A comparison of waterbird and invertebrate communities present following summer rainfall events in 2006 and 2012, in wetlands of the Lake Bryde Natural Diversity Recovery Catchment.

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Department of Environment and Conservation
Our environment, our future

Executive Summary

A summer rainfall event in 2006 resulted in widespread filling of Lake Bryde and other wetlands of the Lakelands Nature Reserve chain. This first event occurred before completion of a waterway designed to prevent the accumulation of surface runoff at Lake Bryde and direct it into downstream wetlands. To assess the responses of invertebrate and water bird communities to this significant hydrological event, these fauna were documented on 4 dates between March 2006 and March 2007. A second filling event occurred during summer in 2012 after completion of the waterway. Invertebrates were sampled and waterbirds surveyed on 6th and 7th of February 2012 after a similar post-filling time period as occurred prior to sampling in March 2006. This report aims to compare the waterbird and invertebrate fauna of the two filling events and identify issues affecting these faunas which may arise from the function of the waterway.

The smaller rainfall event of 2012 did not result in the same depths throughout the wetland chain as was observed in March 2006. Consequently water chemistry (particularly salinity) and water depth were different between sampling dates. The waterway probably resulted in more water in Termination Lakes 5 and 6 and less in Termination Lake 1 than would have otherwise occurred. In Termination Lake 1, lowering of the lake outlet reduced water residence time and resulted in lower salinities due to flushing of salt loads.

The number of waterbird broods observed was higher in 2012 compared to 2006, although most were observed on Lake Bryde. Termination Lake 5 did not support breeding, whereas breeding was observed on this lake in March 2006. While breeding was supported by increased abundance of invertebrates in 2012 most of the observed pattern is explained by either reduced breeding habitat (Termination Lake 5) or increased visibility while sampling (Lake Bryde) both as a result of lower water depths. The data do not suggest that the waterway had an effect on the overall extent of waterbird breeding.

The abundance of waterbirds during 2012 was similar (Intermediate Termination Lake 1 and Termination Lake 1) or higher (Lake Bryde, Termination Lake 5) than observed in March 2006. Waterbird species richness was greater in 2012 than immediately after filling in March 2006 except at Termination Lake 1. At this wetland, richness was only one half that recorded in 2006. There is no clear evidence for a causal relationship between this lower richness and the environmental parameters, except that low lake depth may have resulted in an absence of the diver feeding guild.

Waterbird community structure was similar when data from 2012 were compared with data from similar depths and salinities on sampling dates during the 2006 hydroperiod.

Invertebrate species richness was dominated by species of assemblage E (of Pinder *et al*. 2004) in both 2006 and 2012 and across all wetlands. Members of

this assemblage are ubiquitous, predominantly insects and tolerant of sub-saline conditions. Lake Bryde supported slightly less richnesss in 2012 and Termination Lake 1 supported higher richness than previously recorded. Invertebrate species richness and abundance were influenced by salinity. Community composition may have been more dependent on development times following filling at Lake Bryde and on colonisation from the available local species pool at wetlands downstream of Lake Bryde.

The main observable effect of the waterway was an increased volume of water into downstream wetlands than would otherwise be expected given the magnitude of the filling event. Lowering of the outlet height in Termination Lake 1 resulted in flushing of salt from this wetland and contributed to a greater depth in Termination Lake 5 and a possible increase in salt load. Termination Lake 1 supported a diverse (although salt tolerant) invertebrate fauna but waterbird species richness was reduced. Reduced depth in this wetland would have shortened the time both waterbird and invertebrate communities could persist. Termination Lake 5 supported similar waterbird and invertebrate communities after both filling events despite slightly higher salinity in 2012.

Introduction

The Lake Bryde Natural Diversity Recovery Catchment was established in 1999 as one of a series of catchments managed by the Department of Environment and Conservation (Wallace 2001). The Recovery Catchment includes many fresh and naturally saline wetlands and lies in the headwaters of the Lockhart catchment, a sub-catchment of the Swan-Avon basin. The catchment and surface water flows through it have been described and analysed by Farmer *et al.* (2002).

Lake Bryde is a focal point of the Recovery Catchment and is threatened by the increasing salinity of surface runoff from the wider catchment. Farmer *et al.* (2002) identified that increased runoff had occurred because of land clearing in the catchment and at valley floor sites where it accumulated it resulted in increased salinity, the later mobilisation of which would likely affect wetlands. Downstream of Lake Bryde an extensive drainage system has been constructed, forming a waterway designed to prevent water accumulating in the vicinity of Lake Bryde. The waterway directs surface runoff into a series of wetlands downstream of Lake Bryde.

Farmer *et al.* (2002) also noted that surface flows were impeded by Lake Bryde Road upstream of the inlet to Lake Bryde. The resulting accumulation of water was causing severe salinisation at this locality with potential impacts on the quality of inflow to Lake Bryde.

