Wheatbelt Wetland Biodiversity Monitoring

Fauna Monitoring at Lake Pleasant View 1999-2012

Report WWBM-FR03

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Cover photo: Lake Pleasant View from the north shore looking south toward Mt Manypeaks photographed in October 2009. D. Cale.

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1 Summary

Lake Pleasant View is a permanent freshwater sedge swamp that has remained in high condition despite its situation in a mostly agricultural landscape. It is an important wetland for the threatened Australasian bittern. There was little evidence of changing conditions in the wetland during the study period, other than a trend of increasing total filtered nitrogen in autumn, possibly associated with the agricultural lands around it. Salinity increases seasonally over summer and autumn but not to an extent that would affect the fauna and there was no tendency for this to increase over the study period. Groundwater beneath the lake is not rising (Mike Lyons, DBCA, pers. comm.).

The aquatic invertebrate community is diverse and includes a number of species restricted to similar wetlands in the far south-west and/or south coast. Neither composition nor richness showed any clear directional change across the monitoring period. There was some indication of a relationship between the invertebrates and depth in spring, but this may just represent sampling in slightly different stages of the hydrological cycle.

Few species of waterbirds use Pleasant View and those that do are low in abundance. However, they represent a wide variety of ecological guilds utilising different habitats and food resources. The low diversity and abundance is probably associated with the dense emergent vegetation (with little open water) and the presumed low productivity of waterbird food typical of such wetlands. There was no directional change in waterbird richness or composition over time, with annualised composition very stable. Pleasant View is an important wetland for the threatened Australasian bittern and for this reason deserves to be periodically monitored for condition, especially its hydrology and water chemistry.

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; Cale & Pinder, 2018a b c).

Lake Pleasant View was included in the monitoring program as a representative of freshwater wetlands with high and possibly threatened conservation value on the southern margin of the wheatbelt (Cale *et al.*, 2004). It was given the site code SPM024.

3 Wetland description

Lake Pleasant View is a sedge and reed dominated wetland in the south-coastal region of Western Australia. The wetland has an area of 201 ha (Halse, Pearson & Patrick, 1993a) and lies within an A class nature reserve (No. 15107) 35 km east of Albany. The wetland abuts farmland on two sides and eutrophication from agricultural fertilisers is a potential threatening process (Environment Australia, n.d)

Water depth has been monitored annually in September and November since 1979 and has "oscillated between 0.1 and 2.2m and salinities have mainly been within the range 0.2 to 0.9ppt (exceptionally to 1.6ppt) over the past 34 years" (Lane *et al.*, 2017). The wetland has been described as seasonal (Halse *et al.*, 1993a), or semi-permanent, with only three years between 1979 and 1991 experiencing a dry spell of 1-4 months (Environment Australia, n.d).

This wetland is important for the globally endangered Australasian bittern (Jaensch, Vervest & Hewish, 1988; Jaensch, Clarke & Lane, 2009; Jaensch & Watkins, 1999; Clarke, Jaensch & Lane, 2011). This species breeds at Lake Pleasant View and has occasionally been recorded in sufficient abundance (i.e. >= 5 birds) to exceed 1% of the south-west Australian population which has been estimated at between 38 and 154 birds (Pickering, 2013). This is a threshold criterion for importance under the Ramsar convention and highlights the value of Lake Pleasant View (Jaensch & Watkins, 1999). Chestnut teal have also been recorded at the wetland in abundances in excess of its 1% threshold (Jaensch & Watkins, 1999).

The vegetation of Lake Pleasant View has been described by Gurner *et al.* (2000). The wetland supports a diverse sedge community including *Baumea articulata*, *B. juncea*, *B. rubiginosa*, *Ghania* *trifida, Juncus* sp., *Lepidosperma tenue* and *Schoenus* sp. and woodland components including *Eucalyptus occidentalis* and *Melaleuca cuticularis*. There appears to have been little change in habitat structure across the wetland excepting some replacement of tall and short sedges by shrub thicket particularly at the wetland's northern edge (Jaensch *et al.*, 2009, see table 5). The area of open water has been variably described as 0.04% of total wetland area (Halse, Pearson & Patrick, 1993b) and 5% of wetted area (Cale *et al.*, 2004) and probably reflects differences in methodology, while the observation that 75% of the wetland was open water in 1985-86 (D Cale pers. obs. in Cale *et al.*, 2004) probably reflects a difference of perspective with areas of low sedge density (or little emergence) being considered open water.

4 Sampling Program

Lake Pleasant View was visited 21 times between August 1999 and March 2012 (Table 1). While waterbird and water chemistry data are presented for the full sampling period, the complete suite of invertebrate data are presented for the period 1999- 2007 and a reduced suite lacking Rotifera and Protista is presented for the entire sampling period. Site A at this wetland is located adjacent to the depth gauge on the wetland's south-eastern margin and site B was on the north-east margin and always shallower.

Table 1. Site visits, collected datasets and depth for Lake Pleasant View, 1998 – 2012.

Sample	Monitoring Year	Date	Invertebrates sampled?	Waterbirds surveyed?	Depth (m)
Lw99	1999/00	30/08/1999	×	✓	0.82
Sp99	1999/00	24/10/1999	✓	✓	0.92
Au99	1999/00	21/03/2000	×	✓	0.6
LW01	2001/02	25/08/2001	×	✓	0.26
Sp01	2001/02	24/10/2001	✓	✓	0.35
Au01	2001/02	28/03/2002	×	✓	0.64
LW03	2003/04	14/08/2003	×	✓	0.47
Sp03	2003/04	24/10/2003	✓	✓	0.87
Au03	2003/04	27/03/2004	×	✓	0.51
LW05	2005/06	11/08/2005	×	✓	1.34
Sp05	2005/06	27/10/2005	✓	✓	1.4
Au05	2005/06	25/03/2006	×	✓	1
LW07	2007/08	9/08/2007	×	✓	0.58
Sp07	2007/08	25/10/2007	✓	✓	0.66
Au07	2007/08	2/04/2008	×	✓	0.27
LW09	2009/10	27/08/2009	×	✓	1.09
Sp09	2009/10	29/10/2009	✓	✓	1.18
Au09	2009/10	24/03/2010	×	✓	0.68
LW11	2011/12	1/09/2011	×	✓	0.64
Sp11	2011/12	22/10/2011	✓	✓	0.68
Au11	2011/12	29/03/2012	×	✓	0.28

5 Physical and chemical environment

Physico-chemical data is provided in Appendix 1.

Hydrology

During the monitoring period depth ranged between 0.26 m and 1.4 m, with a mean of 0.76 ± 0.33 m. Depth tended to increase from late-winter (mean = 0.74 ± 0.37 m) to spring (mean = 0.86 ± 0.34 m) following winter rainfall and then decline over summer to a minimum depth in autumn (mean = 0.56 ± 0.25 m). During 2001/2 the wetland was relatively shallow in spring (0.35 m) but deeper (0.64 m) in the following autumn, probably as a result of the 173.8 mm of rainfall at Manypeaks in December 2001. Depths were relatively high throughout 2005/6 (1.4 m in spring and still 1 m in autumn) and 2009/10 (1.18 m in spring and still 0.68 m in the following autumn) but still followed the usual seasonal pattern (Fig. 1). The wetland was probably permanently inundated over the monitoring period including during years between sampling (Lane *et al.*, 2017 , Bart Huntley unpublished data). However, at low water depth (e.g. late-winter 2001 and autumn 2012) the wetland had a greatly reduced wetted area and a broad margin of sedge growing in lake sediments that were dry at the surface, presenting a different range of habitats than present during wetter periods.

Depth was negatively correlated (rho = -0.85, $p < 0.01$, df = 19) with salinity (electrical conductivity and total dissolved solids).

pH

Water pH ranged from 6.18 – 7.81, with the exception of one extreme value in spring 2007 when a, possibly spurious, pH of 8.9 was recorded from laboratory analyses because a malfunctioning field meter prevented *in situ* measurement. In spring, pH varied between the two sites in some years. In 2001 and 2003 spring pH varied between sites by approximately 0.8 units, with site B lower in 2001 and site A lower in 2003. There was no seasonal pattern of changes in pH and no evidence for a trend of change in pH across the monitoring period.

