Wheatbelt Wetland Biodiversity Monitoring

Fauna Monitoring at Noobijup Swamp 1998-2013

Report WWBM-FR04

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Contents

1 Summary

A trend of declining water depth across the monitoring period coincided with significant changes in water chemistry and faunal composition. At the commencement of monitoring in 1998, water chemistry in the southern and northern parts of the wetland was similar, the wetland was sub-saline (<4000 μS/cm), pH was circum neutral or higher and lake depth was in excess of 0.7 m throughout the year. From 2004 pH began to gradually decline at the lakes southern end (site A), reaching a minimum of 4.18 by 2012 and a similar decline was seen at the northern end (site B) after 2008 where pH was 4.83 by 2012. Salinity was up to 13360 μS/cm at the northern end, where shallow depths increased evapo-concentration, but up to just 4730 μS/cm at the southern end. These changes are likely to be in response to reduced water levels which caused seasonal drying, evapo-concentration of salts and acidic conditions following oxidation reactions in the drying peat of the lake bed.

Changes in water chemistry had an effect on vegetation, with senescence of areas of reed bed habitat, and the richness and composition of invertebrate and waterbird communities. The total invertebrate pool included 216 species collected across the monitoring period. maximum richness (115 species) was recorded in 1998, after which richness steadily declined so that by 2008 and 2010 invertebrate richness was just 50 and 55 species respectively. Community composition changed not only through loss of species but by a disproportionally greater loss of freshwater species typical of sedge swamps (and rotifers in particular). Changes in the invertebrate community were most closely correlated with increased acidity, but the additional effect of higher salinity may have exacerbated the effects of acidity in some years. It is also possible that water chemistry differences between ends of the wetland may have ameliorated the worst effects of changing conditions by providing refuge areas for some species.

The waterbird community included 15 species across the monitoring period, but was neither abundant nor diverse; with 1-8 species and up to 50 individuals per survey. This is typical of sedge swamps which have little habitat heterogeneity and little open water. There was a tendency for richness to be lower between 2008 and 2012 with dabbling species absent and a lower occurrence and abundance of reed specialists occurred after 2008 in response to declining health of reed habitats. Two sensitive species, the spotless crake and little bittern were recorded infrequently (<15% of surveys) and not recorded at all after 2004. Observed changes in community structure do not unequivocally indicate a change in the character of the waterbird community over time because of the generally low occurrence rate of many species.

2 Background to the Wheatbelt wetland biodiversity monitoring project

The loss of productive land and decline of natural diversity in Western Australia as a result of salinisation, triggered a series of escalating community and government responses through the 1980s and 1990s. The first thorough review of the consequences of salinisation across Western Australian government agencies was released in 1996 (Wallace, 2001). This review resulted in the publication of: *Salinity; a Situation Statement for Western Australia* (Government of Western Australia, 1996a) which provided the basis for a detailed action plan published as *Western Australian Salinity Action Plan* (Government of Western Australia, 1996b). The Salinity Action Plan was reviewed and revised several times between 1996 and 2000 (including Government of Western Australia, 2000) details of which are provided by (Wallace, 2001). Amongst the actions detailed in the Salinity Action Plan the Department of Biodiversity Conservation and Attractions (as its predecessor CALM) was tasked with the establishment of six Natural Diversity Recovery Catchments in which remedial actions targeted at salinisation would protect natural diversity. Additionally the department was tasked to "... monitor a sample of wetlands and their associated flora and fauna, in the south-west, to determine long-term trends in natural diversity and provide a sound basis for corrective action" (Government of Western Australia, 1996b).

The department's response to the latter task was two-fold. Firstly, re-expansion of a long-term monitoring program (later known as the South West Wetlands Monitoring Program or SWWMP. This program monitored depth, salinity and pH at wetlands across the south-west and was established in the late 1970s to provide data on waterbird habitats (Lane, Clarke & Winchcombe, 2017) for determining timing of the duck hunting season and bag limits. The second response was a new program to monitor flora and fauna at 25 representative wetlands, including some in the Natural Diversity Recovery Catchments. The addition of two further recovery catchments added three wetlands to the program in 2010 to 2011. The 28 monitored wetlands were chosen using a number of criteria (Cale, Halse & Walker, 2004) to ensure representativeness and to build on already available data.

For sampling of fauna, the wetlands were divided into two groups and each half sampled each alternate year. For monitoring of flora, three groups were established with each group sampled every third year (see Lyons *et al.*, 2007 for details). Detailed methods for the fauna component, including methods for analyses presented below, will be detailed in a separate report in this series.

Previous publications based on the monitoring data have included assesment of the sampling design (Halse *et al.*, 2002), waterbird composition by wetland (Cale & Halse, 2004, 2006) and wetland case studies (Cale, 2005; Lyons *et al.*, 2007; Cale *et al.*, 2010, 2011).

Noobijup Swamp met all of the criteria used to select wetlands for this monitoring program, but, in particular, it represented a freshwater wetland with high conservation value expected to remain unchanged in the medium term, and it was within one of the original Natural Diversity Recovery Catchments (Muir Unicup). It was given the site code SPM007.

3 Wetland description

Noobijup Swamp is part of a mosaic of important and diverse wetlands known as the Byenup Lagoon system (Environment Australia, n.d.). This 183 ha wetland lies within an A class nature reserve (No. 26680) approximately 65 km east of Manjimup. A regional management plan (CALM, 1998) recognised altered water regimes due to rising water tables, increased run-off and increased salt loads as major threats to wetlands in the Muir-Unicup system generally.

The wetland has previously been studied in the context of peat formation, landscape position, geomorphic evolution, water chemistry and sediment development (Ryder, 2000) and further investigations into the hydrogeology and chemistry are underway within DBCA to better understand processes driving acidification in the Muir-Unicup wetlands. The wetland is elongate and has a flat lake bed which rapidly grades into relatively steep terrestrial environs. Noobijub is broadly understood to be a tributory of a larger east-west trending palaeodrainage and palaeovalley system[1]. According to Ryder (2000) the wetland was probably formed from a creek line which 'clogged' with sediments and ceased to flow and analysis of its sediments show a clay layer at 1.5m depth which suggests the lake is perched and largely dependent on surface water inputs, although ground water inflow into the lake is important to keeping sediments wet in the absence of surface water (Wroe, 2011).

Water depth, salinity and pH in Noobijup Swamp have been monitored by Lane *et al.* (2017) since September 1999. During the period 1999-2011, September and November depth was between 0.2 m and 1.7 m. Salinity for this period was between 0.5 and 2.6 ppt. Graphical presentation of these data (Lane *et al.*, 2017) indicates a declining trend for depth and pH and a possible increase in the variability of salinity. Ryder (2000) noted that between July 1995 and May 1997 Noobijup had a total depth range between 50 cm in autumn and 120 cm in spring and that maximum depth occurred approximately 3 months after maximum rainfall.

Invertebrate communities have been sampled in the Muir-Unicup wetlands by various authors (DeHaan, 1987; Horwitz, 1994; Storey, 1998; Ryder, 2000) revealing a relatively species rich fauna. Ryder (2000) sampled invertebrates from Noobijup Swamp in order to elucidate trophic structure and discovered a system largely dependent on biofilms and emergent macrophytes through primary consumers like the Chironomidae. He also identified marked seasonal shifts in trophic structure. However, only Storey (1998) specifically sampled Noobijup Swamp for the purposes of measuring biodiversity. Storey (1998) collected a total of 44 macroinvertebrate taxa over three seasons, of which 11 were considered south-western Australian endemics. They also collected 37 microinvertebrate taxa (unpublished data), some of which are also south-west endemics. Noobijup Swamp was sampled by the same authors over three seasons in 2003/4 (unpublished data), collecting 50 macroinvertebrate taxa (microinvertebrate taxa were not identified). The wetland is also included in a survey of invertebrates in Muir-Byenup wetlands being undertaken by DBCA as part of Science and Conservation's contribution to implementing the 2014-23 Forest Management Plan, with sampling between 2014 and 2016. Analyses in this report are restricted to our own data; an analysis of all available data will occur separately.

[1] J. Rutherford DBCA pers. comm.

