2.94	2.78	4.81	12	3	25.0	25.0	0	42	1	2.4
Limnocharidae	0.0	70	1	1.4	3.3	7.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Limnesiidae	3.9	70	8	11.4	13.7	13.5	34	2.00	5.88	4.76	8.25	12	7	58.3	58.3	0	42	5	11.9
Oribatida	13.7	70	10	14.3	12.4	14.2	34	6.00	17.65	17.26	6.76	12	1	8.3	8.3	0	42	2	4.8
Oxidae	9.2	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	5	11.9
Pionidae	8.7	70	17	24.3	33.2	21.3	34	1.00	2.94	2.78	4.81	12	0	0.0	0.0	0	42	6	14.3
Unidentified	5.3	70	9	12.9	11.0	7.4	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	2	4.8
Unioncolidae	23.7	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	12	100.0	100.0	0	42	8	19.0
Ceinidae	16.9	70	29	41.4	29.3	26.9	34	8.00	23.53	21.83	31.82	12	0	0.0	0.0	0	42	18	42.9
Perthidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Amphisopidae	36.8	70	30	42.9	55.7	26.7	34	6.00	17.65	16.67	28.87	12	0	0.0	0.0	0	42	3	7.1
Janiridae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Palaemonidae	64.6	70	12	17.1	8.3	18.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	34	81.0
Parastacidae	7.9	70	9	12.9	14.8	12.6	34	6.00	17.65	15.48	13.52	12	10	83.3	83.3	0	42	4	9.5
Caenidae	3.6	70	8	11.4	10.7	11.4	34	3.00	8.82	8.33	14.43	12	0	0.0	0.0	0	42	8	19.0
Baetidae	12.1	70	11	15.7	10.8	15.5	34	4.00	11.76	11.11	19.25	12	0	0.0	0.0	0	42	15	35.7
COLLEMBOLA	0.0	70	3	4.3	4.3	9.6	34	5.00	14.71	12.30	14.69	12	0	0.0	0.0	0	42	1	2.4
MECOPTERA	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Sisyridae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Aeshnidae	51.1	70	27	38.6	37.5	31.7	34	11.00	32.35	29.37	34.03	12	2	16.7	16.7	0	42	18	42.9
Coenagrionidae	25.3	70	32	45.7	33.8	37.3	34	6.00	17.65	16.67	28.87	12	4	33.3	33.3	0	42	21	50.0
Cordulidae	21.6	70	15	21.4	16.6	16.1	34	4.00	11.76	12.10	4.77	12	0	0.0	0.0	0	42	3	7.1
Gomphidae	3.1	70	2	2.9	1.4	3.1	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Lestidae	53.9	70	42	60.0	56.7	27.6	34	17.00	50.00	45.44	28.92	12	7	58.3	58.3	0	42	10	23.8

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community		Mixed Cyperaceae with submerged herbaceous					Mixed Restionaceae					Mixed Cyperaceae/Restionaceae					*Lepidosperma long*		
	SD	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***
					i.e. how common					***i.e. how common***					***i.e. how common***				
Libellulidae	31.2	70	33	47.1	37.4	26.5	34	8.00	23.53	23.61	30.71	12	0	0.0	0.0	0	42	7	16.7
Macrodiplactidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Megapodagrionidae	2.0	70	1	1.4	0.7	1.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Synthemidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Ecnomidae	9.8	70	2	2.9	2.7	6.0	34	4.00	11.76	10.71	12.88	12	0	0.0	0.0	0	42	0	0.0
Hydroptilidae	31.0	70	6	8.6	8.9	6.7	34	4.00	11.76	11.11	19.25	12	0	0.0	0.0	0	42	16	38.1
Leptoceridae	4.0	70	42	60.0	51.9	21.1	34	12.00	35.29	32.54	44.56	12	12	100.0	100.0	0	42	29	69.0
Corixidae	20.2	70	45	64.3	51.9	32.6	34	11.00	32.35	31.75	8.78	12	6	50.0	50.0	0	42	17	40.5
Gerridae	17.7	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Hebridae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Hydrometridae	2.0	70	1	1.4	0.7	1.5	34	1.00	2.94	2.78	4.81	12	1	8.3	8.3	0	42	0	0.0
Mesoveliidae	18.5	70	15	21.4	18.9	20.5	34	5.00	14.71	14.88	9.16	12	3	25.0	25.0	0	42	6	14.3
Nepidae	9.8	70	5	7.1	4.8	4.6	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42	1	2.4
Notonectidae	62.9	70	44	62.9	53.4	38.9	34	14.00	41.18	38.69	32.46	12	7	58.3	58.3	0	42	5	11.9
Pleidae	0.0	70	1	1.4	0.7	1.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Naucoridae	7.9	70	1	1.4	1.3	3.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Saldidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Veliidae	6.7	70	10	14.3	11.1	11.9	34	5.00	14.71	12.70	11.25	12	5	41.7	41.7	0	42	4	9.5
Ceratopogonidae	5.4	70	17	24.3	23.5	19.1	34	14.00	41.18	49.60	46.93	12	0	0.0	0.0	0	42	14	33.3
Chaoborinae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42	0	0.0
Chironominae	3.2	70	52	74.3	64.9	27.7	34	17.00	50.00	51.39	10.49	12	7	58.3	58.3	0	42	30	71.4
Culicidae	9.8	70	23	32.9	42.6	25.6	34	11.00	32.35	28.77	24.66	12	5	41.7	41.7	0	42	10	23.8
Empididae	3.1	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Ephydridae	0.0	70	1	1.4	3.3	7.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Orthocladiinae	10.8	70	13	18.6	17.0	12.5	34	6.00	17.65	19.05	10.31	12	10	83.3	83.3	0	42	15	35.7
Sciomyzidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Simulidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Stratiomyidae	2.0	70	9	12.9	13.4	7.8	34	1.00	2.94	2.78	4.81	12	0	0.0	0.0	0	42	5	11.9
Tabanidae	0.0	70	2	2.9	4.0	7.2	34	3.00	8.82	7.54	7.18	12	0	0.0	0.0	0	42	1	2.4
Tanypodinae	23.7	70	41	58.6	51.5	23.3	34	17.00	50.00	45.04	28.34	12	4	33.3	33.3	0	42	22	52.4
Tipulidae	0.0	70	1	1.4	3.3	7.5	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Pyralidae	2.0	70	2	2.9	2.9	6.4	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42	1	2.4
Carabidae	0.0	70	0	0.0	0.0	0.0	34	1.00	2.94	4.17	7.22	12	0	0.0	0.0	0	42	0	0.0
Chyrsomelidae	5.9	70	1	1.4	1.4	3.2	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Curculionidae	9.8	70	1	1.4	3.3	7.5	34	7.00	20.59	19.25	8.34	12	3	25.0	25.0	0	42	3	7.1
Dryopidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Dytiscidae	29.5	70	52	74.3	70.7	14.0	34	25.00	73.53	78.17	30.87	12	11	91.7	91.7	0	42	32	76.2
Elmidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Gyrinidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Haliplidae	2.0	70	5	7.1	5.6	5.9	34	1.00	2.94	2.78	4.81	12	0	0.0	0.0	0	42	1	2.4
Helminthidae	0.0	70	1	1.4	1.4	3.2	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Hydraenidae	2.0	70	2	2.9	4.0	7.2	34	1.00	2.94	2.78	4.81	12	1	8.3	8.3	0	42	2	4.8
Hydrochidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42	0	0.0
Hydrophilidae	34.0	70	40	57.1	49.5	31.1	34	21.00	61.76	63.49	9.98	12	5	41.7	41.7	0	42	16	38.1
Limnichidae	15.7	70	1	1.4	1.4	3.2	34	8.00	23.53	26.39	22.95	12	3	25.0	25.0	0	42	0	0.0
Noteridae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Ptilodactilidae	0.0	70	3	4.3	6.2	8.5	34	1.00	2.94	4.17	7.22	12	0	0.0	0.0	0	42	0	0.0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community		Mixed Cyperaceae with submerged herbaceous					Mixed Restionaceae					Mixed Cyperaceae/Restionaceae					*Lepidosperma long*		
	SD	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***
					i.e. how common					***i.e. how common***					***i.e. how common***				
Scirtidae	21.6	70	17	24.3	38.6	37.7	34	3.00	8.82	7.54	7.18	12	7	58.3	58.3	0	42	1	2.4
Staphylinidae	0.0	70	2	2.9	6.7	14.9	34	0.00	0.00	0.00	0.00	12	1	8.3	8.3	0	42	0	0.0
Unidentified	1.1	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Calanoida	35.7	70	30	42.9	40.9	24.8	34	10.00	29.41	26.98	35.10	12	11	91.7	91.7	0	42	13	31.0
Cyclopoida	0.9	70	30	42.9	38.7	9.9	34	12.00	35.29	30.16	28.70	12	6	50.0	50.0	0	42	18	42.9
Harpacticoida	2.8	70	3	4.3	3.4	5.8	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	3	7.1
CONCHOSTRACA	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Cyprididae	18.1	70	44	62.9	70.4	20.3	34	16.00	47.06	42.06	41.67	12	1	8.3	8.3	0	42	30	71.4
Gomphodellidae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	3	7.1
Ilyocyprididae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Limnocytheridae	0.0	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	1	2.4
Notodromadidae	0.0	70	14	20.0	19.1	13.6	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	7	16.7
Unidentified Ostracoda	12.3	70	0	0.0	0.0	0.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Chydoridae	11.6	70	21	30.0	33.5	27.6	34	10.00	29.41	27.38	41.39	12	1	8.3	8.3	0	42	16	38.1
Daphniidae	27.8	70	22	31.4	34.7	24.3	34	8.00	23.53	21.83	31.82	12	6	50.0	50.0	0	42	8	19.0
Macrothricidae	20.2	70	11	15.7	15.1	20.8	34	10.00	29.41	32.14	15.57	12	1	8.3	8.3	0	42	3	7.1
Moinidae	3.9	70	1	1.4	1.3	3.0	34	0.00	0.00	0.00	0.00	12	0	0.0	0.0	0	42	0	0.0
Habitat richness																			
Total richness per wetlan																			
Percentage of habitat																			

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*itudinale*		*Mixed Restionaceae/ Lepidosperma*								*B. articualta/Lepidosperma*					*M. raphiophylla/B. articulata*			
	Mean percentage	***SD***	***Gnangara***			***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***
	i.e. how common		***Times found***	***Times habitat***	***Percentage***				***i.e. how common***					***i.e. how common***					***i.e. how common***
(Hydra)	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