Salinity and ionic composition

Regression of total dissolved solids (TDS) on electrical conductivity (Ec), at site A in spring, confirms a significant relationship ($R^2_{adj} = 0.952$, $p < 0.000$, df = 5); with TDS (g/l) = 0.000565* Ec (µS/cm) + 0.0099. Salinity (electrical conductivity) remained in the fresh range (i.e. < 4400 µS/cm) throughout the monitoring period. TDS, measured only at one site in spring, varied between 0.34 and 0.83 g/l (382 and 1384 µS/cm). Maximum salinity was 3820 µS/cm at site A in autumn 2012 (when lake depth was 0.28 m) while a minimum of 218 µS/cm was recorded at site B in spring 2003 (depth 0.87 m). Salinity was highest in autumn in all years except 2001/2 when autumn salinity was lower (and depth higher) than the previous late winter and spring because of a summer rainfall event.

In spring, salinity at sites A and B was very similar (< 20 µS/cm difference) in 1999 and 2001, but in later years a greater difference between sites was observed. The most marked difference occurred in 2003 when salinity at site A was higher (1038 µS/cm) than site B (218 µS/cm). Smaller differences in 2005, 2007 and 2009 maintained the pattern of lower salinity at site B, but in 2011 the pattern was reversed and salinity was higher (1121 µS/cm) at site B than site A (883 µS/cm). These data suggest the lake was poorly mixed and may have multiple sources of inflow differing in salinity.

Ionic composition displayed a cation dominance of Na>Mg>Ca>K and anion dominance of Cl>HCO3>SO4. Salinity was strongly correlated with depth (see above) and weakly correlated with total filtered phosphorus (rho = -0.46, $p < 0.05$, df = 19) and total chlorophyll concentration (rho = 0.49, $p < 0.05$, df =19), as well as ionic components and hardness.

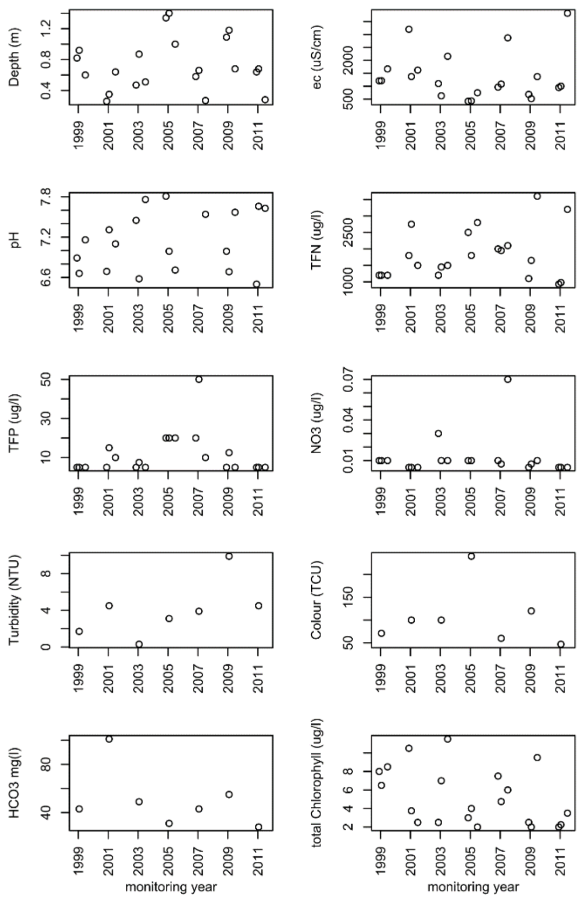

Figure 1. Water chemistry parameters at Lake Pleasant View for late-winter, spring and autumn between 1999 and 2012. ec is electrical conductivity, TFP total filtered phosphorus, TFN total filtered nitrogen, NO3 nitrate, HCO3 bicarbonate ion and total chlorophyll is the sum of the photosynthetic pigments chlorophyll a, b and c and phaeophytin. Tick marks are positioned at spring sampling.

Nutrients and chlorophyll

Nitrate (NO_3^-) concentrations were low (range 5 to 70 µg/l) and only two samples exceeded 10 µg/l. Total filtered nitrogen concentration was in the range 930 - 3600 µg/l with mean 1792 ± 744µg/l. Sites differed from each other during spring, with concentrations at site B (mean = 1937 ± 672 µg/l) significantly higher (paired t test: t= -3.18, $p < 0.05$, df = 6) than at site A (mean = 1428 ± 552 µg/l). Until 2007 TFN was higher in winter and spring than in autumn, but in later years (2009/10 and 2011/12) there was an increase in the autumn concentration of TFN (3600 and 3200 µg/l respectively), with no similar increase in late-winter or spring concentrations. These TFN values are moderately high and indicate some enrichment, with most values higher than the default trigger value (in ANZECC & ARMCANZ, 2000) for total unfiltered nitrogen (1500 µg/L for south-western Australian wetlands – TFN trigger values not derived but would be even lower). It is not known if the increased autumn values later in the series were due to changes in landuse on adjacent agricultural land or to hydrological changes. Except for the increased concentration in autumn there was no evidence of a trend of changing concentration for TFN across the study period.

Total filtered phosphorus (TFP) concentrations were low, with only a single sample, at site B in spring 2007, in excess of 20 µg/l. There was no significant difference in concentration between sites (paired t test: $t = -1.11$, $p > 0.05$, $df = 6$) and no apparent seasonal trend or trend over the study period.

Chlorophyll concentrations ranged between 2.5 – 11.5 µg/l (mean = 5.00 ± 2.97 µg/l), with all values well below the default water quality trigger value of 30 µg/l for south-western Australian wetlands (ANZECC & ARMCANZ, 2000). There was no clear seasonal pattern and no trend across the monitoring period. There was no significant difference between sites across the monitoring period (paired t test: $t = 1.11$, $p > 0.05$, $df = 6$), suggesting primary production was homogenously distributed across the wetland. There was evidence for sustained periods of relatively high planktonic primary production (Fig. 1). Throughout 1999/2000 and 2007/08 and in late-winter and spring 2001 and spring and autumn of 2004/5, higher chlorophyll concentrations and equal proportions of chlorophyll and the degradation product phaeophytin suggest the persistent turnover of populations of planktonic algae.

Concentrations of nutrients and chlorophyll suggest the lake was, at most, mesotrophic throughout the study period. While TFN concentrations were sufficient to support higher levels of primary production, such production would have been limited by the available phosphorus. However, more recently (since spring 2016), filamentous algae may have become more prevalent in the wetland (Alan Clarke, DBCA, pers. comm.) and this would not have been picked up by chlorophyll analyses. Analyses of water samples collected in November 2018 by Alan Clarke (DBCA Busselton) did not show any further increase in nutrient concentrations in the lake that might have triggered this algal growth, with TFN 1300 and 1700 µg/l (sites A and B respectively) and TFP <10 µg/l at both sites. It is possible that the filamentous algae was washed into the lake from adjacent farmland and has maintained and possibly expanded its presence.

To summarize, Lake Pleasant View was probably permanently inundated over the period of monitoring and remained fresh, with salinity generally only increasing in autumn as lake depth fell (e.g. the maximum salinity of 3820 µS/cm in autumn 2012). Differences in salinity and nutrients between two locations on the lake suggest there may be a number of points of inflow; probably of differing water quality. There is evidence that since at least 2009 autumn concentrations of TFN have increased and are above management trigger values for south-west wetlands (*sensu* ANZECC & ARMCANZ, 2000).

6 Fauna

Aquatic invertebrate diversity

Lake Pleasant View supported 236 species of invertebrate during the monitoring period. Seventeen species were collected on all occasions including: insects (*Hellythira litua*, Scirtidae sp., *Paramerina levidensis*, *Tanytarsus bispinosus*, *Cladopelma curtivalva* and *Bezzia* sp), molluscs (*Glyptophysa* sp.)

amphipods (*Austrochiltonia subtenuis* and *Perthia australis*), copepods (*Calamoecia attenuata*, *C. tasmanica subattenuata* and *Mesocyclops brooksi*), ostracods (*Kennethia cristata*, *Lacrimicypris kumbar* and *Alboa worooa*), water mites (*Limnochares australica*) and unidentified nematodes. There was a relatively high rate of turnover of other species from year to year. Sixty two percent of rotifers and protists were recorded only once during the 5 years they were collected. Within the remaining groups 85 species (40%) were collected only once over the 7 sampling periods. Between 1999 and 2007, rotifers and protists (which were not identified thereafter) accounted for 13 to 33% (mean 20.2 ± 7.5) of species richness annually.