Storey (1998, see Table 2) described the wetland as “Freshwater, dense *Baumea* along margins, lighter cover throughout, little open water”. The vegetation of the wetland has been more thoroughly described by Ogden and Froend (1998) and includes extensive reed beds of *Baumea juncea*, *B. arthrophylla* and *B. articulata* across the lake bed. These reed beds were identified as crucial to peat formation and the functioning of food webs in the wetland (Ryder, 2000).

4 Sampling Program

Noobijup Swamp was visited 23 times between August 1998 and March 2011 (Table 1). An oversight in autumn 2004/05 meant that the wetland was not visited and no data were collected. Invertebrate samples were collected in 2012 but not processed, so, while waterbird and water chemistry data are presented for the full sampling period, invertebrate data are presented for the period 1998 to 2010. When the lake was dry waterbirds were surveyed by ‘listening for’ species and by scoping from a few locations on the lakes edge.

Table 1. Site visits, collected datasets and depth for Noobijup Swamp, 1998 – 2013.

Sample	Monitoring Year	Date	Invertebrates sampled?	Waterbirds surveyed?	Depth
SPM007	1998/99	24/08/1998	×	✓	1
SPM007	1998/99	6/11/1998	✓	✓	0.7
SPM007	1998/99	19/04/1999	×	✓	
SPM007	2000/01	25/08/2000	×	✓	1.41
SPM007	2000/01	16/11/2000	✓	✓	1.28
SPM007	2000/01	16/02/2001	×	✓	0.85
SPM007	2002/03	27/08/2002	×	✓	0.78
SPM007	2002/03	22/10/2002	✓	✓	0.8
SPM007	2002/03	16/04/2003	×	✓	0
SPM007	2004/05	31/08/2004	×	✓	0.52
SPM007	2004/05	3/11/2004	✓	✓	0.43
SPM007	2004/05	5/04/2005	×	×	
SPM007	2006/07	13/09/2006	×	✓	0.55
SPM007	2006/07	19/10/2006	✓	✓	0.49
SPM007	2006/07	22/03/2007	×	✓	0
SPM007	2008/09	26/08/2008	×	✓	0.47
SPM007	2008/09	14/10/2008	✓	✓	0.5
SPM007	2008/09	25/03/2009	×	✓	0.22
SPM007	2010/11	25/08/2010	×	✓	0.34
SPM007	2010/11	28/10/2010	✓	✓	0.28
SPM007	2010/11	30/03/2011	×	✓	0
SPM007	2012/13	9/08/2012	×	✓	0.18
SPM007	2012/13	9/11/2012	×	✓	0.26
SPM007	2012/13	21/03/2013	×	✓	0

5 Physical and chemical environment

Physico-chemical data is provided in Appendix 1.

5.1 Hydrology

A depth gauge was not installed in Noobijup until September 1999. Consequently, depth recordings for 1998 and autumn 1998/99 are estimates. The greatest depth recorded during this project was 1.41 m in spring 2000, although Lane *et al.* (2017) report a depth in excess of 1.6 m in September 1999.

The wetland contained water on all sampling occasions prior to spring 2002, but in following years tended to dry in autumn. Even when the lake was dry, peat sediments tended to remain wet, although this was more apparent at the southern end (site A). Ground water inflow into the lake is important to keeping sediments wet in the absence of surface water (Wroe, 2011). There was a statistically significant trend of declining water depth in late-winter (Mann-Kendall tau = -0.86, $p < 0.001$) and spring (Mann-Kendal tau = -0.64, $p < 0.05$) across the monitoring period. The observed decline in depth is the result of reduced rainfall and reduced groundwater inflow due to eucalypt plantations[2], the planting of which roughly coincided with the commencement of the monitoring period (Hearn, 2001).

5.2 pH

In conjunction with lower water levels there was a reduction in pH such that depth and pH were significantly correlated across the monitoring period (rho = 0.6, df = 19, $p < 0.05$). Before 2002 spring pH at site A (southern end) and site B (northern end) was similar (7.15 – 7.63). However, in spring 2002 pH dropped at site B (6.46) and increased at site A (7.95). In 2004 and 2006 the two sites had similar but lower pH (6.02 - 6.67). In 2008 the pH at site A dropped to 4.54 and was relatively constant (4.18 -4.67) over the remainder of the monitoring period. In contrast, between 2008 and 2012, pH at site B declined gradually from 6.57 to 4.83. The lowest pH recorded in this study was 4.18 at site A in spring 2012, although Lane *et al.* (2017) indicate pH was lower in 2005 and 2007 (approximately 4) at the same end of the lake. So, it appears that pH declined dramatically into the acidic range as early as 2005. While there were periods of higher pH (e.g. 2006) this became the norm in the southern part of the wetland through the remainder of the monitoring period while the northern part remained less acidic, establishing a spatial heterogeneity of pH within the wetland until 2012, by which time there was little difference between ends of the wetland. Changes in pH are likely to be the result of oxidation of peat sediments during seasonal drying which in turn is the result of lower depths after 2002.

5.3 Salinity and ionic composition

Electrical conductivity (ec) was measured on all sampling occasions and used as a measure of salinity. The relationship between ec and total dissolved solids (TDS), at site A in spring, was significantly linear ($r^2 = 0.97$, $p < 0.001$, df = 6) and TDS can be calculated as: TDS mg/l = 17.3312 +

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[2] J Rutherford DBCA pers. comm.

0.5644 * ec (μS/cm). Salinity was negatively correlated with depth (r = -0.61, df = 19, $p < 0.05$) and increased annually from late-winter through spring to autumn as water levels declined. Cations showed a Na>Mg>Ca>K dominance pattern on all occasions except spring 1998 when K and Ca were reversed. The dominant anion was Cl.

There was a tendency for salinity at site B to be greater than at site A in spring, indicating that the wetland was poorly mixed. At Site B, spring salinity ranged from 3800 to 13360 μS/cm with the maximum recorded in 2010 as the site was drying. Spring salinity at site B tended to be lower prior to 2010 (mean= 4628 μS/cm ± 803.5), than after (mean = 11900μS/cm ± 2064), in accord with the significant declining trend in lake depth and the correlation between depth and salinity. At site A spring salinity ranged between 1865 and 5580 μS/cm, with the maximum recorded in 2004. At this site, spring salinity tended to be lower in years preceding 2004 (mean = 2221 μS/cm ± 481) than in following years (mean = 3432 μS/cm ± 1091), but was variable.

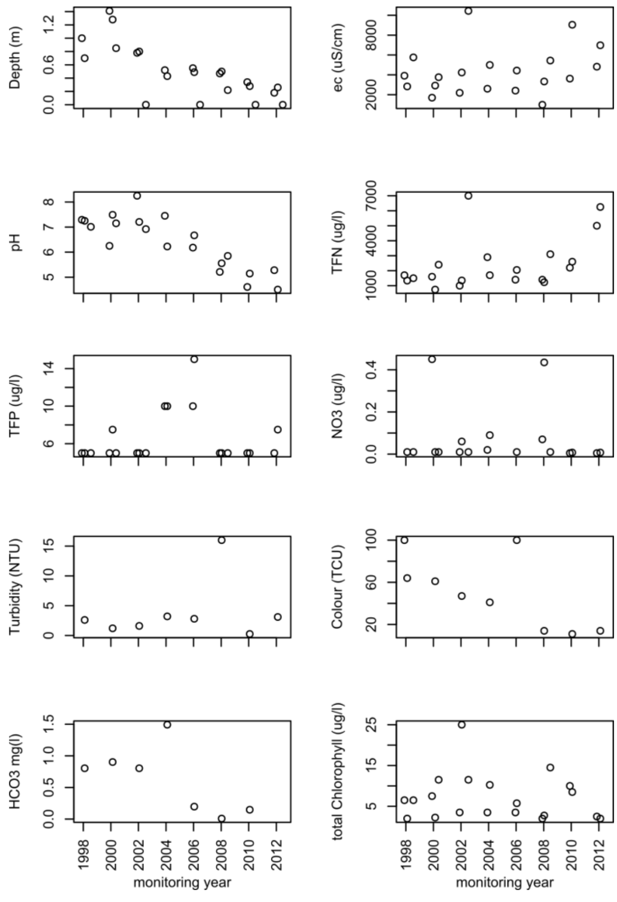

Figure 1. Water chemistry parameters at Noobijup Swamp for late-winter, spring and autumn sampling occasions between 1998 and 2013. ec is electrical conductivity, TFP total filtered phosphorus, TFN total filtered nitrogen, NO3 nitrate, HCO3 bicarbonate ion and total chlorophyll is the sum of the photosynthetic pigments chlorophyll a, b and c and phaeophytin. Tick marks are positioned at spring sampling.