NEMATODA	3.6	7.1		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	1	1.1	1.7
NEMERTINI	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
PORIFERA	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	4	4.3	3.7
TURBELLARIA	12.6	20.5		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	13	14.0	16.9
TEMNOCEPHALIDEA	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Hirudinea	13.5	9.7		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	25	26.9	25.2
Oligochaeta	28.2	33.6	1	9	11.11	9	1	11.11	11.11	0	15	8	53.33	53.33	0	93	29	31.2	28.9
Ancylidae	3.1	3.8		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	3	3.2	2.5
Lymnaeidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	3	3.2	2.9
Physidae	24.1	20.8		9	0.00	9	0	0.00	0.00	0	15	5	33.33	33.33	0	93	38	40.9	40.7
Planorbidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	8	8.6	9.5
Hydriella	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Sphaeriidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Lycosidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Tetragnathidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Pisauridae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Unidentified	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Arrenuridae	5.4	7.9		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	15	16.1	21.2
Astigmata	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Eylaidae	4.2	8.3		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Halacoroidea	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Hydrachnidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	4	4.3	3.9
Hydrodromidae	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	1.0
Limnocharidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	5	5.4	5.0
Limnesiidae	6.7	9.0	1	9	11.11	9	1	11.11	11.11	0	15	2	13.33	13.33	0	93	11	11.8	10.9
Oribatida	8.3	16.7		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	3	3.2	3.0
Oxidae	7.4	8.6		9	0.00	9	0	0.00	0.00	0	15	4	26.67	26.67	0	93	5	5.4	4.1
Pionidae	16.8	22.5		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	17	18.3	19.9
Unidentified	2.4	4.8	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	8	8.6	11.1
Unioncolidae	11.7	13.5	1	9	11.11	9	1	11.11	11.11	0	15	7	46.67	46.67	0	93	13	14.0	11.5
Ceinidae	43.6	42.6		9	0.00	9	0	0.00	0.00	0	15	3	20.00	20.00	0	93	51	54.8	52.2
Perthidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Amphisopidae	12.5	25.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	33	35.5	38.1
Janiridae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Palaemonidae	53.0	52.0		9	0.00	9	0	0.00	0.00	0	15	12	80.00	80.00	0	93	61	65.6	56.5
Parastacidae	9.2	8.1	1	9	11.11	9	1	11.11	11.11	0	15	2	13.33	13.33	0	93	3	3.2	3.4
Caenidae	13.9	22.0		9	0.00	9	0	0.00	0.00	0	15	4	26.67	26.67	0	93	7	7.5	6.5
Baetidae	28.2	19.8		9	0.00	9	0	0.00	0.00	0	15	8	53.33	53.33	0	93	12	12.9	10.7
COLLEMBOLA	1.2	2.4		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	4	4.3	4.8
MECOPTERA	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Sisyridae	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Aeshnidae	49.8	15.8	3	9	33.33	9	3	33.33	33.33	0	15	2	13.33	13.33	0	93	15	16.1	15.8
Coenagrionidae	33.9	29.3	2	9	22.22	9	2	22.22	22.22	0	15	7	46.67	46.67	0	93	24	25.8	23.6
Cordulidae	5.0	7.3	3	9	33.33	9	3	33.33	33.33	0	15	4	26.67	26.67	0	93	4	4.3	4.7
Gomphidae	5.5	6.9		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	0.8
Lestidae	39.0	23.6	2	9	22.22	9	2	22.22	22.22	0	15	5	33.33	33.33	0	93	15	16.1	17.7

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*itudinale*		*Mixed Restionaceae/ Lepidosperma*								*B. articualta/Lepidosperma*					*M. raphiophylla/B. articulata*			
	Mean percentage	***SD***	***Gngangara***			***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***
	i.e. how common		***Times found***	***Times habitat***	***Percentage***				***i.e. how common***					***i.e. how common***					***i.e. how common***
Libellulidae	9.5	16.0	1	9	11.11	9	1	11.11	11.11	0	15	1	6.67	6.67	0	93	4	4.3	4.9
Macrodiplactidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Megapodagrionidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Synthemidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Ecnomidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	3	3.2	2.6