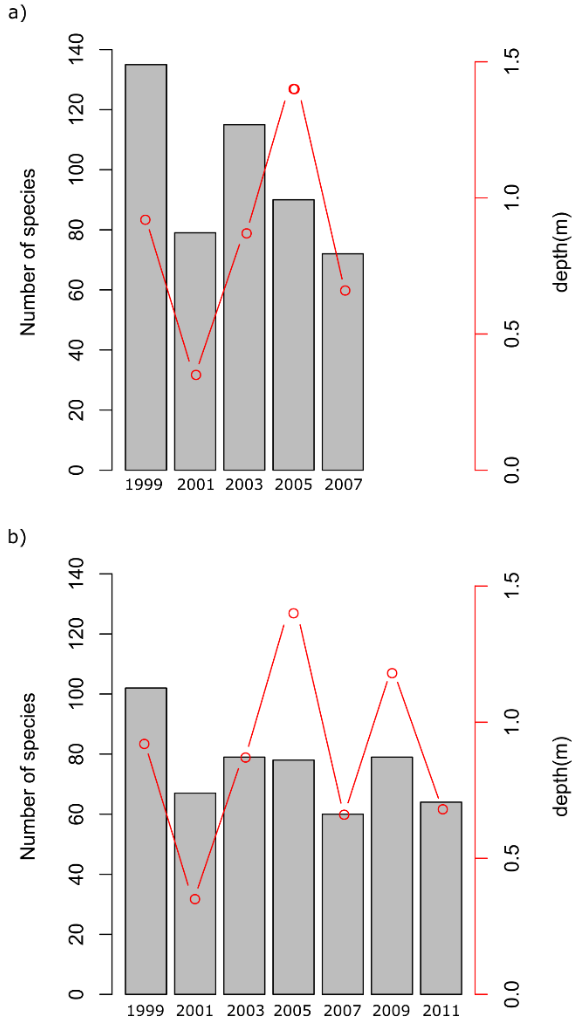

Figure 2. Invertebrate richness and depth in spring of each monitoring year. a) The full suite of invertebrate taxa and b) all invertebrate taxa except Rotifera and Protista.

A few species are known only from Lake Pleasant View and a small number of other similar wetlands or wetland complexes in the south-west or south coast regions. These include two undescribed species of *Newnhamia* ostracods (given the informal labels '295' and 'FC'). The 'FC' species is otherwise known only from eight Muir-Byenup swamps. The '295' species occurs in many of the same Muir-Byenup swamps but also three other south west freshwater wetlands: Mettler Lake, Ngopitchup

Swamp (near Kojonup) and Kulikup Swamp (east of Boyup Brook). A leech (Richardsonianidae sp. nov. (Pleasant View)) of the family Hirudinidae is believed to be undescribed (Fred Govedich pers. comm.) but leeches are not well known from south-western Australia (Atlas of Living Australia has just one record of Hirudinidae from southern WA) and comparisons have not been made with specimens from other locations, so this is likely to be more widespread than Pleasant View. A water mite of the genus *Arrenurus*, collected from Lake Pleasant View in 2009 resembles *Arrenurus glaucus* (Smit 2010), which was described from a couple of south-west rivers, but it has not been found in other DBCA projects in flowing or non-flowing waters in WA so may be uncommon. Finally, two species of rotifer, *Scaridium* n. sp. and *Monommata* n. sp. have only been collected from Lake Pleasant View. Rotifers are unlikely to be restricted to a single wetland but these may be regional endemics occurring in similar wetlands.

The presence of two species of *Cherax*, the gligie (*Cherax quinquecarinatus*) and the common koonac (*Cherax preissii*) is significant because they are probably a primary food source for the threatened Australasian bittern (see below).

Invertebrate abundance was generally low with 86% of 592 species counts falling in log abundance classes 1 (<10) and 2 (10 to <100). Taxa which were regularly abundant included *Calamoecia* spp (Copepoda), *Kenethia cristata* (Ostracoda)*, Austrochiltonia subtenuis* (Amphipoda) and larvae of a number of Chironomidae. Eighty two percent of single occurrence species had an abundance of log abundance class 1 and it is possible that many of these species were always present in the wetland, but at sufficiently low abundance to be collected rarely.

Total species richness (including rotifers and protists) was measured for the 1999 – 2007 monitoring years and ranged from 72 – 135 (Fig. 2a). A narrower range of taxa, excluding the rotifers and protists, were identified for the entire monitoring period 1999-2011 (to reduce costs) and richness calculated from these taxa ranged from 60 – 102 (Fig. 2b). Species richness 'with' (S) and 'without' rotifers and protists (R) was positively correlated and total species richness can be predicted from the richness of the fauna without rotifers and protists using the equation S=1.55*R – 21.73 (R^2_{adj} = 0.85, p = 0.016, df = 3). Further discussion of the invertebrate community uses the dataset without rotifers and protists.

Species richness was not correlated with any measured environmental variables. While there was no statistically significant correlation between any of the chlorophyll fractions and species richness, high richness (when calculated with rotifers and protists) in 1999 and 2003 (Fig. 2a) was associated with the only invertebrate sampling occasions on which chlorophyll b and c concentrations (implying the presence of particular species of phytoplankton) were in excess of background levels (Appendix 1). Richness was not correlated with depth or salinity.This fits with the analyses of Pinder *et al.* (2005) that suggest richness in wheatbelt wetlands is not related to salinity below 2.6 g/L (= ~ 4000 µS/cm). Despite the lack of correlation between depth and richness across the dataset, the three lowest richness values (2001, 2007 and 2011) concided with the three lowest spring depths. This may indicate that the community was sampled earlier in the hydrological cycle and so the full community had not developed.

Invertebrate community composition

Lake Pleasant View invertebrate communities included seven of the invertebrate assemblages described by Pinder *et al.* (2004). Six or seven of these assemblages were present in all years except

2001 when only four assemblages were recorded. Species typical of freshwater swamps (assemblage A) and fresh to sub-saline wetlands (F) were equally species rich and accounted for the bulk of species present on all occasions. Insects with ubiquitous distributions and a range of salinity tolerances (cf. assemblage E) accounted for approximately 20% of species richness each year.

The pattern of community composition was very similar from year to year and was unaffected by the inclusion of rotifera and protists (except to increase species rchness). An ordination (NMDS) of invertebrate community composition (Fig. 3) indicates that the Lake Pleasant View fauna was most similar to marker wetland 9 ('freshwater sedge swamps') and remained so throughout the monitoring period. Community composition varied little, relative to the set of marker wetlands, and there is no evidence of a directional change in character of the wetland's fauna. The similarity between annual communities at Lake Pleasant View might seem surprising given the high proportion of species with a single occurrence. However, these comprised a similar proportion of richness (16-19%) in most years so they do not strongly influence the patterns revealed by the ordination, other than tending to spread the sites out from one another. The lower richness communities of 2001, 2007 and 2011 tended to group away from the communities sampled in other years, though with the 2001 community different to those sampled in 2007 and 2011.