5.4 Nutrients and chlorophyll

Total filtered phosphorus (TFP) was generally low (mean = 6.78 ± 3.39 μg/l across all samples) with a maximum of 20 μg/l. Total filtered nitrogen (TFN) was in the range 670 to 10000 μg/L and, while it varied substantially between sample sites in spring, neither site had consistently higher concentrations. This was also true across seasons with no season having consistently higher concentrations. Nitrate concentration was low (close to the detection limit of 0.01 mg/l) except for a single high concentration of 0.86 mg/l at site A in spring 2008. These data suggest a heterogeneous spatial and temporal distribution of nitrogen in the wetland.

The concentration of chlorophyll was in the range 2 to 45.5 μg/l and phaeophytin was frequently a dominant component indicating a high turnover of biomass within the photosynthetic community. Concentration of these pigments was variable both within and across years with no consistent pattern. In spring, concentration of these pigments was also variable between sites with a tendency for site B to have higher concentrations. Like nitrogen, it appears that phytoplankton were heterogeneously distributed within the wetland, however, there was no correlation between TFN and chlorophyll (r^2= 0.16, df = 27, $p > 0.05$).

5.5 Summary of physical and chemical conditions

In 1998, when monitoring began, Noobijup Swamp was permanent with salinities < 4000 μS/cm and circumneutral pH. However, as monitoring proceeded the lake became seasonal, filling to a shallower depth and tending to dry in autumn. Shallower depth coincided with a trend of increasing salinity (maximum 13360 μS/cm) and acidity (minimum pH 4.18) the latter likely in response to oxidation of exposed peat sediments.

6 Fauna

6.1 Aquatic invertebrate diversity

A total of 216 invertebrate taxa were collected during the 7 sampling years. This rich fauna included a high proportion of typically freshwater species, especially of rotifers and cladocerans but also many freshwater insects such as the dragonfly *Austrothemis nigrescens*, and caddisflies *Acritoptila globosa* and *Helythira litua.* A large number of species (38%) were collected in only one year, indicating high species turnover annually. However, a group of 8 widespread species comprising: three ostracods (*Alboa wooroa, Newnhamia fenestra* and *Candonopsis tenuis)*, one larval chironomid (*Chironomus alternans)*, one rotifer (*Euchlanis* sp.) one cyclopoid (*Mesocyclops brooksi)* and two beetles (*Paracymus pygmaeus* and larval *Scirtidae* sp) were collected in all years.

The fauna included some rare and/or restricted invertebrate species. These include a species of rotifer (*Lecane noobijupi*) known only from this swamp plus Lake Angove near Albany (Segers & Shiel, 2003) which was only collected in 1998 and 2002. Another rotifer, *Trichocerca* n. sp. ‘b’ has only been collected from Noobijup Swamp and only in 2000. An undescribed ostracod, *Paralimnocythere* sp. ‘262’ is known only from a small number of freshwater swamps (Noobijup, Goonaping Swamp east of Perth, Ngopitchup Swamp south-east of Kojonup and three other wetlands in the Muir-Byenup system). It was found in Noobijup Swamp in 1998 and 2000. Another ostracod, *Newnhamia* sp. ‘FC’ was collected in Noobijup every year between 1998 and 2006 but not thereafter in this project (but has been collected subsequently, in 2014 and 2016, for another project). This species is also known from several Muir-Byenup wetlands, plus Lake Pleasant View near the town of Manypeaks. An undescribed species of *Pescecyclops* copepod is common in the Muir-Byenup wetlands, but only known from a few other south-west swamps, including an un-named swamp east of Frankland (Pinder *et al.*, 2004), Nalyerin Swamp north-east of Collie (Pinder *et al.*, 2004) and Kulikup Swamp east of Boyup Brook (Cale & Pinder, 2018). It was collected at Noobijup between 1998 and 2006, but also in 1997 and 2014 (DBCA unpublished data). The caddisfly *Ecnomina* F group sp. 'AV16', recorded from Noobijup from 2000 to 2010, is otherwise known from a few other Muir-Byenup wetlands, plus Lake Pleasant View, Nalyerin Swamp and a swamp at Cape Le Grand east of Esperance. That most of these species tended to drop out of the community mid-way through the monitoring period suggests that this rare south-west endemic component may have been particularly susceptible to the change in pH.

Several other species are also south-west endemics but more widely distributed, including the calanoid copepods *Calamoecia tasmanica subattenuata* and *Hemiboeckella andersonae*, the hemipteran *Notonecta handlirschi* and caddisflies *Notoperata tenax* and *Lectrides* sp. 'AV1'. For some of these species vegetated freshwater swamps such as Noobijup are critical habitat.

Annual species richness ranged from 115 (1998) to 50 (2008) with a declining trend (Mann-Kendal tau = -0.905, p = 0.006) across the monitoring period (Fig.2). Species richness was strongly correlated with pH (r = 0.89, df = 7, p = 0.01) i.e. richness declined with increasing acidity. Large declines in pH in 2004 and 2008 were matched by the largest changes in richness; however richness declined in all monitoring years. Water pH was at its lowest for spring sampling in 2010, however richness was higher in this year than in 2008. Seven taxa (other than those present on all occasions) which were always present prior to, and including, 2006 were absent in 2008 but present again in 2010, suggesting a capacity to recolonise or persist in the wetland within some elements of the fauna. The spatial heterogeneity of pH (at least at the northern and southern ends) may have ameliorated the effect on some species as they found refuge in less acidic parts of the wetland, while others would have relied on resting stages or colonisation from other wetlands.

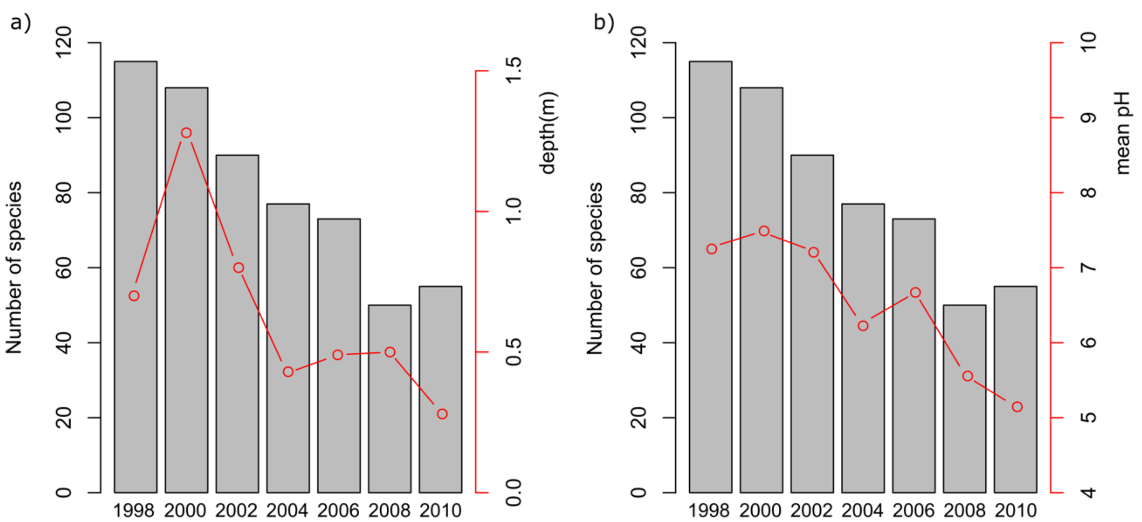

Figure 2. Invertebrate richness in spring of each monitoring year with: a) depth and b) pH (mean of 2 sites) at the time of sampling.

6.2 Invertebrate community composition

An ordination (NMDS) of community structure based on species presence/absence (Fig. 3) indicates that overall community composition in Noobijup Swamp was most similar to marker 9 (freshwater sedge swamps), and remained distinct from other marker wetlands throughout the monitoring period (Fig. 3a). However, dissimilarity between successive years at Noobijup Swamp (Fig. 3b) indicates a directional change in community composition across the monitoring period. Change in composition was not sufficient to alter the similarity between the Noobijup fauna and the fauna of other marker wetlands, essentially because it was so distinctive to begin with. However, the observed changes in composition at Noobijup Swamp result in a similar magnitude of disimilarity to that observed between marker wetlands for sedge swamp (9) and those for fresh or sub-saline wetlands with high richness (i.e. marker 1 and 5 respectively). While compositional change is not toward these latter wetland types it does indicate a significant change in the fauna.