Hydroptilidae	30.1	22.3		9	0.00	9	0	0.00	0.00	0	15	11	73.33	73.33	0	93	18	19.4	15.4
Leptoceridae	55.2	39.2		9	0.00	9	0	0.00	0.00	0	15	13	86.67	86.67	0	93	60	64.5	60.5
Corixidae	39.6	44.0	4	9	44.44	9	4	44.44	44.44	0	15	8	53.33	53.33	0	93	41	44.1	45.8
Gerridae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Hebridae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Hydrometridae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Mesoveliidae	7.1	14.3	1	9	11.11	9	1	11.11	11.11	0	15	2	13.33	13.33	0	93	5	5.4	5.1
Nepidae	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	3	3.2	3.0
Notonectidae	15.6	23.1	3	9	33.33	9	3	33.33	33.33	0	15	2	13.33	13.33	0	93	26	28.0	28.8
Pleidae	12.5	25.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Naucoridae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	1.0
Saldidae	0.0	0.0	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Veliidae	22.0	23.8		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	3	3.2	2.9
Ceratopogonidae	43.0	41.7	7	9	77.78	9	7	77.78	77.78	0	15	7	46.67	46.67	0	93	10	10.8	11.0
Chaoborinae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Chironominae	72.2	21.6	5	9	55.56	9	5	55.56	55.56	0	15	13	86.67	86.67	0	93	64	68.8	66.8
Culicidae	35.9	27.2	2	9	22.22	9	2	22.22	22.22	0	15	0	0.00	0.00	0	93	17	18.3	24.8
Empididae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	0.8
Ephydridae	1.2	2.4		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Orthocladiinae	39.5	10.2	1	9	11.11	9	1	11.11	11.11	0	15	7	46.67	46.67	0	93	23	24.7	27.5
Sciomyzidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Simulidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Stratiomyidae	9.7	7.5		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	8	8.6	8.1
Tabanidae	1.9	3.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	3	3.2	2.8
Tanypodinae	55.3	21.7	4	9	44.44	9	4	44.44	44.44	0	15	10	66.67	66.67	0	93	40	43.0	41.6
Tipulidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	1	6.67	6.67	0	93	2	2.2	1.9
Pyralidae	1.9	3.8	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	7	7.5	6.9
Carabidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	1.7
Chyrsomelidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	1.0
Curculionidae	5.0	7.3	1	9	11.11	9	1	11.11	11.11	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Dryopidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Dytiscidae	85.9	16.8	8	9	88.89	9	8	88.89	88.89	0	15	7	46.67	46.67	0	93	47	50.5	55.9
Elmidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Gyrinidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	0.9
Haliplidae	4.2	8.3		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	1.7
Helminthidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Hydraenidae	2.4	4.8		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	0.8
Hydrochidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Hydrophilidae	55.0	36.6	7	9	77.78	9	7	77.78	77.78	0	15	5	33.33	33.33	0	93	22	23.7	26.4
Limnichidae	0.0	0.0	4	9	44.44	9	4	44.44	44.44	0	15	0	0.00	0.00	0	93	1	1.1	0.8
Noteridae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Ptilodactilidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	2	2.2	3.3

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	*itudinale*		*Mixed Restionaceae/ Lepidosperma*								*B. articualta/Lepidosperma*					*M. raphiophylla/B. articulata*			
	Mean percentage	***SD***	***Gnangara***			***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***
	i.e. how common		***Times found***	***Times habitat***	***Percentage***				***i.e. how common***					***i.e. how common***					***i.e. how common***
Scirtidae	1.9	3.8	3	9	33.33	9	3	33.33	33.33	0	15	0	0.00	0.00	0	93	14	15.1	20.0
Staphylinidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	1.7
Unidentified	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	1.7
Calanoida	30.3	27.6		9	0.00	9	0	0.00	0.00	0	15	8	53.33	53.33	0	93	26	28.0	28.7
Cyclopoida	43.1	18.8	2	9	22.22	9	2	22.22	22.22	0	15	8	53.33	53.33	0	93	37	39.8	38.5
Harpacticoida	8.0	9.3		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	3	3.2	2.5
CONCHOSTRACA	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Cyprididae	54.3	43.7	1	9	11.11	9	1	11.11	11.11	0	15	12	80.00	80.00	0	93	52	55.9	58.2