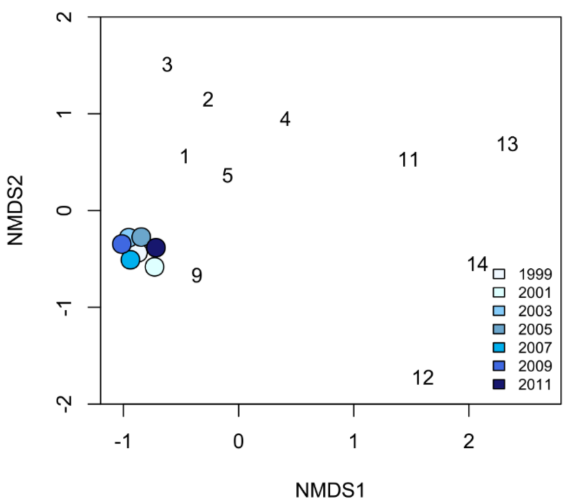

Figure 3. An ordination of spring invertebrate community composition (presence-absence) at Lake Pleasant View with 'marker' wetlands (see methods). For this ordination stress = 0.08. Marker wetland 1=fresh high richness, 2=subsaline sandy sump, 3=fresh, ephemeral wooded swamp, 4=naturally subsaline high richness, 5= secondary subsaline high richness, 9 = fresh sedge swamp, 11 =naturally saline in good condition, 12=naturally hypersaline ephemeral, 13=secondary hypersaline, 14=natural hypersaline basin.

a)

b)

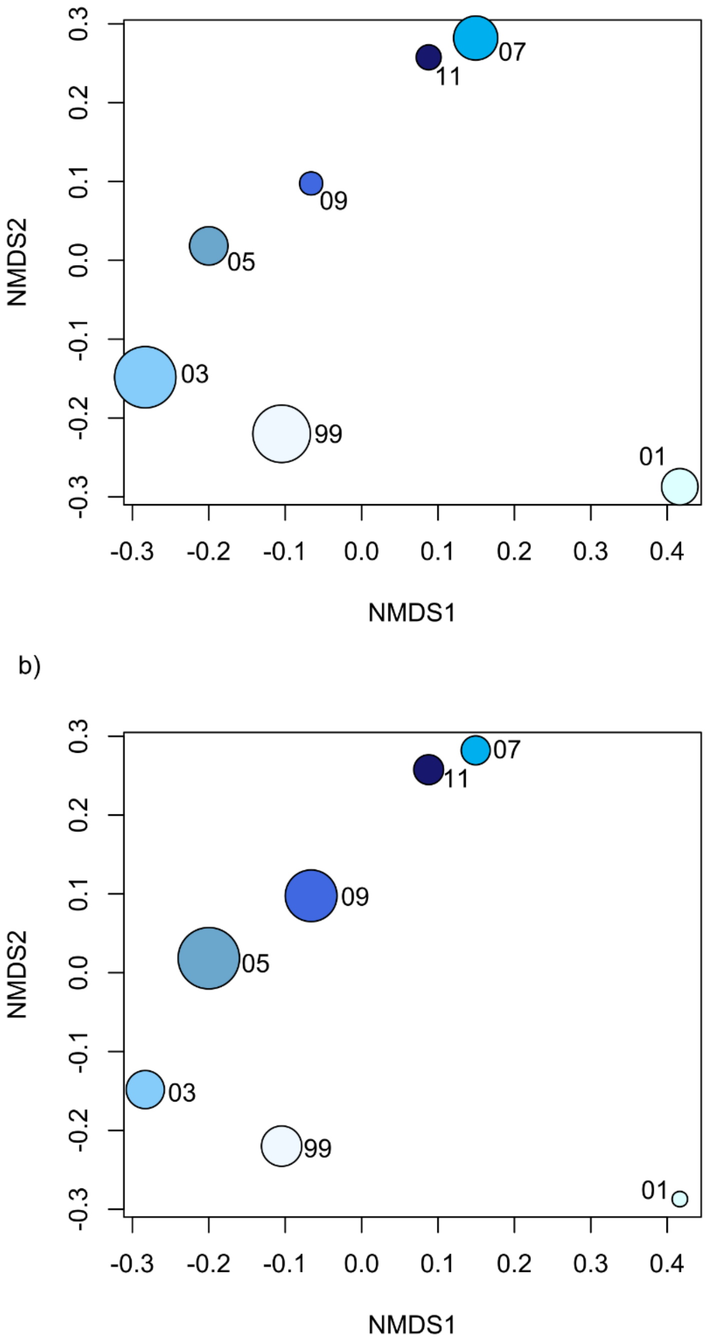

Figure 4 Ordination (NMDS) of Lake Pleasant View invertebrate communities in which point size is coded by: a) total chlorophyll concentration, and b) depth and shows the lack of correlation between community composition and these variables except at the variables' most extreme values.

A redundancy analysis did not identify any statistically significant constraining variables amongst the collected set of water chemistry variables. Consequently, the available data do not reveal any factors that are important in structuring the invertebrate community amongst years. Salinity and pH, which are typical structuring factors in wetland aquatic invertebrate communities, had a narrow range in spring

(516.5 to 1372.5 µS/cm and 6.66 to 7.66 respectively). It is likely that the observed variability of individual water chemistry variables represented an insufficient gradient to cause changes in community composition and that only extreme values crossed thresholds which resulted in changes in community composition in some years. For example, while depth and salinity were not correlated with community composition, the lowest and highest value respectively of each of these variables (0.35 m and 0.83 g/L) was associated with the single most disimilar community, i.e. that occuring in 2001 (Fig. 4b). Similarly, the highest values of total chlorophyll concentration were associated with communities of high richness in 1999 and 2003, grouped near the bottom left of Fig. 4a.

In summary, Lake Pleasant View suports a highly diverse invertebrate community which is relatively stable from year to year and which includes a number of rare and regionally endemic species. Despite high species turnover between years, communities remained similar because this turnover occured amongst a pool of species which either did not reoccur or occurred infrequently and which comprised a similar proportion of richness each year. There is some indication that depth, salinity and chlorophyll might have influenced richness and composition in some years, but these were not linear relationships and may be associated with the stage of the hydroperiod sampled. In general, physico-chemical variables that often affect community composition spanned a small range of values well within the tolerances of most aquatic invertebrates and probably did not influence invertebrtate communities directly.

Waterbirds

A total of nineteen species of waterbird were recorded. However, only 5 species were recorded in more than 50% of surveys. These core species were the purple swamphen, swamp harrier, little grassbird, musk duck and clamorous reed-warbler. The purple swamphen was the only species observed breeding and occurred with abundance between 1 and 27 birds (mean 6.26 $\pm$ 6.22). Abundance was generally low (<10 individuals) for all species, however in the 1999/2000 sampling year the purple swamphen maintained an abundance between 13 and 27 individuals and 61 and 21 Australian white ibis were recorded in autumn of 1999 and 2009 respectively. Abundance of some species, particularly bittern, swamphen, grassbirds and reed-warblers, was difficult to determine accurately because of the dense sedge vegetation.

Two species of particular conservation significance, Australasian bittern and chestnut teal, have previously been observed at Lake Pleasant View (e.g. Clarke *et al.*, 2011). The Australasian bittern was recorded in 8 surveys in this study, with abundance ranging from 1 to 4 birds, but chestnut teal were not observed during any surveys.

Australasian bittern were recorded in all years except 2001 when the lake had low water levels until autumn. Maximum lake depth (i.e. at the gauge plate) did not appear to influence the occurrence of bittern which were recorded from almost the full range of observed lake depths (i.e. 0.28 to 1.18 m). However, bittern were most frequently recorded in autumn (when lake depth was typically lowest) but were present in all surveys during 1999 and only in spring 2009. Higher occurrence in autumn may reflect an aggregation of birds in response to declining water levels in other suitable wetlands (e.g. Pickering, 2013), but in most years also coincided with an increased area of shallows for feeding. The maximum abundance of the species was 4 individuals in autumn 2008 with mean abundance of 2 across the 8 surveys in which it was present. Given an estimated southwest Australian population of 38 - 154 birds (Pickering, 2013) the maximum recorded abundance could represent between 2 and 10

% of the population of this species and highlights the conservation importance of Lake Pleasant View. While breeding was not observed the survey protocol is unlikely to locate nests of this cryptic species and breeding is known to have occurred during some monitoring years (e.g. December 2009 Clarke *et al.*, 2011).

Waterbird richness (Fig. 5) ranged from 1 to 11 species (mean 5.76 ± 2.40). Species richness increased with depth (rho = 0.50, df = 21, p = 0.02), but was not correlated with other measured environmental variables.

Eight feeding guilds were represented across the monitoring period indicating a functionally diverse waterbird community. Dabblers, reed specialist and large waders were the most species rich and reed specialist and shore feeding species of mixed diets were represented most often. Four to five guilds were present during most surveys. The number of feeding guilds present was correlated with water depth (rho = 0.63, df = 19, p < 0.01), a relationship likely to be driven by increased habitat diversity as more of the wetland basin is wetted.