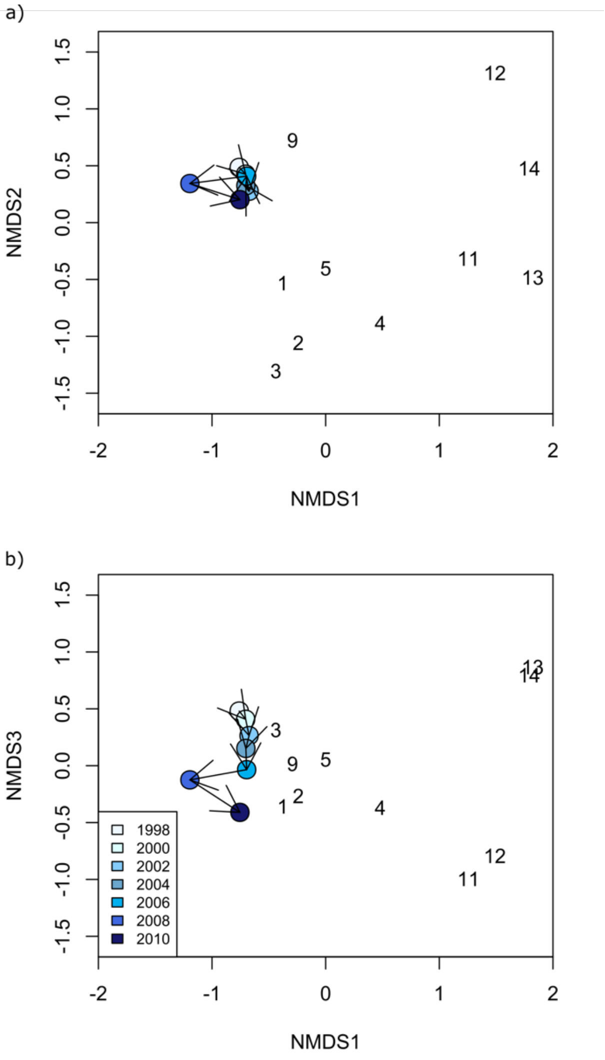

Figure 3. An ordination of spring invertebrate community composition (presence-absence) at Noobijup Swamp with 'marker' wetlands (see methods). For this ordination stress = 0.06. Marker wetland 1=fresh high richness, 2=oligosaline sandy sump, 3=fresh episodic wooded swamp, 4=naturally mesosaline high richness, 5=oligosaline, high richness semi-permanent, 9 = fresh sedge swamp, 11

=naturally saline in good condition, 12=naturally hypersaline claypan, 13=secondary hypersaline sedge fringed, 14=natural hypersaline basin.

Changes in species richness, i.e. species loss as described above (Fig. 2), was the major contributor to change in composition, but species replacement also occurred. Species typical of freshwater swamps and belonging to invertebrate assemblage A of Pinder *et al.* (2004) were disproportionally amongst the types of species lost from the community, with the richness of rotifers of this assemblage particularly decreasing with time. Because of the high proportion of single occurrence species it is difficult to assess how much change was due to species replacement. However, 152 species (70% of all collected taxa) were collected for the first time in 1998 and/or 2000. Of these a subset of 38 species were collected in both of these years but not in 2008 or 2010. Similarly, of the 71 species collected between 2008 and 2010, 33 species were restricted to this period, although they were all single occurrences. While these data suggest at least a portion of the fauna had been replaced, many of the species restricted to the latter period were of assemblage A and the composition, at least in 2010, 'stretches' the boundary of what is characteristic about Noobijup's fauna, rather than resulting in a clear shift in the character of the fauna.The greatest change in community dissimilarity occurred in 2008, relative to other samples both within Noobijup Swamp and from representative marker wetlands. This did not match the observed pH, particularly relative to 2010 (Fig. 4), and may reflect the additional effects of higher salinity in both 2006 and 2007 (see Salinity and ionic composition section below).

In determining which environmental factors might have driven changes in composition, water pH was the only significant ($F = 1.86$, $df = 1,5$, $p < 0.01$) factor correlated with community composition in a constrained ordination (RDA) of species presence/absence. Water pH explained 27% of the observed variation in community composition, with the remaining 73% of variation. dependent on factors not measured in this study.

When sample points are scaled by pH in an ordination (NMDS; stress = 0.04) (Fig. 4) it is apparent that decreasing pH was associated with changes in community composition and the relationship may be by steps, with 2004 and 2006 communities at pH 6.02 to 6.67 showing compositional similarity intermediate between 2008 and 2010 communities at relatively low pH (4.54 to 6.57) and pre 2004 communities with higher pH (6.46 to 7.63). It should be remembered that pH prior to each invertebrate sampling would also have influenced community composition and that the spatial variation in pH between site A and B further confuses the observed relationship. Salinity did not constitute a statistically significant factor in determining community composition, partly due to the relatively stable salinities prior to 2006 and partly because of the disparity in salinity between the two sampling sites. For example, in 2010 the maximum spring salinity (13360 μS/cm) occurred at site B, however this had little effect on species richness or composition of the wetland because site A had much lower salinity (4730 μS/cm) and supported a higher species richness.

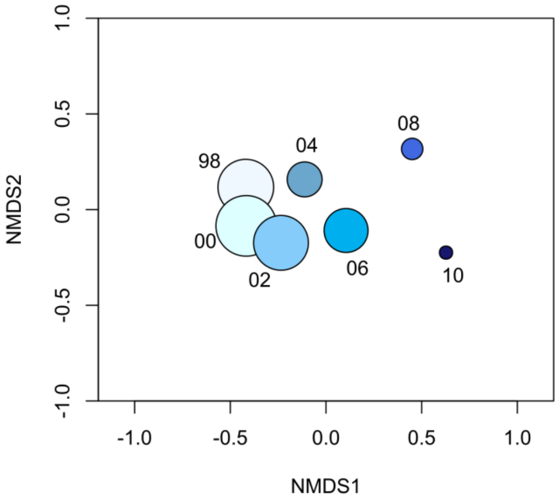

Fig 4 A non-metric multidimensional scaling (NMDS) ordination of spring invertebrate community composition (presence-absence) at Noobijup Swamp. Sample points are scaled by pH and show the influence of pH (the only significant constraining variable in a redundancy analysis) on community composition.

6.3 Waterbird Richness

Fifteen species of waterbird were recorded at Noobijup Swamp between late winter 1998 and autumn 2013 (i.e. autumn 2012/13 sampling year). Abundance was low; the greatest total number of birds recorded was 44 in late-winter 2000 at the highest recorded depth. Musk duck had the highest recorded abundance of 20 birds in late-winter 2000 and the purple swamphen had the highest rate of occurrence being present in 95% of surveys. Little grassbird were frequently encountered between 2004 and 2010 at depths between 0.28 and 0.55 m, but were not present at greater depth in the early part of the monitoring period nor in shallow depths in 2012 when severe senescence of reed beds was observed, particularly at the northern end of the wetland.

Most species had a low frequency of occurrence with only five core species found in six or more surveys. Two cryptic species, little bittern and spotless crake, were infrequently recorded but are particularly hard to detect whilst circumnavigating a wetland and were probably present more frequently. Seven species (including little bittern and spotless crake) with low occurrence (< 6 surveys) were recorded from 1998 to 2004 but not from 2006 onward. White-faced heron had low overall occurrence but were still present in 5 of the 8 surveyed years.

Breeding was recorded only in spring 2000 when two species, black swan and purple swamphen bred. However, the low abundance, cryptic nature of many species, and dense sedge stands, are likely to have reduced the detection of breeding activity. This is particularly true for clamorous reed warbler and little grassbird which had relatively high occurrence and might have been expected to breed.