Gomphodellidae	3.6	7.1		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	2	2.2	1.8
Ilyocyprididae	4.2	8.3		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Limnocytheridae	1.2	2.4		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	0	0.0	0.0
Notodromadidae	21.0	30.7		9	0.00	9	0	0.00	0.00	0	15	2	13.33	13.33	0	93	9	9.7	11.0
Unidentified Ostracoda	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	5	5.4	4.0
Chydoridae	27.9	20.0		9	0.00	9	0	0.00	0.00	0	15	8	53.33	53.33	0	93	21	22.6	22.8
Daphniidae	19.9	21.2		9	0.00	9	0	0.00	0.00	0	15	3	20.00	20.00	0	93	16	17.2	18.3
Macrothricidae	15.6	23.1	5	9	55.56	9	5	55.56	55.56	0	15	1	6.67	6.67	0	93	6	6.5	5.5
Moinidae	0.0	0.0		9	0.00	9	0	0.00	0.00	0	15	0	0.00	0.00	0	93	1	1.1	0.8
Habitat richness			**28**																
Total richness per wetlan			50																
Percentage of habitat			56.0																

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community		M. raphiophylla/submerged herbaceous					*Astartea fascicularis*					Submerged herbaceous					Open wat		
	SD	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	**total visits**	**times found**	**Percent**
					i.e. how common					***i.e. how common***					***i.e. how common***				
(Hydra)	0.0	48	1.00	2.08	1.45	2.51	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
NEMATODA	3.7	48	2.00	4.17	2.90	5.02	39	1.00	2.56	3.57	7.14	115	1	0.9	1.0	3.0	65	0	0.0
NEMERTINI	0.0	48	1.00	2.08	1.45	2.51	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
PORIFERA	4.1	48	2.00	4.17	3.53	3.20	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
TURBELLARIA	20.8	48	3.00	6.25	7.87	6.85	39	0.00	0.00	0.00	0.00	115	8	7.0	10.5	17.2	65	7	10.8
TEMNOCEPHALIDEA	0.0	48	0.00	0.00	0.00	0.00	39	2.00	5.13	2.50	5.00	115	0	0.0	0.0	0.0	65	0	0.0
Hirudinea	25.0	48	17.00	35.42	34.85	18.63	39	3.00	7.69	8.39	13.66	115	28	24.3	17.9	18.5	65	6	9.2
Oligochaeta	18.6	48	16.00	33.33	32.84	23.09	39	2.00	5.13	9.58	16.01	115	41	35.7	45.1	34.1	65	18	27.7
Ancylidae	3.6	48	3.00	6.25	5.62	6.35	39	0.00	0.00	0.00	0.00	115	1	0.9	0.5	1.6	65	1	1.5
Lymnaeidae	4.4	48	1.00	2.08	3.70	6.42	39	0.00	0.00	0.00	0.00	115	4	3.5	2.3	4.8	65	1	1.5
Physidae	34.4	48	33.00	68.75	73.12	23.31	39	0.00	0.00	0.00	0.00	115	53	46.1	39.9	36.2	65	9	13.8
Planorbidae	6.3	48	17.00	35.42	28.16	28.34	39	0.00	0.00	0.00	0.00	115	11	9.6	9.3	13.6	65	6	9.2
Hydriella	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Sphaeriidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	1.5	3.0	65	10	15.4
Lycosidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Tetragnathidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Pisauridae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Unidentified	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Arrenuridae	26.7	48	11.00	22.92	29.40	25.46	39	0.00	0.00	0.00	0.00	115	9	7.8	9.2	8.4	65	1	1.5
Astigmata	0.0	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	1	1.5
Eylaidae	0.0	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	10	8.7	8.4	11.0	65	0	0.0
Halacoroidea	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.2	65	0	0.0
Hydrachnidae	6.5	48	8.00	16.67	19.91	18.86	39	2.00	5.13	11.11	15.71	115	14	12.2	12.0	9.5	65	0	0.0
Hydrodromidae	2.2	48	2.00	4.17	5.79	5.57	39	5.00	12.82	7.78	9.69	115	3	2.6	2.4	4.9	65	1	1.5
Limnocharidae	11.2	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	8	7.0	10.6	19.5	65	1	1.5
Limnesiidae	14.4	48	16.00	33.33	41.44	36.49	39	12.00	30.77	17.32	26.01	115	28	24.3	19.7	19.8	65	2	3.1
Oribatida	6.7	48	2.00	4.17	2.90	5.02	39	1.00	2.56	1.25	2.50	115	9	7.8	6.3	9.4	65	2	3.1
Oxidae	6.9	48	2.00	4.17	5.15	5.60	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Pionidae	12.8	48	19.00	39.58	48.04	34.09	39	3.00	7.69	6.07	7.23	115	37	32.2	28.1	14.5	65	5	7.7
Unidentified	13.0	48	6.00	12.50	14.47	6.98	39	1.00	2.56	2.78	5.56	115	20	17.4	19.1	12.6	65	7	10.8
Unioncolidae	16.2	48	4.00	8.33	8.33	14.43	39	16.00	41.03	23.85	31.37	115	3	2.6	2.8	4.6	65	0	0.0
Ceinidae	16.4	48	17.00	35.42	25.27	38.49	39	0.00	0.00	0.00	0.00	115	46	40.0	34.1	37.7	65	22	33.8
Perthidae	0.0	48	0.00	0.00	0.00	0.00	39	2.00	5.13	7.14	14.29	115	0	0.0	0.0	0.0	65	0	0.0
Amphisopidae	27.9	48	33.00	68.75	64.10	30.22	39	0.00	0.00	0.00	0.00	115	49	42.6	37.8	28.8	65	20	30.8