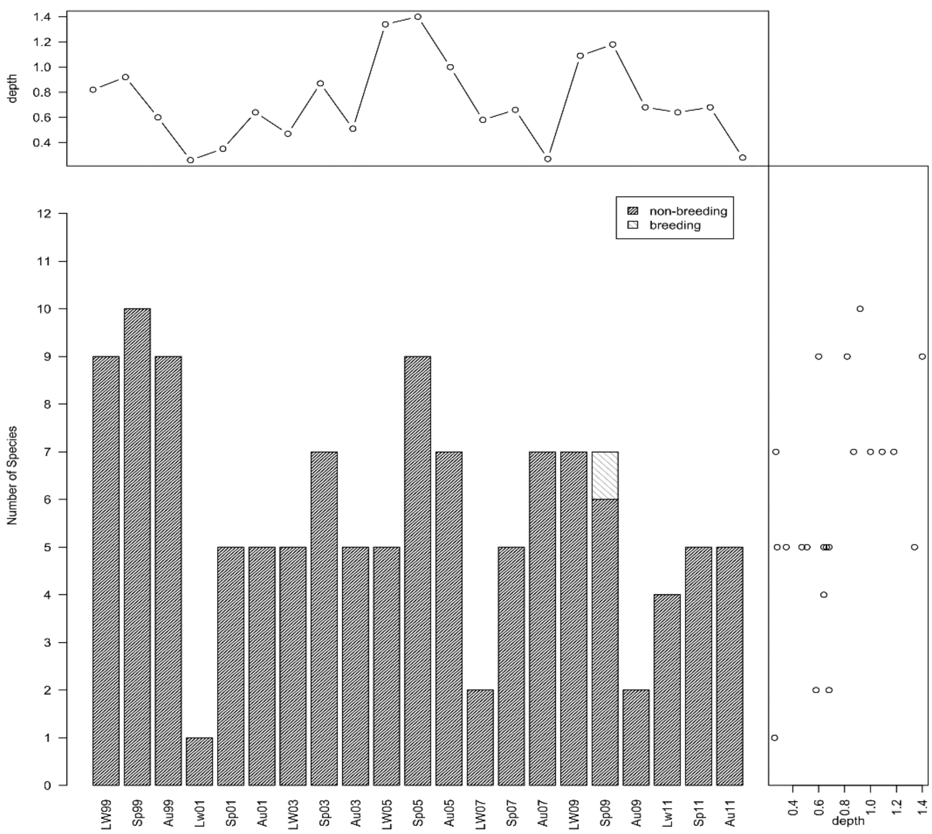

Figure 5 Waterbird species richness across the monitoring period

Annual waterbird composition (summed across all three surveys in a sampling year) varied little across the monitoring period. This is particularly apparent in an ordination (Fig. 6) of these data, where the dissimilarity between surveys from Lake Pleasant View and marker wetlands is orders of magnitude greater than between the surveys at Lake Pleasant View. This is a consequence of nearly all species encountered being recorded at some time each year. Historical data combined from three surveys (late-winter, spring and autumn) in 1983 (Jaensch *et al.*, 1988) lie within the envelope of the contemporary data, indicating no change in the lake's waterbird fauna over several decades.

There was greater variation amongst seasonal surveys than for the annualised data, as species were frequently not present in all seasons of a year. A redundancy analysis identified two significant constraining variables; log electrical conductivity (F=2.75, df=1,p=0.01) and log total filtered nitrogen (F=1.61, df=1,p=0.05). Together, these constrained only 16.5% of variation in composition to the first axis (RDA1) but this was statistically significant (F = 3.35, df = 1,p = 0.005). The second component (RDA2) was not statistically significant and constrained only 5% of the variance in composition. The constrained ordination (Fig.7) shows a small change in community composition, which is related to increasing salinity and TFN, primarily during autumn surveys. Remembering that depth and salinity were correlated and that salinity is low in this wetland (remains within the "fresh" category all year), increased salinity is probably a surrogate for reduced depth and reduced habitat diversity. In most years the relationship identified by the constrained ordination indicates a seasonal effect as increasing salinity and TFN, and decreasing depth, alter habitat availability in autumn compared to late-winter and spring. However, in autumn 2005 the seasonal decline in water depth did not occur. Depth and salinity remained similar throughout the year and yet the waterbird community was like that of other autumn surveys and distinct from the earlier spring and winter surveys, suggesting other seasonal pressures (for example regional waterbird movements) may also be important.

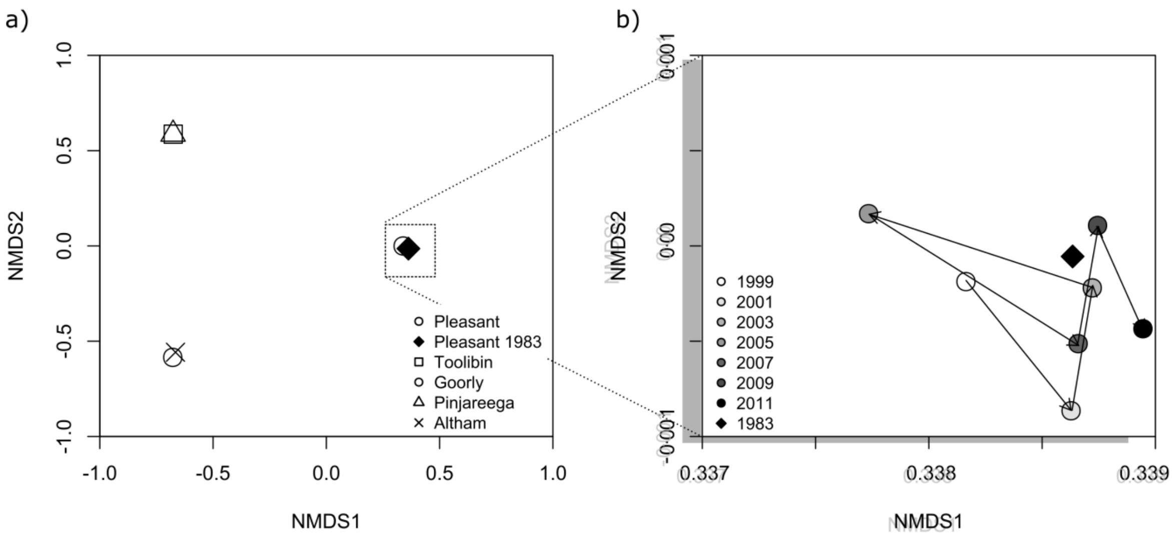

Figure 6. NMDS Ordination of annual waterbird species inventory compiled from late winter, spring and autumn surveys for each year (stress < 0.01). a) showing the Lake Pleasant View community in the context of 'Marker' wetlands (see methods) which reflect different wetland types as follows: Toolibin is subsaline with wooded overstorey, Goorly is shallow hypersaline playa, Pinjareega is secondarily saline open basin, Altham is a naturally saline basin wetland, b) the same ordination 'zoomed in' to the lake Pleasant View surveys, 1999 includes surveys from 1999/00, 2001 from 2001/02 etc.The closed diamond symbol is for historical data from three surveys in 1983 (Jaensch et al., 1988).

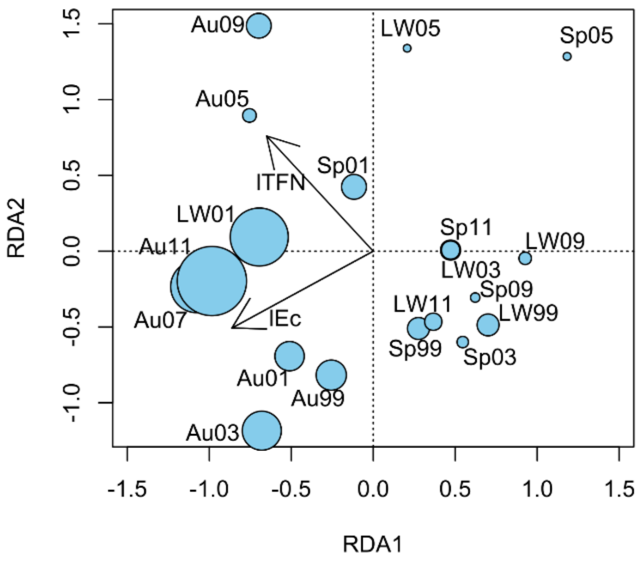

Figure 7 Constrained ordination of waterbird community composition for individual surveys at Lake Pleasant View. Seasonal surveys are labelled according to the monitoring year and season: LW =late-winter, Sp= spring, Au= autumn. Sample points are scaled by electrical conductivity. Significant vectors are: log total filtered nitrogen (lTFN) and log electrical conductivity (lEc)

In summary, the waterbird fauna at Lake Pleasant View is moderately diverse with 19 species, but all were of low abundance. The waterbird fauna is functionally diverse with a variety of feeding guilds present. However, many were represented by a single species reflecting the relatively small areas of habitats, such as open water, typically favoured by more speciose groups such as dabblers and divers.The composition of the community using the wetland each year is very similar and appears to have remained so for several decades. Changing composition through the year is most likely to be influenced by changes in habitat availability as lake depth declines over summer but other seasonal factors may also be important.