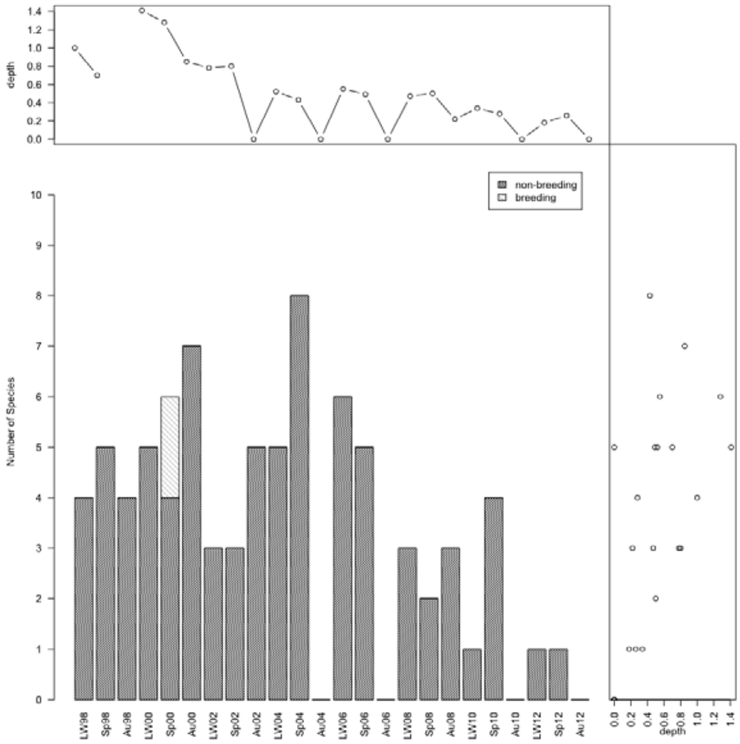

Figure 5 Waterbird species richness across the monitoring period

Richness ranged from 1 to 8 species per survey, which could be considered relatively low. For example, 24 species were recorded from 29 surveys of Lake Pleasant View (another sedge swamp) which resulted in a rank of equal 45 from a wider survey of 197 wetland reserves(Jaensch, Vervest & Hewish, 1988). There was no clear seasonal pattern of species richness with all seasons supporting relatively high richness at some time, however no species were recorded when the wetland was dry.

The richness of feeding guilds was relatively high, given the small number of species present, as most guilds were represented by a single species during a survey. The reed guild however, was consistently represented by multiple species (i.e. Little grassbird, clamorous reed warbler, spotless crake and little bittern) indicating the importance of this habitat to birds at Noobijup Swamp (Fig. 6). Guild richness was reduced in 2002 and since late-winter 2008 in line with periods of changing pH and depth as described earlier and probably reflects changes in the health of reed beds associated with this increasingly shallow and acidic period. The dabbler guild has not been present since late-winter 2004, but the three species in this guild (Pacific black duck, Australian shelduck and black swan) are likely to be opportunistic visitors to this wetland. Diving species were not present in the last three sampling years (2008 and 2010 to 2012) when depths were probably too low (<0.5 m).

6.4 Waterbird community composition

An ordination (NMDS) of annual waterbird presence/absence (Fig. 6) clearly indicated that community composition was most similar to Lake Pleasant View; the marker wetland representing typical sedge swamp communities. However, while community composition at Noobijup oscillated backwards and forwards (on all three axes) around this marker wetland, there was a tendency for annual composition to show increasing dissimilarity to the composition of previous years indicating a directional change in community composition. These observed changes are most noticeable after 2008 and are driven principally by species loss (Fig. 5) in the latter half of the monitoring period when depth and pH were low.

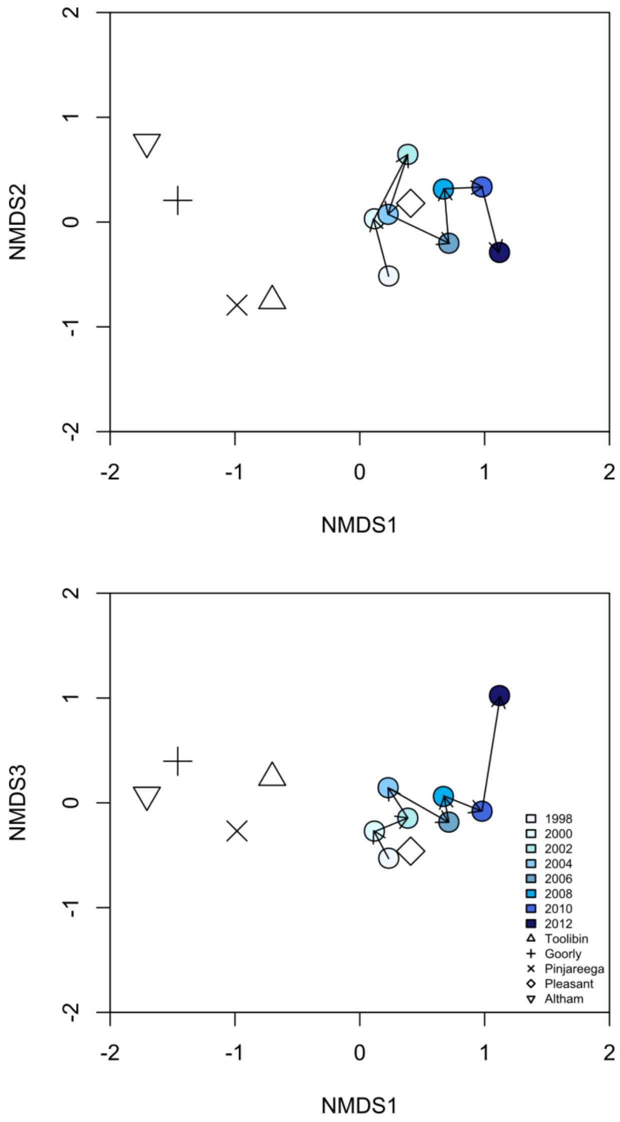

Figure 6. NMDS Ordination of annual Noobijup Swamp waterbird species inventory compiled from late winter, spring and autumn surveys for each year. 1998 includes surveys from 1998/99, 2000 from 2000/01 etc. 'Marker' wetlands (see methods) reflect different wetland types as follows: Toolibin is mesosaline with wooded over storey, Goorly is shallow hypersaline playa, Pinjareega is secondarily saline open basin, Pleasant [View] is a semi-permanent freshwater sedge swamp, Altham is a naturally saline basin wetland.

The importance of pH was indicated in a constrained ordination (RDA), of waterbird presence/absence in individual surveys, where it is the only significant constraining variable ($F = 2.4$, $df = 1,18$, $p < 0.05$). This redundancy analysis constrained only 10% of the variance in water bird community composition to RDA1 and pH, indicating that most variance was not explained by the measured variables. To visualise the relationship between pH and community composition sample points in an ordination (NMDS) of all waterbird surveys (Fig.7) have been scaled by pH. This figure shows considerable variation in community composition for any level of pH, and reflects the low frequency of occurrence of the majority of species, which is apparently not determined by any of the measured environmental variables and probably reflects opportunistic (or short-term) utilisation of the wetland. Also it is likely that changes in community composition across the monitoring period are in response to changes in habitat, i.e. the condition of reed beds (an unquantified field observation), their underlying peat sediments and supported food resources, which occurred because of the long term changes in pH irrespective of short term fluctuations.

Surveys from 2008 to 2012, when pH was low, tend toward the upper right half of the ordination (Fig. 7), but overlap surveys from 2002. In contrast, the majority of surveys from before 2004, when community composition had more frequent occurrence of core species and higher richness overall, lie in the lower left half of the ordination. In 2004 species richness was the highest recorded and included the little grassbird. This species has a strong influence on the ordination of survey communities (linking surveys where it was present) because of its absence before 2004 and the low overall richness of surveys between 2008 and 2012. In 2002, when pH was in fact the most alkaline recorded the fauna was of low species richness like years of low pH. While this might suggest a unimodal response to pH and a preference for circumneutral conditions, there is insufficient data to reject other possibilities such as the regional effects on richness of below average rainfall in 2002.

In summary, both species richness and compositional similarity suggest the waterbird community in the latter part of the monitoring period differs from that in the early part. These differences coincide with low pH and water depth both of which affected habitat condition. However, this apparent change in community structure is not unequivocal because the low richness and frequency of occurrence of species exaggerates the importance of the presence or absence of individual species some of which are hard to detect (e.g. spottless crake) and some of which are likely to only opportunistically use the wetland.