In January 2006, before the waterway was completed, a high rainfall event across the South-west land division resulted in the flooding of valley floors and the associated wetland chains throughout the Lake Bryde Recovery Catchment. This event provided an opportunity to collect baseline data for water chemistry, aquatic invertebrates and waterbirds in selected wetlands under high water level (and low salinity) conditions (Cale 2007). Several of the Lake Bryde catchment wetlands were sampled on four occasions over 12 months. This study indicated that under low salinity the wetlands supported a diverse aquatic invertebrate fauna and in Lake Bryde many species were recorded for the first time despite a history of monitoring. In 2012, after the completion of the waterway, a similar event occurred which enabled the collection of similar data (on 6-7 February) for comparison against the baseline data.

This report presents results for aquatic invertebrate sampling and waterbird surveys conducted following the 2012 rainfall event and compares them with the 2006/7 data in order to a) increase our understanding of the species composition and diversity of invertebrates and waterbirds in the wetland chain in relation to environmental conditions, and b) identify issues which may link the functioning of the waterway and the waterbird and invertebrate faunas supported by the wetland chain.

Methods

Sampling Protocol

The original seven wetlands (Appendix 1) were surveyed in March 2006 (20-22/3/2006), October 2006 (30-31/10/2006 and 1/11/2006) and in March 2007 (20-21/3/2007). At each wetland, data were collected for water chemistry, waterbirds and aquatic invertebrates. In 2012 only four of these wetlands retained water by the February 2012 (6-7/2/2012) sampling date. Lake Bryde lies immediately above the waterway, while Termination Lakes 1 and 5 and intermediate Termination Lake 1 lie in the path of the waterway (See map in Appendix 1 for relative location of wetlands). An additional wetland; Termination Lake 6 was added to the survey in February 2012 and lies at the most downstream end of the wetland chain but is not connected by the waterway.

The sampling protocol has been described in detail elsewhere (Cale *et al.* 2004), and was consistent across all sampling dates. Additional data for Lake Bryde were used in some analyses. These were collected between 1997 and 2007, using the same sampling protocols, as part of the State Salinity Strategy Wetland Monitoring Program (Cale *et al*., 2004).

Waterbirds were surveyed on each occasion using binoculars and spotting scope to identify all species, count all individuals and count the number of broods of breeding species. No attempt was made to search for nests; consequently breeding records are likely to be an underestimate, at least of numbers and possibly of breeding species. In 2006, a boat was used to gain better access to all parts of the larger wetlands (e.g. Bryde and East Lake Bryde). On smaller wetlands the wetted perimeter of the lake was traversed on foot. There was insufficient water to require the use of a boat in 2012.

A list of the parameters measured to elucidate wetland water chemistry is provided in Appendix 2. These parameters were measured at each wetland on each sampling occasion. At Lake Bryde, the depth gauge maintained by the South-west Wetlands Monitoring Program (Lane *et al.* 2009) was used to record depth. At Termination Lake 1 a depth gauge maintained by DEC staff (Natural Resources Branch) was used. In other wetlands maximum depth was estimated by frequent measurements with a graduated staff while collecting invertebrate samples. Depth at Lake Bryde was also recorded continuously using an SPE capacitance probe and data logger (http://www.speloggers.com.au). Counts from this data logger were transformed (*post hoc*) using a simple linear regression against recordings at the depth gauge. Field measurement of pH, electrical conductivity and temperature were made using a WTW 340i Multimeter. Water samples for the laboratory determination of other parameters were collected in acid washed bottles and either frozen or refrigerated until transported to The Chemistry Centre (WA) for processing. Water samples for total nitrogen and phosphorus were filtered through 0.45μm filters prior to freezing and chlorophyll samples were collected by filtering known volumes through Whatman glass microfibre filter papers.

Invertebrate samples were collected and processed as previously (Cale *et al.* 2004, Cale 2007). However, Rotifera were not identified during the 2012 sampling and were consequently dropped from the dataset for other dates to maintain comparable species lists over time. Abundance of invertebrates was estimated during sample processing using $\log_{10}$ class intervals, i.e. 1-10 individuals is log class 1, 11-100 = 2, etc. For comparison between samples total abundance was calculated as the sum of the frequency in each class interval multiplied by the intervals lower value.

<u>Analysis</u>
Ordination and classification were used to compare species assemblages across sites and seasons. Ordinations were carried out using the non parametric multidimensional scaling (nMDS) algorithm provided in the vegan package (version 1.15, Oksanen *et al.* 2009) for the r statistical environment (R Development Core Team 2009). Presence-absence data and Bray-Curtis association measures were used without scaling or centring for both ordination and classification analyses. Classification analysis was performed using the Un-weighted Pair Group Mean Averaging (UPGMA) algorithm provided by *hclust* from the standard R libraries. Water chemistry parameters were compared between seasons and sites using UPGMA classification and Euclidean distance. Depth data were scaled within site (effectively yielding a proportion of maximum recorded depth for the site), remaining parameters were not scaled.