Lake Pleasant View is important for the globally endangered Australasian bittern which was recorded in most years during the study; and most frequently encountered in autumn. A maximum of 4 individuals were recorded which could be between 2 and 10 % of the southwest Australian population.

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Appendix 1. Depth and water chemistry data

Physico-chemical variables measured at Lake Pleasant View. In spring, values of pH, conductivity, temperature, oxygen, nutrients and photosynthetic pigments were measured at both site A and site B. The mean of these paired values were used in analyses. For other dates measurements were made at site A only.

Date	30/08/1999	24/10/1999	24/10/1999	21/03/2000	25/08/2001	24/10/2001	24/10/2001	28/03/2002	14/08/2003	24/10/2003	24/10/2003	27/03/2004	11/08/2005	27/10/2005	27/10/2005	25/03/2006	9/08/2007	25/10/2007	25/10/2007	2/04/2008	27/08/2009	29/10/2009	20/10/2009	24/03/2010	1/09/2011	22/10/2011	22/10/2011	29/03/2012
season	LW	Sp	Sp	Au	LW	Sp	Sp	Au	LW	Sp	Sp	Au	LW	Sp	Sp	Au	LW	Sp	Sp	Au	LW	Sp	Sp	Au	LW	Sp	Sp	Au
site	A	A	B	A	A	A	B	A	A	A	B	A	A	A	B	A	A	A	B	A	A	A	B	A	A	A	B	A
Depth (m)	0.82	0.92	0.92	0.6	0.26	0.35	0.35	0.64	0.47	0.87	0.87	0.51	1.34	1.4	1.4	1	0.58	0.66	0.66	0.27	1.09	1.18	1.18	0.68	0.64	0.68	0.68	0.28
Conductivity (µS/cm)	1210	1214	1214	1668	3200	1384	1361	1621	1100	1038	218	2155	418	483	382	747	963	1195	968	2870	683	682	351	1370	948	883	1121	3820
pH	6.89	6.65	6.67	7.16	6.69	7.75	6.87	7.1	7.45	6.18	6.98	7.76	7.81	6.82	7.16	6.71		8.9	-9999	7.54	6.99	6.71	6.66	7.57	6.5	7.53	7.79	7.63
TFN (µg/L)	1200	1100	1300	1200	1800	2500	3000	1500	1200	1100	1800	1500	2500	1600	2000	2800	2000	1700	2200	2100	1100	1000	2300	3600	930	1000	960	3200
TFP(µg/L)	5	5	5	5	5	20	10	10	5	5	10	5	20	20	20	20	20	10	90	10	5	5	20	5	5	5	5	5
Chlorophyll-a (µg/L)	0.5	0.5	0.5	2	5	0.5	1	0.5	1	4	0.5	7	1	4	1	0.5	0.5	0.5	0.5	4	1	0.5	0.5	5	0.5	1	0.5	2
Chlorophyll-b (µg/L)	1	2	1	2	3	0.5	0.5	0.5	0.5	1	0.5	2	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	0.5	0.5	2	0.5	0.5	0.5	0.5
Chlorophyll-c (µg/L)	0.5	2	2	4	0.5	0.5	0.5	0.5	0.5	2	0.5	2	1	0.5	0.5	0.5	3	0.5	0.5	1	0.5	0.5	0.5	2	0.5	0.5	0.5	0.5
Phaeophytin-a (µg/L)	6	2	3	0.5	2	1	3	1	0.5	0.5	5	0.5	0.5	0.5	0.5	0.5	3	6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Temperature (°C)	15.1	17.8	15.5	21.3	12.5	22.5	22	25.5	17.1	19.6	23.6	22.3	14.7	17.3	19	17.6		18.3	20.3	18.8	14.7	20.6	21.3	20.7	18.1	19.4	21.4	28.8
Dissolved Oxygen(%)	92	64.3	48.8	68	97	116.7	123.4	86.3	NA	NA	NA	NA	57.5	70.3	79.8	50.5		76.3	80.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
NO3 (mg/L)	0.01	0.01		0.01	0.005	0.005		0.005	0.03	0.01		0.01	0.01	0.01			0.01	0.005	0.01	0.07	0.005	0.005	0.01	0.01	0.005	0.005	0.005	0.005
Turbidity (NTU)		1.7				4.5				0.3				3.1				3.9				9.9				4.5		
Colour (TCU)		71				100				100				240				60				120				47		
TDS (g/L)		0.71				0.83				0.58				0.34				0.67				0.36				0.47		
Alkalinity (mg/L)		35				83				40				25				35				45				23		
Hardness (mg/L)		110				130				86				49				98				58				54		
Si (mg/L)		3				1.8				4				9.5				2.5				1.2				1.3		
Na (mg/L)		220				217				159				82.1				196				111				150		
Ca (mg/L)		10				18				10.2				5.6				9.1				5.3				0.05		
Mg (mg/L)		21				21				14.7				8.4				18.4				11				13		
K (mg/L)		13				22				12				9.3				15				14.7				12.7		
Mn (mg/L)		0.01				0.01				0.0005				0.002				0.0005				0.0005						
Cl (mg/L)		350				330				290				137				335				210				264		
HCO3 (mg/L)		43				101				49				31				43				55				28		
CO3 (mg/L)		1				1				1				1				0.5				0.5				0.5		
SO4 (mg/L)		7				31				9.4				8.7				5.5				6.9				14.2		
Iron(mg/L)		0.29				0.41				0.25				1.6				NA				NA				NA		
Tot Chlorophyll (µg/L)	8	6.5	6.5	8.5	10.5	2.5	5	2.5	2.5	7.5	6.5	11.5	3	5.5	2.5	2	7.5	7.5	2	6	2.5	2	2	9.5	2	2.5	2	3.5