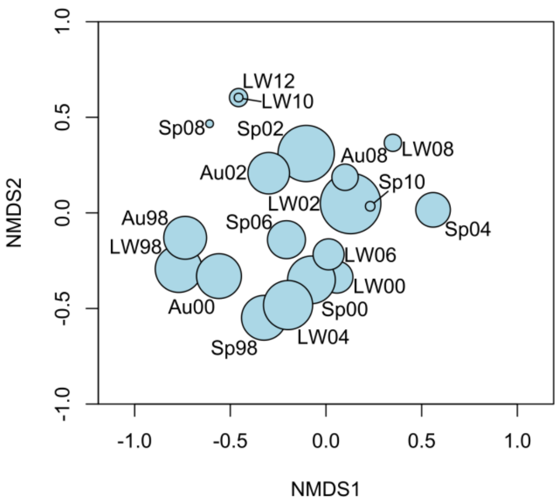

Figure 7 Ordination (NMDS: stress = 0.12) of waterbird community composition for individual surveys at Noobijup Swamp. Seasonal surveys are labelled according to the monitoring year and the consecutive seasons LW =late-winter, Sp= spring, Au= autumn. Sample points are scaled by pH which was the only statistically significant constraint in a redundancy analysis (RDA).

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Appendix 1. Depth and water chemistry data

Physico-chemical variables as used in analyses for Noobijup Swamp. Values for pH, conductivity, temperature, oxygen and TFN and TFP for the spring samples are averages of measurements from site A and site B. For other dates these measurements are for site A only. Other measurements are also for site A only.

Date	24/08/1998	6/11/1998	19/04/1999	25/08/2000	16/11/2000	16/02/2001	27/08/2002	22/10/2002	16/04/2003	31/08/2004	3/11/2004	5/04/2005	13/09/2006	19/10/2006	22/03/2007	26/08/2008	14/10/2008	25/03/2009	25/08/2010	28/10/2010	30/03/2011	9/08/2012	9/11/2012	21/03/2013
season	LW	Sp	Au	LW	Sp	Au	LW	Sp	Au	LW	Sp	Au	LW	Sp	Au	LW	Sp	Au	LW	Sp	Au	LW	Sp	Au
Depth (m)	1	0.7		1.41	1.28	0.85	0.78	0.8	0	0.52	0.43		0.55	0.49	0	0.47	0.5	0.22	0.34	0.28	0	0.18	0.26	0
Conductivity (µS/cm)	3910	1865	5760	1699	2030	3760	2190	2770	10440	2600	5580		2410	3420		986	2060	5440	3620	4730		4820	3520	
pH	7.29	7.15	7.01	6.25	7.35	7.15	8.25	7.95	6.92	7.45	6.43		6.18	6.67		5.21	4.54	5.85	4.61	4.67		5.28	4.18	
TFN (µg/L)	1700	980	1500	1600	670	2400	1000	1200	7000	2900	2200		1400	2700		1400	860	3100	2200	1500		5000	2500	
TFP(µg/L)	5	5	5	5	5	5	5	5	5	10	10		10	20		5	5	5	5	5		5	10	
Chlorophyll-a (µg/L)	0.5	0.5	0.5	5	0.5	7	2	3	3	0.5	1		0.5	0.5		0.5	2	5	5	5		1	0.5	
Chlorophyll-b (µg/L)	0.5	0.5	1	1	0.5	2	0.5	0.5	2	0.5	0.5		0.5	0.5		0.5	0.5	5	0.5	1		0.5	0.5	
Chlorophyll-c (µg/L)	0.5	0.5	1	1	0.5	2	0.5	0.5	0.5	0.5	0.5		0.5	0.5		0.5	0.5	4	4	1		0.5	0.5	
Phaeophytin-a (µg/L)	5	0.5	4	0.5	0.5	0.5	0.5	0.5	6	2	3		2	0.5		0.5	0.5	0.5	0.5	0.5		0.5	0.5	
Temperature (°C)	14.6	17.6	17.6	13	22.4	20.4	11.3	20.6	24.6	7.8	9.7		12.8	15.1		6.6	13.6	14.5	12.7	13.7		12	24.7	
Dissolved Oxygen(%)	350	56		87	7.6	40	66.4	53.6		72.5			49.7	58.5										
NO3 (mg/L)		0.01	0.01	0.45	0.01	0.01	0.01	0.06	0.01	0.02	0.17			0.01		0.07	0.86	0.01	0.005	0.005		0.005	0.01	
Turbidity (NTU)		2.6			1.2			1.6			3.2			2.8			16			0.25			3.1	
Colour (TCU)	100	64			61			47			41			100			14			11			14	
TDS (g/L)		1.2			1.2			1.4			3.3			2			1.2			2.6			1.9	
Alkalinity (mg/L)	10	40			45			40			75			10			0.5			8			0.5	
Hardness (mg/L)	480	290			290			360			800			480			140			700			510	
Si (mg/L)		0.5			0.5			0.23			58			1.3			1.8			8.5				
Na (mg/L)		330			294			412			964			499			288			770				
Ca (mg/L)	28.7	20			20			26			69.8			28.7			17.4			44				
Mg (mg/L)		59			58			73			151			99.6			22.7			143				
K (mg/L)		4			3			5			21.6			3.6			7.5			8.4				
Mn (mg/L)		0.01			0.025			0.01			0.008						0.001							
Cl (mg/L)	1140	610			580			750			1900			1140			582			1590				
HCO3 (mg/L)		49			55			49			91			12			0.5			9				
CO3 (mg/L)	1	1			1			1			1			1			0.5			0.5				
SO4 (mg/L)		29			22			63			6.3			18.3			30.9			27.4				
Iron(mg/L)								0.025			0.2						0.78							
Tot Chlorophyll (µg/L)	6.5	2.0	6.5	7.5	2.0	2.0	11.5	3.5	11.5	3.5	5		3.5	2.0		2.0	3.5	14.5	10.0	7.5		3.5	2.0	

Appendix 2. Aquatic invertebrate data

Noobijup Swamp species matrix. Species in this presence/absence matrix have been combined to the lowest common taxonomic level across all samples, in order to analyse community composition across the monitoring period.

	TAXON	LowestIDNC	1998	2000	2002	2004	2006	2008	2010	occurrences
Protista	Arcella discoides	BP010102	1				1	1		3
	Arcella sp. a (SAP)	BP0101A0	1			1				2
	Arcella sp. b (SAP)	BP0101A2	1			1				2
	Arcella cf. catinus (SAP)	BP0101A5						1		1
	Centropyxis aculeata	BP020101	1	1			1			3
	Centropyxis sp. b (SAP)	BP0201A0	1							1
	Centropyxis ecornis	XX000013						1		1
(sponges)	Spongillidae	IA019999	1		1					2
Hydrazoa	Hydra sp.	IB010199		2		1	1			3
Turbellaria	Turbellaria	IF999999				1				1
Nematoda	Nematoda	II999999	3	3	1	2	1		1	6
Tardigrada	Tardigrada	IR999999	1							1
Rotifera	Rotaria sp.	JB041099	2							1
	Bdelloidea	JB999999	2	2				1	1	4
	Sinantherina sp.	JF030699							1	1
	Testudinella patina	JF050201		2	1	1				3
	Testudinella insinuata	JF050202		2						1
	Testudinella parva	JF050213			1					1
	Asplanchnopus hyalinus	JP010202		1						1
	Brachionus quadridentatus quadridentatus	JP020248					2			1
	Keratella australis	JP020301			1					1
	Keratella javana	JP020306	1	4	1	1				4
	Keratella procurva	JP020308	2	3	1	1				4
	Platyias quadricornis	JP020601	2		1					2
	Colurella adriatica	JP030101					1			1
	Lepadella sp.	JP030299		2	1	1				3
	Dicranophorus sp.	JP040499		1						1
	Euchlanis sp.	JP060199	2	1	1	1	1	1	1	7
	Lecane bulla	JP090110	2	2	1	1	2			5
	Lecane closterocerca	JP090112	2		1					2
	Lecane flexilis	JP090123	2				1			2
	Lecane hamata	JP090129	2			1				2
	Lecane ludwigii	JP090136	2	2	1	1	1	1		6
	Lecane luna	JP090137		2						1
	Lecane lunaris	JP090138	2	2		1	1			4
	Lecane quadridentata	JP090154	2	2	1	2		1		5
	Lecane rhytida	JP090155					1	1	1	3
	Lecane subtilis	JP090165			1					1
	Lecane latissima	JP090174	2	2		1	1			4
	Lecane noobijupi	JP090182	2		1					2
	Lindia sp.	JP100199	2							1
	Mytilina ventralis	JP120108	1	2						2
	Lophocharis sp.	JP120299	2			1				2
	Cephalodella gibba	JP130201			1	1	1			3
	Cephalodella forficula	JP130202	2	1			1			3
	Monommata arndti	JP130404		2						1
	Monommata maculata	JP130409			2	1				2
	Monommata phoxa	JP130410					1			1
	Monommata sp. A	JP1304A0	2							1
	Notommata sp.	JP130599	2							1
	Proales fallaciosa	JP140204		2						1
	Polyarthra dolichoptera	JP150201	1				2			2
	Synchaeta sp.	JP150399		1	1		1			3
	Trichocerca elongata	JP160311	2							1
	Trichocerca longiseta	JP160320	2							1
	Trichocerca rattus	JP160328	2							1
	Trichocerca rattus carinata	JP160341		1						1
	Trichocerca sp.nov. b (Noobijup)	JP1603A1		1						1
	Trichotria pocillum	JP170201	2							1
	Trichotria tetractis similis	JP170202	2	2	1	2				4
	Macrochaetus altamirai	JP170301	2	2	1					3
	Macrochaetus subquadratus	JP170304				1				1
	Scaridium bostjani	JP180101					1			1
	Scaridium longicaudum	JP180103			1					1