Janiridae	0.0	48	1.00	2.08	3.70	6.42	39	0.00	0.00	0.00	0.00	115	2	1.7	3.2	9.5	65	0	0.0
Palaemonidae	36.1	48	24.00	50.00	36.68	48.22	39	1.00	2.56	1.25	2.50	115	32	27.8	22.6	32.1	65	2	3.1
Parastacidae	4.7	48	1.00	2.08	1.45	2.51	39	19.00	48.72	37.56	29.68	115	6	5.2	5.9	8.9	65	9	13.8
Caenidae	8.2	48	7.00	14.58	10.14	17.57	39	0.00	0.00	0.00	0.00	115	5	4.3	5.3	12.3	65	7	10.8
Baetidae	14.8	48	4.00	8.33	8.33	14.43	39	0.00	0.00	0.00	0.00	115	9	7.8	10.3	10.9	65	5	7.7
COLLEMBOLA	7.0	48	3.00	6.25	7.24	3.49	39	5.00	12.82	10.10	6.94	115	4	3.5	3.6	5.0	65	2	3.1
MECOPTERA	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Sisyridae	0.0	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Aeshnidae	10.9	48	12.00	25.00	32.47	25.97	39	7.00	17.95	10.28	14.15	115	31	27.0	28.0	24.3	65	6	9.2
Coenagrionidae	15.5	48	16.00	33.33	32.49	7.10	39	5.00	12.82	7.78	9.69	115	23	20.0	23.6	18.5	65	9	13.8
Cordulidae	6.3	48	6.00	12.50	15.46	16.80	39	2.00	5.13	6.35	7.45	115	18	15.7	17.3	9.5	65	9	13.8
Gomphidae	1.8	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.0	65	0	0.0
Lestidae	19.7	48	11.00	22.92	23.27	23.18	39	20.00	51.28	44.42	20.01	115	50	43.5	37.3	24.0	65	18	27.7

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community		M. raphiophylla/submerged herbaceous					*Astartea fascicularis*					Submerged herbaceous					**Open wat**		
	SD	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	**total visits**	**times found**	**Percent**
					i.e. how common					***i.e. how common***					***i.e. how common***				
Libellulidae	6.3	48	6.00	12.50	16.09	14.98	39	1.00	2.56	1.25	2.50	115	30	26.1	26.4	19.3	65	20	30.8
Macrodiplactidae	0.0	48	0.00	0.00	0.00	0.00	39	3.00	7.69	3.75	7.50	115	0	0.0	0.0	0.0	65	0	0.0
Megapodagrionidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Synthemidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Ecnomidae	3.7	48	1.00	2.08	2.08	3.61	39	3.00	7.69	3.75	7.50	115	10	8.7	13.1	24.8	65	5	7.7
Hydroptilidae	21.7	48	5.00	10.42	7.25	12.55	39	0.00	0.00	0.00	0.00	115	17	14.8	19.2	23.4	65	2	3.1
Leptoceridae	15.8	48	34.00	70.83	66.54	19.48	39	16.00	41.03	22.32	35.76	115	59	51.3	49.3	26.7	65	16	24.6
Corixidae	43.4	48	33.00	68.75	71.50	26.42	39	13.00	33.33	31.03	7.51	115	90	78.3	73.3	21.9	65	47	72.3
Gerridae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Hebridae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Hydrometridae	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	1	0.9	1.4	4.2	65	0	0.0
Mesoveliidae	3.4	48	5.00	10.42	11.40	7.21	39	3.00	7.69	5.28	6.11	115	1	0.9	0.7	2.2	65	2	3.1
Nepidae	6.7	48	2.00	4.17	5.79	5.57	39	3.00	7.69	6.07	7.23	115	2	1.7	2.8	8.3	65	0	0.0
Notonectidae	28.9	48	28.00	58.33	66.15	52.86	39	11.00	28.21	20.65	16.67	115	60	52.2	46.8	30.7	65	21	32.3
Pleidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Naucoridae	2.2	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	2	1.7	2.8	8.3	65	0	0.0
Saldidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	3.6	8.4	65	3	4.6
Veliidae	4.4	48	4.00	8.33	7.70	9.81	39	21.00	53.85	40.85	28.71	115	3	2.6	2.0	4.5	65	4	6.2
Ceratopogonidae	13.8	48	4.00	8.33	6.43	6.52	39	3.00	7.69	13.15	14.70	115	24	20.9	25.4	24.3	65	15	23.1
Chaoborinae	0.0	48	0.00	0.00	0.00	0.00	39	2.00	5.13	2.50	5.00	115	0	0.0	0.0	0.0	65	0	0.0
Chironominae	14.6	48	45.00	93.75	92.76	3.49	39	17.00	43.59	46.96	14.08	115	101	87.8	85.2	14.4	65	46	70.8
Culicidae	33.6	48	5.00	10.42	18.52	32.08	39	14.00	35.90	47.18	37.30	115	23	20.0	21.2	24.0	65	9	13.8
Empididae	1.8	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Ephydridae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	1.6	4.8	65	0	0.0
Orthocladiinae	23.9	48	10.00	20.83	20.55	14.71	39	10.00	25.64	21.11	18.72	115	25	21.7	24.4	20.4	65	14	21.5
Sciomyzidae	0.0	48	2.00	4.17	7.41	12.83	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Simulidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Stratiomyidae	7.5	48	10.00	20.83	20.27	7.00	39	0.00	0.00	0.00	0.00	115	8	7.0	6.9	8.8	65	2	3.1
Tabanidae	4.4	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	1.1	2.3	65	1	1.5
Tanypodinae	13.5	48	34.00	70.83	70.41	4.23	39	16.00	41.03	30.02	24.16	115	87	75.7	67.9	23.2	65	35	53.8
Tipulidae	2.6	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.5	1.4	65	0	0.0
Pyralidae	5.1	48	3.00	6.25	7.24	3.49	39	1.00	2.56	1.25	2.50	115	10	8.7	7.9	13.2	65	1	1.5