Appendix 2. Aquatic invertebrate data

Lake Pleasant View invertebrate species matrix. Species in this log-class abundance 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	1999	2001	2003	2005	2007	2009	2011	occurrences
Protista	*Arcella discoides*	BP010102					1			1
	Arcella vulgaris	BP010106	1							1
	Arcella sp. c (SAP)	BP0101A3				1				1
	Arcella cf. polypora (SAP)	BP0101A6	1							1
	Difflugia gramen	BP030101					1			1
	Difflugia cf. *oblonga* (SAP)	BP0301A0	1							1
	Difflugia sp. d (SAP)	BP0301A4	1							1
	Nebela sp.	BP040199				1				1
(sponges)	Spongillidae	IA019999	1							1
Hydrazoa	*Hydra* sp.	IB010199		1		1	2	1	1	5
Temnocephala	*Zygopella* pista	IF410201						1		1
Turbellaria	Turbellaria	IF999999	1							1
Nemertini	Nemertini	IH999999	1			1				2
Nematoda	Nematoda	II999999	2	3	3	2	1	1	1	7
Rotifera	Philodinidae	JB049999	1							1
	Bdelloidea	JB999999		2			1			2
	Conochilus dossuarius	JF010106			1					1
	Lacinularia sp.	JF030799				1				1
	Testudinella patina	JF050201		1						1
	Testudinella insinuata	JF050202	1		1					2
	Testudinella amphora	JF050204	1		1	1				3
	Testudinella parva	JF050213		2						1
	Asplanchnopus multiceps	JP010201	1							1
	Asplanchnopus hyalinus	JP010202		1						1
	Brachionus angularis	JP020201			1					1
	Brachionus calyciflorus	JP020206	1				1			2
	Keratella javana	JP020306	2	2	1	2	2			5
	Keratella procurva	JP020308	2	1	1	2	2			5
	Platyias quadricornis	JP020601	2							1
	Lepadella biloba	JP030211			1	2				2
	Epiphanidae	JP059999			1					1
	Euchlanis dilatata	JP060101	2		1					2
	Lecane bulla	JP090110	3	3	1	2	2			5
	Lecane closterocerca	JP090112			1					1
	Lecane flexilis	JP090123		1						1
	Lecane ludwigii	JP090136	3	2	1					3
	Lecane lunaris	JP090138	2		1		1			3
	Lecane quadridentata	JP090154	2		1					2
	Lecane signifera	JP090159			1		1			2
	Lecane latissima	JP090174			1					1
	Lecane cf. *signifera* (SAP)	JP0901B5	2							1
	Mytilina ventralis	JP120108	1			2				2
	Lophocharis salpina	JP120203				1				1
	Cephalodella gibba	JP130201	1		1		1			3
	Monommata atices	JP130401	1							1
	Monommata dentata	JP130405	1		1					2
	Monommata maculata	JP130409	1	2	1		1			4
	Polyarthra dolichoptera	JP150201			1					1
	Synchaeta tremula	JP150301		1						1
	Trichocerca bicristata	JP160302	1							1
	Trichocerca longiseta	JP160320	1		1					2
	Trichocerca rattus	JP160328	1							1
	Trichocerca tigris	JP160336	1							1
	Trichocerca rattus carinata	JP160341			1					1
	Trichocerca chattoni	JP160342	1				1			2
	Trichocerca sp.	JP160399				2				1
	Trichocerca cf. *iernis* (SAP)	JP1603A3	1							1
	Trichocerca cf. *insignis* (SAP)	JP1603A4	1							1
	Trichotria tetractis similis	JP170202	1		1		1			3
	Scaridium cf. *bostjani* (SPM)	JP1801A0	1							1
	Scaridium sp. nov. (Pleasant View) (SAP)	JP1801A1		1	1					2
Mollusca	*Ferrissia petterdi*	KG060101	1		1	1	1	2		5
	Glyptophysa sp	KG070299	2	2	2	3	1	2	1	7
Annelida	Aeolosomatidae	LA019999							1	1

	TAXON	LowestIDNC	1999	2001	2003	2005	2007	2009	2011	occurrences
(leeches)	*Placobdelloides* sp.	LH010799	1				2			2
	Richardsonianidae sp. nov. (Pleasant View)	LH0399A0			1	1				2
(earthworms)	*Insulodrilus bifidus*	LO030503	1		2	1				3
	Naididae (ex Tubificidae)	LO049999	1		1					2
	Dero nivea	LO050202		1			1			2
	Dero furcata	LO050203	1	1			1			3
	Dero WA4 (cf. graveli)	LO0502A2				1				1
	Pristina longiseta	LO050501	1		2		1		1	4
	Pristina aequiseta	LO050502		1						1
	Pristina leidyi	LO050507		1						1
	Chaetogaster diaphanus	LO050702	1							1
	Ainudrilus nharna	LO052101		1						1
	Enchytraeidae	LO089999		1	1	1	1		1	5
Arachnida	*Hydrachna* sp. 1 (SAP)	MM0101A2			1					1
(water mites)	*Limnochares australica*	MM020101	2	2	2	2	2	2	2	7
	Eylais sp.	MM030199		1	1					2
	Hydryphantidae	MM059999			1					1
	Oxus sp.	MM090399	1		1			1	1	4
	Limnesia dentifera	MM120101					1			1
	Arrenurus australicus	MM230102			1	1	1		1	4
	Pezidae	MM259999	1				1			2
	Oribatida sp.	MM9999A1	2	1	2	2		2	1	6
	Mesostigmata	MM9999A2	1		1	1		1		4
	Trombidioidea	MM9999A6			1	1				2
	Arrenurus cf *glaucus*	XX000046						1		1
Cladocera	*Alona affinis*	OG030213	2		1	2				3
(water fleas)	*Alona setigera*	OG030214	1		1	1		4	3	5
	Alona guttata	OG030225	2							1
	Alonella clathratula	OG030301	2	3	1	1				4
	Camptocercus australis	OG030701			1	1		3		3
	Chydorus sp.	OG030999	2		1	3				3
	Euryalona orientalis	OG031401			1					1
	Graptoleberis testudinaria	OG031501	2		1	3				3
	Kurzia longirostris	OG031602						2	1	2
	Pleuroxus inermis	OG032502				2				1
	Armatalona macrocopa	OG033401	2			2				2
	Ceriodaphnia sp.	OG040199		3	1	2				3
	Scapholeberis kingi	OG040401	1		1			3	1	4
	Simocephalus exspinosus	OG040502			1	2				2
	Simocephalus elizabethae	OG040505	1		2	3	3	4	3	6
	Ilyocryptus spinifer	OG050105		3	1			3	2	4
	Macrothrix breviseta	OG060201	1		1				1	3
	Macrothrix indistincta	OG060211		3						1
Ostracoda	*Gomphodella* aff. *maia* (SAP)	OH0101A0	2	2		1		3	3	5
(seed	*Limnocythere porphyretica*	OH010204	1						2	2
shrimps)	*Candonopsis tenuis*	OH070101	2	1		1	2		3	5
	Alboa worooa	OH080101	2	2	1	3	3	4	3	7
	Bennelongia australis	OH080301	1		1	1		3		4
	Cypretta aff. *globosa*	OH0805A1	3		1	2		3	2	5
	Reticypris walbu	OH081505	1							1
	Ilyodromus sp.	OH081999			1			3	2	3
	Cypricercus sp. 415 'not humped'	OH0821B4	3	1	1	2		3		5
	Lacrimicypris kumbar	OH082501	2	2	2	2	1	4	2	7
	Sarscypridopsis aculeata	OH090101				2				1
	Newnhamia fenestrata	OH110101	1	2	1	2	2	1		6
	Newnhamia sp. FC (south-west SAP)	OH1101A1					1			1
	Kennethia cristata	OH110201	3	2	2	2	3	3	4	7
Copepoda	*Boeckella triarticulata*	OJ110101			1					1
	Calamoecia attenuata	OJ110203	2	3	3	3	3	4	4	7
	Calamoecia tasmanica subattenuata	OJ110211	2	3	2	2	2	3	3	7
	Microcyclops varicans	OJ310101	2	3	2					3
	Australocyclops australis	OJ310301		1						1
	Macrocyclops albidus	OJ310601	3		2	2	1	4	3	6
	Mesocyclops brooksi	OJ310703	3	3	2	3	2	4	3	7
	Paracyclops sp 1 (SAP)	OJ3111A1						3		1
	Canthocamptus australicus	OJ610101	1							1
	Australocamptus sp. 5 (SAP)	OJ6199A4		2		1				2
	Harpacticoida sp. 2 (SAP)	OJ6999B0	1	1						2
Amphipoda	*Austrochiltonia subtenuis*	OP020102	2	3	3	3	3	4	4	7
	Perthia sp.	OP080199	2	1	2	3	2	3	3	7
Decapoda	*Cherax preissii*	OV010113		1	1					2
	Cherax quinquecarinatus	OV010116	1						1	2
Coleoptera	*Haliplus* sp.	QC060199	1							1