	TAXON	LowestIDNC	1998	2000	2002	2004	2006	2008	2010	occurrences
Mollusca	Austropeplea sp.	KG050199			1					1
	Ferrissia petterdi	KG060101	2	2						2
	Glyptophysa cf. gibbosa	KG0702A5	1	3	2	1				4
Annelida	Insulodrilus bifidus	LO030503	1	1	1					3
(earthworms)	Naididae	LO049999	1	1	1	1	1	1		6
	Dero furcata	LO050203	2	1	2					3
	Dero WA4 (cf. graveli)	LO0502A2				2	1			2
	Pristina longiseta	LO050501	1	1						2
	Pristina leidyi	LO050507				1	2	2	4	4
	Chaetogaster diastrophus	LO050701			1		1			2
	Antipodrilus davidis	LO051601				1			1	2
	Enchytraeidae	LO089999	2		1	2		1		4
Arachnida	Limnochares australica	MM020101	2	2	1	1	1	1		6
(water mites)	Diplodontus sp.	MM050299	1	2	1		1			4
	Frontipoda sp.	MM090299			1					1
	Oxus australicus	MM090301	2	1	1					3
	Koenikea nr australica (=verrucosa)	MM1602A8		1						1
	Acercella falcipes	MM170101					1			1
	Arrenurus sp.	MM230199	1							1
	Halacaridae	MM249999			1		2			2
	Pezidae	MM259999	1	1	1				1	4
	Oribatida sp.	MM9999A1	3	1	2	2	2		3	6
	Mesostigmata	MM9999A2	2	1		1	1			4
	Trombidioidea	MM9999A6	1				2			2
Cladocera	Alona setigera	OG030214	1							1
(water fleas)	Alonella clathratula	OG030301		1		1	3			3
	Alonella cf. exigua	OG0303C8	2							1
	Camptocercus australis	OG030701	2	2	1					3
	Chydorus sp.	OG030999	2	2			2			3
	Graptoleberis testudinaria	OG031501	2	2						2
	Armatalona macrocopa	OG033401	2	3	2				1	4
	Ceriodaphnia sp.	OG040199	2				3	1		3
	Scapholeberis kingi	OG040401	2				1			2
	Ilyocryptus sp.	OG050199	2	2						2
	Macrothrix sp.	OG060299		1		1				2
Ostracoda	Gomphodella aff. maia	OH0101A0	2	2	2	2	3			5
(seed	Limnocythere dorsosicula	OH010201				1				1
shrimps)	Paralimnocythere sp. 262	OH0103A1	1	1						2
	Candonopsis tenuis	OH070101	1	1	2	2	3	2	1	7
	Alboa worooa	OH080101	2	3	2	2	4	2	3	7
	Cypretta baylyi	OH080501	2							1
	Cypretta aff. globosa	OH0805A1	2	2		1				3
	Diacypris spinosa	OH080703				1				1
	Mytilocypris mytiloides	OH081204				1				1
	Ilyodromus amplicolis	OH081901	1							1
	Newnhamia fenestrata	OH110101	2	2	1	1	3	2	3	7
	Kennethia cristata	OH110201							4	1
Copepoda	Boeckella sp.	OJ110199			2		3	2	2	4
	Calamoecia attenuata	OJ110203	4	4	2	1		1	4	6
	Calamoecia tasmanica subattenuata	OJ110211	4			3	4	2	3	5
	Hemiboeckella andersonae	OJ110302					3			1
	Microcyclops varicans	OJ310101		2	2					2
	Metacyclops sp. 4	OJ3102A6	1	2	1		1			4
	Macrocyclops albidus	OJ310601	3	3	1					3
	Mesocyclops brooksi	OJ310703	2	2	3	3	3	3	3	7
	Paracyclops sp 1 (nr timmsi)	OJ3111A1	1					1	2	3
	Paracyclops sp. 4	OJ3111A8						2	2	2
	Meridiecyclops baylyi	OJ311701						1		1
	Australocamptus sp. 5	OJ6199A4			1	1		1	2	4
	Nitocra sp. 5 (nr reducta)	OJ6401A6	1							1
	Harpacticoida sp. 2	OJ6999B0	2		1	1	1	2	1	6
Amphipoda	Austrochiltonia subtenuis	OP020102		1	2				1	3
	Perthia acutitelson	OP080101	2	2		2	2	2	2	6
Decapoda	Cherax preissii	OV010113			1		1	1	1	4
Coleoptera	Uvarus pictipes	QC090701						1		1
(beetles)	Limbodessus shuckhardi	QC091002					1		1	2
	Limbodessus inornatus	QC091006			1			1		2
	Allodessus bistrigatus	QC091101	1	1		1		1		4
	Antiporus sp.	QC091699		1						1
	Sternopriscus browni	QC091809	1	1		1				3
	Megaporus howitti	QC092103				1				1
	Megaporus solidus	QC092107	1	1	2	2	2	1		6
	Platynectes aenescens	QC092207		1						1
	Rhantus suturalis	QC092301				1				1
	Lancetes lanceolatus	QC092401	1	1	1		1			4