Carabidae	3.7	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.0	65	0	0.0
Chyrsomelidae	2.2	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	1	0.9	0.9	2.6	65	1	1.5
Curculionidae	0.0	48	0.00	0.00	0.00	0.00	39	6.00	15.38	16.90	13.81	115	6	5.2	4.4	13.3	65	2	3.1
Dryopidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Dytiscidae	24.7	48	27.00	56.25	63.22	32.68	39	33.00	84.62	83.27	16.67	115	73	63.5	66.5	30.7	65	40	61.5
Elmidae	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	0	0.0	0.0	0.0	65	0	0.0
Gyrinidae	1.9	48	2.00	4.17	2.90	5.02	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Haliplidae	3.7	48	1.00	2.08	2.08	3.61	39	0.00	0.00	0.00	0.00	115	12	10.4	9.0	11.0	65	0	0.0
Helminthidae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.2	65	0	0.0
Hydraenidae	1.8	48	1.00	2.08	3.70	6.42	39	1.00	2.56	1.25	2.50	115	5	4.3	4.2	8.7	65	0	0.0
Hydrochidae	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	1.25	2.50	115	2	1.7	1.5	4.4	65	0	0.0
Hydrophilidae	16.5	48	17.00	35.42	40.98	20.62	39	14.00	35.90	40.16	22.76	115	60	52.2	51.8	27.0	65	17	26.2
Limnichidae	1.8	48	0.00	0.00	0.00	0.00	39	5.00	12.82	6.25	12.50	115	0	0.0	0.0	0.0	65	2	3.1
Noteridae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Ptilodactilidae	7.5	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community		M. raphiophylla/submerged herbaceous					*Astartea fascicularis*					Submerged herbaceous					**Open wat**		
	SD	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***	**total visits**	**times found**	**Percent**
					i.e. how common					***i.e. how common***					***i.e. how common***				
Scirtidae	26.8	48	2.00	4.17	2.90	5.02	39	11.00	28.21	17.60	19.27	115	4	3.5	2.7	6.6	65	2	3.1
Staphylinidae	3.7	48	1.00	2.08	2.08	3.61	39	1.00	2.56	1.25	2.50	115	0	0.0	0.0	0.0	65	0	0.0
Unidentified	3.7	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	2	1.7	1.4	2.8	65	0	0.0
Calanoida	26.6	48	23.00	47.92	40.94	37.97	39	27.00	69.23	56.17	29.33	115	44	38.3	38.7	20.1	65	25	38.5
Cyclopoida	11.1	48	26.00	54.17	48.18	35.24	39	25.00	64.10	48.17	34.00	115	64	55.7	55.6	19.8	65	23	35.4
Harpacticoida	3.6	48	9.00	18.75	28.82	42.62	39	0.00	0.00	0.00	0.00	115	3	2.6	2.2	4.4	65	1	1.5
CONCHOSTRACA	0.0	48	0.00	0.00	0.00	0.00	39	1.00	2.56	2.78	5.56	115	0	0.0	0.0	0.0	65	0	0.0
Cyprididae	25.6	48	37.00	77.08	81.80	22.59	39	11.00	28.21	30.85	9.29	115	102	88.7	86.5	17.8	65	35	53.8
Gomphodellidae	2.5	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Ilyocyprididae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	1	0.9	0.7	2.0	65	0	0.0
Limnocytheridae	0.0	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Notodromadidae	13.8	48	1.00	2.08	1.45	2.51	39	0.00	0.00	0.00	0.00	115	16	13.9	15.9	18.1	65	1	1.5
Unidentified Ostracoda	8.9	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	115	0	0.0	0.0	0.0	65	0	0.0
Chydoridae	16.1	48	21.00	43.75	46.78	10.75	39	9.00	23.08	13.57	18.86	115	45	39.1	40.5	22.0	65	7	10.8
Daphniidae	12.3	48	20.00	41.67	47.58	20.40	39	13.00	33.33	25.48	17.62	115	54	47.0	46.5	20.4	65	16	24.6
Macrothricidae	8.7	48	1.00	2.08	3.70	6.42	39	8.00	20.51	14.58	17.18	115	4	3.5	3.9	6.1	65	14	21.5
Moinidae	1.8	48	0.00	0.00	0.00	0.00	39	0.00	0.00	0.00	0.00	116	4	3.4	2.9	5.3	65	0	0.0
Habitat richness																			
Total richness per wetlan																			
Percentage of habitat																			

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	er		Spring				
	Mean percentage	SD	*total visits*	*times found*	*Percent*	*Mean percentage*	*SD*
	i.e. how common is the		*i.e. how common is the taxa in this*				
(Hydra)	0.0	0.0	23	0	0.00	0.00	0
NEMATODA	0.0	0.0	23	0	0.00	0.00	0
NEMERTINI	0.0	0.0	23	0	0.00	0.00	0
PORIFERA	0.0	0.0	23	0	0.00	0.00	0
TURBELLARIA	6.8	11.2	23	0	0.00	0.00	0
TEMNOCEPHALIDEA	0.0	0.0	23	1	4.35	4.35	0
Hirudinea	5.8	7.4	23	4	17.39	17.39	0
Oligochaeta	22.5	23.1	23	10	43.48	43.48	0
Ancylidae	1.2	2.9	23	0	0.00	0.00	0
Lymnaeidae	1.2	2.9	23	3	13.04	13.04	0
Physidae	28.5	38.6	23	2	8.70	8.70	0
Planorbidae	6.2	9.8	23	1	4.35	4.35	0
Hydriella	0.0	0.0	23	0	0.00	0.00	0
Sphaeriidae	9.7	15.8	23	4	17.39	17.39	0
Lycosidae	0.0	0.0	23	0	0.00	0.00	0
Tetragnathidae	0.0	0.0	23	0	0.00	0.00	0
Pisauridae	0.0	0.0	23	0	0.00	0.00	0
Unidentified	0.0	0.0	23	0	0.00	0.00	0