	TAXON	LowestIDNC	1999	2001	2003	2005	2007	2009	2011	occurrences
(beetles)	*Hygrobia* sp.(wattsi)	QC070199	1	1	1	1		2		5
	Uvarus pictipes	QC090701	1	1	2			1		4
	Limbodessus inornatus	QC091006				1		1		2
	Allodessus bistrigatus	QC091101	1							1
	Antiporus sp.	QC091699		1		1				2
	Sternopriscus browni	QC091809	1		1					2
	Sternopriscus storeyi	QC091818				1		2	2	3
	Sternopriscus wattsi	QC091819				1				1
	Megaporus howitti	QC092103	2	1						2
	Megaporus solidus	QC092107	1		1	1	1	2		5
	Rhantus suturalis	QC092301	1			1		1		3
	Lancetes lanceolatus	QC092401	1				1		1	3
	Spencerhydrus pulchellus	QC093302	1		1	1	1	1	1	6
	Onychohydrus scutellaris	QC093401			1					1
	Berosus approximans	QC110404						1		1
	Enochrus eyrensis	QC111102	1	2	2			1	1	5
	Limnoxenus zelandicus	QC111401	1	1	2	1	1			5
	Paracymus pygmaeus	QC111601	1	1	1			1		4
	Hydrophilus sp.	QC111899			1					1
	Sternolophus sp.	QC111999				1				1
	Hydraena cygnus	QC130116			1	1		1		3
	Scirtidae sp.	QC209999	2	2	2	1	2	2	1	7
	Limnichidae	QC359999		1						1
	Hydrochus australis	QCA00106			1					1
Diptera	Tipulidae type C (SAP)	QD0199A2			1					1
(flies, midges,	Tipulidae type F (SAP)	QD0199A5			1					1
mosquitoes)	*Anopheles annulipes* s.l.	QD070101			1					1
	Aedes alboannulotus	QD070501	1	1						2
	Culex pipiens molestus	QD070701		1						1
	Culex latus	QD070707	1		1			2		3
	Culex (*Neoculex*) sp. 1 (SAP)	QD0707A0	1							1
	Coquillettidia linealis	QD070801	1				1	2	1	4
	Bezzia sp.	QD090499	1	1	2	1	1	1	1	7
	Clinohelea sp.	QD090699	1	1						2
	Culicoides sp.	QD090899		1					1	2
	Tabanidae	QD239999	1							1
	Stratiomyidae	QD249999						1		1
	Empididae	QD359999		1			1			2
	Sciomyzidae	QD459999			1					1
	Ephydridae sp. 5 (SAP)	QD7899A9					1	1	1	3
	Procladius paludicola	QDAE0803	2			2				2
	Procladius sp. (normal claws)	QDAE08A2					1		3	2
	Alotanypus dalyupensis	QDAE1001					1	3		2
	Ablabesmyia notabilis	QDAE1102	1		2					2
	Paramerina levidensis	QDAE1201	2	2	2	3	2	4	3	7
	Pentaneurini genus C	QDAE99B8			2		1	3	2	4
	Corynoneura sp. (V49) (SAP)	QDAF06A2	2		1		1		1	4
	Paralimnophyes pullulus (V42)	QDAF1202		2		1	1	3	3	5
	Cricotopus 'brevicornis'	QDAF15A1				1				1
	Compterosmittia sp. A (SAP)	QDAF19A0	2		1					2
	Limnophyes vestitus (V41)	QDAF2801	2	1						2
	Tanytarsus bispinosus	QDAH0405	2	2	2	2	2	3	3	7
	Chironomus occidentalis	QDAI0408	2		2			2		3
	Chironomus tepperi	QDAI0414				2				1
	Chironomus aff. *alternans* (V24)	QDAI04A0			1	2		4		3
	Dicrotendipes conjunctus	QDAI0603	2		1	3	1	3		5
	Dicrotendipes sp. A (V47) (SAP)	QDAI06A0						3		1
	Polypedilum nr. *convexum* (SAP)	QDAI08A2			1					1
	Cryptochironomus aff *griseidorsum*	QDAI19A0							1	1
	Cladopelma curtivalva	QDAI2201	2	1	1	2	2	3	2	7
	Parachironomus sp. 1 (VSCL35)	QDAI25A0	1		2	2			1	4
Ephemeroptera	*Cloeon* sp.	QE020299	1							1
Hemiptera	*Mesovelia horvathi*	QH520104						1		1
(waterbugs)	*Hydrometra strigosa*	QH540106						1		1
	Hydrometra sp.	QH540199	1							1
	Microvelia sp.	QH560199	2	1	1	1		2		5
	Saldula sp.	QH600299	1							1
	Diaprepocoris barycephala	QH650101						1		1
	Diaprepocoris personata	QH650102			2	1				2
	Sigara sp.	QH650299				1		2		2
	Micronecta sp.	QH650599		1			1			2
	Notonecta handlirschi	QH670201				1	1	2	1	4
	Anisops hyperion	QH670402	1							1
	Anisops elstoni	QH670407	1		2	2	1	2		5
	Paranisops endymion	QH670502	1							1

	TAXON	LowestIDNC	1999	2001	2003	2005	2007	2009	2011	occurrences
	Paraplea brunni	QH680101	1							1
Lepidoptera	Lepidoptera sp. 15 (SAP)	QL9999A6				1				1
Odonata	*Austroagrion cyane*	QO020501	2							1
(dragonflies,	*Ischnura heterosticta heterosticta*	QO021002				3				1
damselflies)	*Xanthagrion erythroneurum*	QO021301					1	2	1	3
	Austrolestes analis	QO050101	1	1		1	1	1	1	6
	Austrolestes annulosus	QO050102	2		2	2	2	2	2	6
	Austrolestes aridus	QO050103		3						1
	Austrolestes io	QO050105						1		1
	Austrolestes aleison	QO050108	1				1			2
	Adversaeschna brevistyla	QO120201	2	2	1			2		4
	Hemianax papuensis	QO121201				1	1		1	3
	Austrothemis nigrescens	QO170301	2		1	2	2	1	2	6
	Diplacodes bipunctata	QO170701			2					1
	Orthetrum caledonicum	QO171601			1					1
	Procordulia affinis	QO300202	1	1						2
Trichoptera	*Hellyethira litua*	QT030410	2	1	2	2	2	2	2	7
(caddisflies)	*Ecnomina* E group	QT080299			1					1
	Ecnomina F group sp. AV18	QT0803A2	1		1					2
	Ecnomina F group sp. AV16	QT0803A3	1		1		1	2	1	5
	Ecnomina F group sp. AV20	QT0803A4	1	1						2
	Ecnomus pansus/turgidus	QT0804A0					1	1	1	3
	Notoperata tenax	QT250605	1	1			1	2	1	5
	Oecetis sp.	QT250799	1					1		2

Appendix 3. Waterbird data

Abundance of species for each seasonal survey at Lake Pleasant View.

		30/08/1999	24/10/1999	21/03/2000	25/08/2001	24/10/2001	28/03/2002	14/08/2003	24/10/2003	27/03/2004	11/08/2005	27/10/2005	25/03/2006	9/08/2007	25/10/2007	2/04/2008	27/08/2009	29/10/2009	24/03/2010	1/09/2011	22/10/2011	29/03/2012
Purple Swamphen (southern)	*Porphyrio porphyrio*	13	14	27		1	2	2	6	5	5	5	5	6	1	5	8	3	8	2	1	3
Swamp Harrier	*Circus approximans*	2	1	1	1	2	1	1	1	1	2	1			2		1	1		2	1	1
Little Grassbird	*Megalurus gramineus*	2	7	10		5		4	3		3	2		3	5	2	11	4	2		3	5
Musk Duck	*Biziura lobata*	9	3	1		2	1	1	1		4	5			1		2	3		1	1	
Clamorous Reed-Warbler	*Acrocephalus australis*	2	4					2	2	1		5	2		1	2	2	3		1	1	
Australasian Bittern	*Botaurus poiciloptilus*	1	2	2						3			2			4		1				1
Pacific Black Duck	*Anas superciliosa*	7		2					6			2					3	2				
White-faced Heron	*Ardea novaehollandiae*		2	1		1	3						2			3						
Australian White Ibis	*Threskiornis molucca*			61			7		1	9						1						21
Australian Shelduck	*Tadorna tadornoides*	4	2										2									
Grey Teal	*Anas gracilis*										2	2										
Yellow-billed Spoonbill	*Platalea flavipes*		1									1										
Australasian Shoveler	*Anas rhynchotis*																2					
Baillon's Crake	*Porzana pusilla*		1																			
Dusky Moorhen	*Gallinula tenebrosa*	1																				
Hardhead	*Aythya australis*											5										
Little Pied Cormorant	*Phalacrocorax melanoleucos*												1									
Spotless Crake	*Porzana tabuensis*			5																		
Straw-necked Ibis	*Threskiornis spinicollis*												6									
Unidentified wader																3						

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

Group	Name	Code	Richness	Salinity (ppt)	Group description
					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
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