	TAXON	LowestIDNC	1998	2000	2002	2004	2006	2008	2010	occurrences
	Spencerhydrus pulchellus	QC093302	1							1
	Onychohydrus sp.	QC093499		1						1
	Gyrinidae	QC109999		1						1
	Berosus discolor	QC110409							1	1
	Berosus majusculus	QC110417							1	1
	Paranacaena littoralis	QC110904						1		1
	Enochrus eyrensis	QC111102			1	1	1			3
	Helochares tenuistriatus	QC111203	1		1	1			1	4
	Limnoxenus zelandicus	QC111401		1	2	1		1		4
	Paracymus pygmaeus	QC111601	1	2	1	1	1	1	2	7
	Ochthebius sp.	QC130399	1							1
	Gymnocthebius sp. 1	QC1304A0		2		1	1		1	4
	Scirtidae sp.	QC209999	1	1	2	1	2	2	1	7
	Hydrochus australis	QCA00106				1				1
Diptera	Tipulidae type C	QD0199A2	1			1	1			3
(flies, midges,	Tipulidae type E	QD0199A4		1		1				2
mosquitoes)	Anopheles atratipes	QD070105		1					1	2
	Aedes sp.	QD070599							1	1
	Culex latus	QD070707					1		1	2
	Coquillettidia nr linealis	QD0708A0		1	2	2	2	1	1	6
	Bezzia sp. 2	QD0904A0	1		1	1		2		4
	Clinohelea sp.	QD090699						1	1	2
	Culicoides sp.	QD090899			1	1	1			3
	Dasyheleinae	QD0999A2			1					1
	Tabanidae	QD239999			1					1
	Stratiomyidae	QD249999		1	1	1				3
	Empididae	QD359999			1					1
	Dolichopodidae sp. A	QD3699A0	1							1
	Sciomyzidae	QD459999							1	1
	Ephydridae sp. 5	QD7899A9	1		1	1		1		4
	Muscidae	QD899999		1						1
	Procladius paludicola	QDAE0803			1		2			2
	Alotanypus dalyupensis	QDAE1001		1		1			3	3
	Paramerina levidensis	QDAE1201	2	2	2	2	2	1		6
	Pentaneurini sp. A	QDAE99A2						1		1
	Pentaneurini genus C	QDAE99B8		1	1					2
	Parakiefferiella sp. S1	QDAF03A5		1						1
	Corynoneura sp. (V49)	QDAF06A2	2	1	1					3
	Paralimnophyes pullulus	QDAF1202	3	2	2	2	2	2	2	7
	Compterosmittia? sp. A	QDAF19A0						2		1
	Orthocladiinae 'woodminer'	QDAF99C3	2	1						2
	Tanytarsus bispinosus	QDAH0405	3	2	2	3	3	1		6
	Tanytarsus fuscithorax	QDAH0410							3	1
	Paratanytarsus sp. B	QDAH06A1		1						1
	Chironomus tepperi	QDAI0414		1		3				2
	Chironomus aff. alternans	QDAI04A0	3	1	3	2	3	1	2	7
	Dicrotendipes conjunctus	QDAI0603		2			3		2	3
	Dicrotendipes sp. A (V47)	QDAI06A0	3	2	2	1	1			5
	Cladopelma curtivalva	QDAI2201							3	1
	Parachironomus sp. 1	QDAI25A0	3	2	2		1			4
	Cloeon sp.	QE020299	1	1						2
Hemiptera	Hebrus axillaris	QH530101	1		1					2
(waterbugs)	Microvelia sp.	QH560199	2	1	1	1	2		1	6
	Diaprepocoris barycephala	QH650101	1	2						2
	Sigara sp.	QH650299		1	1					2
	Notonecta handlirschi	QH670201		1	1		2		2	4
	Anisops sp.	QH670499	1				1	1	1	4
Lepidoptera	Lepidoptera (non-pyralid) sp3	QL9999A1	1							1
Odonata	Austroagrion cyane	QO020501	1							1
(dragonflies,	Xanthagrion erythroneurum	QO021301			1		1			2
damselflies)	Austrolestes analis	QO050101		1			1		1	3
	Austrolestes annulosus	QO050102							1	1
	Adversaeschna brevistyla	QO120201					1		1	2
	Hemianax papuensis	QO121201							1	1
	Austrothemis nigrescens	QO170301		1	1	1				3
	Diplacodes sp.	QO170799		1						1
	Procordulia affinis	QO300202	1	1	1	1		1		5
Trichoptera	Acritoptila globosa	QT030201	2	1						2
(caddisflies)	Hellyethira litua	QT030410	1	1	1					3
	Ecnomina F group sp. AV16	QT0803A3		1	1	1	1	2	1	6
	Ecnomina F group sp. AV20	QT0803A4						1		1
	Ecnomus pansus/turgidus	QT0804A0	1	1			1			3
	Lectrides sp. AV1	QT2502A1	1							1
	Notoperata tenax	QT250605		1	1					2
	Oecetis sp.	QT250799			1					1

	TAXON	LowestIDNC	1998	2000	2002	2004	2006	2008	2010	occurrences
	Triplectides niveipennis	QT251115	1		1					2

Appendix 3. Waterbird data

Abundance of waterbird species for each seasonal survey at Noobijup Swamp.

		1998			2000			2002			2004			2006			2008			2010			2012			Occurrence[1]
		Aug	Oct	Mar	Aug	Oct	Mar	Aug	Nov	Mar	Aug	Oct	Mar	Aug	Oct	Mar	Aug	Oct	Mar	Aug	Oct	Mar	Aug	Oct	Mar	
Purple Swamphen	*Porphyrio porphyrio*	11	6	7	15	7	7	6	3	2	5	6		3	5		7	1	1	4	2		1			95
Clamorous Reed-Warbler	*Acrocephalus australis*		9		6	5	8	5	5	2	3	16		7	4				1		1					65
Musk Duck	*Biziura lobata*	13	5	6	20	3	7				2			2	3											45
Swamp Harrier	*Circus approximans*				1	1		1				1		1			1				1					35
Little Grassbird	*Megalurus gramineus*											4		5	3		1		1		1					30
Little Pied Cormorant	*Phalacrocorax melanoleucos*	1		1			5							1	1											25
White-faced Heron	*Ardea novaehollandiae*			2			3			1		3						1								25
Pacific Black Duck	*Anas superciliosa*	3				2	13				1															20
Black Swan	*Cygnus atratus*					2			1	2																15
Spotless Crake	*Porzana tabuensis*						6			2		1														15
Australian Shelduck	*Tadorna tadornoides*				2						2															10
Australian White Ibis	*Threskiornis molucca*											1												3		10
Darter	*Anhinga melanogaster*		1																							5
Little Bittern	*Ixobrychus minutus*		3																							5
Yellow-billed Spoonbill	*Platalea flavipes*											1														5

[1]% of surveys where water was present.

Appendix 4 Invertebrate Marker Wetlands

Background

Ordination of invertebrate community composition is a simple tool for visualising the changes in composition over time; linking samples of greatest similarity by their proximity. However, the scale (and therefore ecological significance) of changes between samples is not identified. An ecological context for the observed differences between samples can be provided by including samples of known types (marker wetlands) in the ordination to define an ecological ‘space’.

Marker wetlands for the invertebrate ordination were derived from a classification of 200 wetlands across the Wheatbelt (Pinder *et al.* 2004) which identified 14 wetland groups on the basis of invertebrate community composition. Eleven groups were relevant to the suite of wetlands in the monitoring program and from each of these the wetland having species richness closest to the group average was selected as a candidate marker wetland. Where multiple wetlands shared the average richness all were selected. An ordination of the selected wetlands was conducted and used to determine a minimum set that could define a useful ecological space. Where multiple samples from a wetland group were included those that differed most from other wetland groups were retained. Markers for wetland groups 10 and 11 were sufficiently similar that a single one from wetland group 11 was selected. The final set of ten marker wetlands is detailed in the following table.

Invertebrate ordination marker wetlands derived from the fourteen wetland groups described by Pinder *et al.* (2004)

Group	Name	Code	Richness	Salinity (ppt)	Group description
WG1	Calyerup Creek	SPS094	66	4	species-rich mostly freshwater wetlands. sampled in September 1998.
WG2	Job’s Sump	SPS060	51	3.5	series of 8 shallow claypans with relatively high turbidity and some unique faunal elements. Job’s sump has a sandy bed and is not turbid like other members of the group. Sampled in October 1997 when approximately 80% full
WG3	Nolba Swamp	SPS194	49	<1	group of northern tree swamps; freshwater wetlands dominated by an overstorey of trees, Nolba is episodically filled and was sampled while full in July 1998.
WG4	Maitland’s Lake	SPS142	44	9.5	subsaline wetlands many of which were probably naturally saline but subject to secondary salinity. Maitland’s was sampled in September 2000 at about 70% full.
WG5	Lake Caitup	SPS135	49	3.5	this lake is deep and fringed by sedges and melaleuca and represents a group of subsaline wetlands some of which are subject to secondary salinity but of less overall salinity than WG4. Lake Caitup was sampled in September 1998
WG9	Mt Le Grande Swamp	SPS133	66	<1	southern freshwater swamps found in the jarrah forest and Esperance sandplain region. Most are dominated by sedges and some include Yates. Sampled in September 1998
WG11	Dambouring Lake	SPS152	20	30	naturally saline wetlands in good condition. Sampled in September 1999
WG12	Beaumont Lake	SPS130	16	50	a shallow ephemeral clay pan in Beaumont Nature Reserve, represents a series of naturally hypersaline and secondarily hypersaline wetlands in the southern Wheatbelt. Sampled in September 1998

Group	Name	Code	Richness	Salinity (ppt)	Group description
WG13	Master's Salt Lake	SPS097	7	220	degraded hypersaline lake. Sampled in October 1997
WG14	Monger's Lake	SPS166	11	130	naturally hypersaline wetland with high species richness. Sampled in August 1999