Arrenuridae	1.2	2.9	23	0	0.00	0.00	0
Astigmata	0.9	2.1	23	0	0.00	0.00	0
Eylaidae	0.0	0.0	23	0	0.00	0.00	0
Halacoroidea	0.0	0.0	23	0	0.00	0.00	0
Hydrachnidae	0.0	0.0	23	0	0.00	0.00	0
Hydrodromidae	3.3	8.2	23	1	4.35	4.35	0
Limnocharidae	0.8	1.9	23	0	0.00	0.00	0
Limnesiidae	1.6	3.9	23	6	26.09	26.09	0
Oribatida	1.7	2.6	23	2	8.70	8.70	0
Oxidae	0.0	0.0	23	11	47.83	47.83	0
Pionidae	4.3	8.4	23	5	21.74	21.74	0
Unidentified	8.8	9.5	23	4	17.39	17.39	0
Unioncolidae	0.0	0.0	23	4	17.39	17.39	0
Ceinidae	40.1	40.1	23	18	78.26	78.26	0
Perthidae	0.0	0.0	23	0	0.00	0.00	0
Amphisopidae	32.3	40.9	23	9	39.13	39.13	0
Janiridae	0.0	0.0	23	2	8.70	8.70	0
Palaemonidae	17.5	40.4	23	20	86.96	86.96	0
Parastacidae	20.6	39.3	23	10	43.48	43.48	0
Caenidae	12.0	16.2	23	10	43.48	43.48	0
Baetidae	7.2	8.9	23	10	43.48	43.48	0
COLLEMBOLA	6.7	16.3	23	1	4.35	4.35	0
MECOPTERA	0.0	0.0	23	0	0.00	0.00	0
Sisyridae	0.0	0.0	23	0	0.00	0.00	0
Aeshnidae	10.7	15.3	23	2	8.70	8.70	0
Coenagrionidae	16.1	23.0	23	1	4.35	4.35	0
Cordulidae	12.1	16.7	23	7	30.43	30.43	0
Gomphidae	0.0	0.0	23	0	0.00	0.00	0
Lestidae	28.2	27.1	23	1	4.35	4.35	0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	**er**		**Spring**				
	Mean percentage	**SD**	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***
	i.e. how common is the		***i.e. how common is the taxa in this***				
Libellulidae	48.9	48.9	23	3	13.04	13.04	0
Macrodiplactidae	0.0	0.0	23	0	0.00	0.00	0
Megapodagrionidae	0.0	0.0	23	0	0.00	0.00	0
Synthemidae	0.0	0.0	23	1	4.35	4.35	0
Ecnomidae	5.3	8.9	23	2	8.70	8.70	0
Hydroptilidae	1.7	2.6	23	12	52.17	52.17	0
Leptoceridae	51.0	43.3	23	17	73.91	73.91	0
Corixidae	69.0	27.5	23	3	13.04	13.04	0
Gerridae	0.0	0.0	23	2	8.70	8.70	0
Hebridae	0.0	0.0	23	0	0.00	0.00	0
Hydrometridae	0.0	0.0	23	1	4.35	4.35	0
Mesoveliidae	6.7	10.3	23	5	21.74	21.74	0
Nepidae	0.0	0.0	23	1	4.35	4.35	0
Notonectidae	34.3	34.3	23	7	30.43	30.43	0
Pleidae	0.0	0.0	23	0	0.00	0.00	0
Naucoridae	0.0	0.0	23	0	0.00	0.00	0
Saldidae	5.3	7.8	23	0	0.00	0.00	0
Veliidae	13.3	24.2	23	3	13.04	13.04	0
Ceratopogonidae	12.7	24.8	23	5	21.74	21.74	0
Chaoborinae	0.0	0.0	23	0	0.00	0.00	0
Chironominae	68.4	41.7	23	15	65.22	65.22	0
Culicidae	15.8	22.7	23	4	17.39	17.39	0
Empididae	0.0	0.0	23	3	13.04	13.04	0
Ephydridae	0.0	0.0	23	0	0.00	0.00	0
Orthocladiinae	25.2	37.8	23	9	39.13	39.13	0
Sciomyzidae	0.0	0.0	23	0	0.00	0.00	0
Simulidae	0.0	0.0	23	6	26.09	26.09	0
Stratiomyidae	4.2	8.0	23	2	8.70	8.70	0
Tabanidae	0.9	2.1	23	3	13.04	13.04	0
Tanypodinae	65.9	28.7	23	16	69.57	69.57	0
Tipulidae	0.0	0.0	23	1	4.35	4.35	0
Pyralidae	3.3	8.2	23	0	0.00	0.00	0
Carabidae	0.0	0.0	23	0	0.00	0.00	0
Chyrsomelidae	1.2	2.9	23	0	0.00	0.00	0
Curculionidae	4.5	8.1	23	1	4.35	4.35	0
Dryopidae	0.0	0.0	23	0	0.00	0.00	0
Dytiscidae	74.9	35.4	23	10	43.48	43.48	0
Elmidae	0.0	0.0	23	0	0.00	0.00	0
Gyrinidae	0.0	0.0	23	0	0.00	0.00	0
Haliplidae	0.0	0.0	23	0	0.00	0.00	0
Helminthidae	0.0	0.0	23	0	0.00	0.00	0
Hydraenidae	0.0	0.0	23	1	4.35	4.35	0
Hydrochidae	0.0	0.0	23	0	0.00	0.00	0
Hydrophilidae	38.4	45.9	23	6	26.09	26.09	0
Limnichidae	6.7	16.3	23	0	0.00	0.00	0
Noteridae	0.0	0.0	23	0	0.00	0.00	0
Ptilodactilidae	0.0	0.0	23	0	0.00	0.00	0

Appendix 2: Aquatic macroinvertebrates in dominant vegetation communities in monitored Gnangara mound wetlands

Vegetation community	er		**Spring**				
	Mean percentage	**SD**	***total visits***	***times found***	***Percent***	***Mean percentage***	***SD***
	i.e. how common is the		***i.e. how common is the taxa in this***				
Scirtidae	6.7	16.3	23	1	4.35	4.35	0
Staphylinidae	0.0	0.0	23	0	0.00	0.00	0
Unidentified	0.0	0.0	23	2	8.70	8.70	0
Calanoida	48.8	36.9	23	3	13.04	13.04	0
Cyclopoida	44.2	29.8	23	15	65.22	65.22	0
Harpacticoida	0.9	2.1	23	2	8.70	8.70	0
CONCHOSTRACA	0.0	0.0	23	0	0.00	0.00	0
Cyprididae	49.5	40.5	23	11	47.83	47.83	0
Gomphodellidae	0.0	0.0	23	0	0.00	0.00	0
Ilyocyprididae	0.0	0.0	23	0	0.00	0.00	0
Limnocytheridae	0.0	0.0	23	0	0.00	0.00	0
Notodromadidae	0.8	1.9	23	0	0.00	0.00	0
Unidentified Ostracoda	0.0	0.0	23	2	8.70	8.70	0
Chydoridae	10.5	17.8	23	10	43.48	43.48	0
Daphniidae	18.1	22.3	23	2	8.70	8.70	0
Macrothricidae	19.5	25.9	23	3	13.04	13.04	0
Moinidae	0.0	0.0	23	1	4.35	4.35	0
Habitat richness							
Total richness per wetlan							
Percentage of habitat							