Results
<u>Water chemistry</u>
The rainfall event triggering this study filled Lake Bryde from empty to a depth of 0.112 m in 24 hours on December 7th 2011. Further inflow, resulted in a peak depth of 0.820 m on December 20th (Fig. 1). Rainfall data (Fig 1a) for the Newdegate Research Station (Station 10692, BOM 2012) indicate that in 2006 Lake Bryde and the wetland chain may have filled more rapidly following 88 mm of rainfall (this may have been substantially higher at Lake Bryde; K. Hemmings pers. com.) on January 13th. A depth of 1.82 m was recorded for Lake Bryde in March 2006 two months after filling would have commenced.

Depth in Lake Bryde was 0.58m when sampling was conducted from 6-7th February 2012. At this time, Lake Bryde was shallower, more saline, had more alkaline pH and higher turbidity than was recorded in March 2006 (when depth was 1.82 m) after the filling event that year. Depth recorded at Lake Bryde in February 2012 was similar to that recorded in March 2007 (0.61m), 14 months after filling (Fig2 d). This pattern contrasts with the depth at other wetlands in the chain (Fig. 2a-c). Depth in Termination Lake 5 (T5) in February 2012 was estimated to be equivalent to the value recorded after filling in March 2006, however the exposure of *Melaleuca* trunks (inundated in 2006) on the west shore suggest that depth was slightly lower. During 2012 depth at Intermediate Termination Lake 1 (ITL1) was lower than in March 2006, immediately following filling, but higher than sampling dates later in that hydroperiod. Termination Lake 1 (T1) was shallower and more saline in 2012 than on all previous occasions despite the relatively greater depths observed downstream at TL5 and upstream at ITL1. Termination Lake 6 (T6) was not sampled in 2006. In 2012 T6 was shallow (0.25 m estimated) and showed signs (senescent algal growth and a strand line of the valves of concostrachan crustacea) of having reached at least twice this depth.

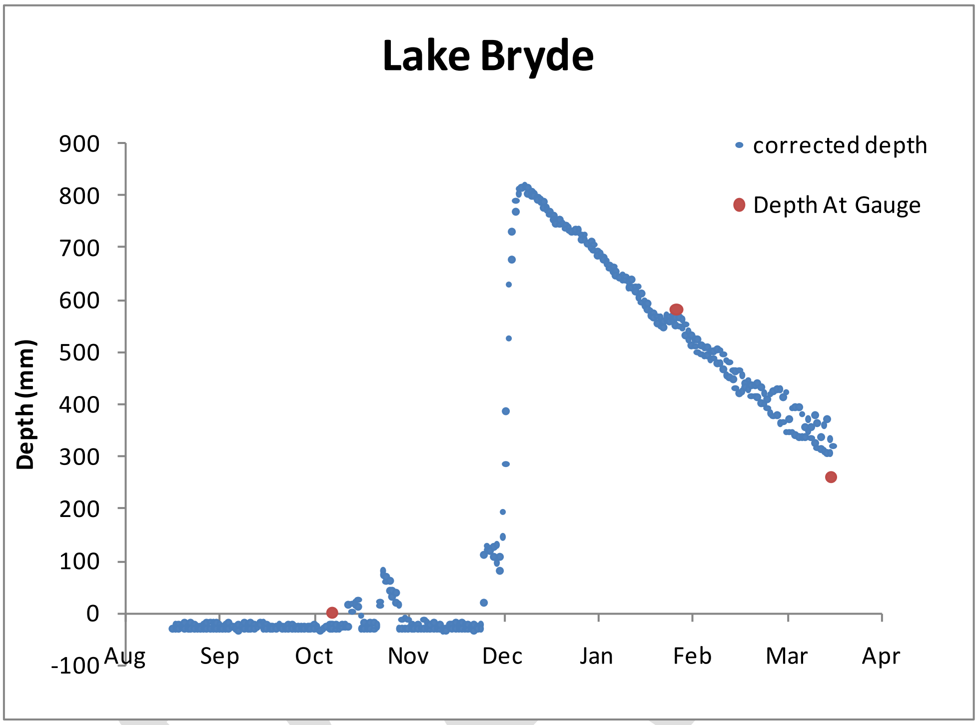

Figure 1 Depth at Lake Bryde recorded by the SPE data logger. Corrected depth has been transformed using a simple linear regression to calibrate logger values against depth gauge readings *post hoc*.

Salinity in Lake Bryde was fresh to brackish (*sensu* Pinder *et al.* 2005, <3 g/L) with a range 0.37 – 2.3 g/L over all 2006/7 and 2012 sampling occasions, but was higher in February 2012 than in March 2006 (Fig 2d). Salinity was lower in 2012 than at a similar depth in March 2007; compare 1.2 g/L salinity at 0.58 m depth in February 2012 with 2.3 g/L in March 2007 at a depth of 0.61 m. This comparison suggests a relatively lower salt load in the wetland in 2012.

Downstream of Lake Bryde all wetlands were sub-saline (*sensu* Pinder *et al.* 2005; 3 – 10 g/L) after filling in March 2006 and February 2012. In October 2006 and March 2007; T5, T1 and ITL1 were saline (i.e. > 10 g/L). In 2012 salinity was higher in all downstream wetlands compared to March 2006. A comparison of salinity at similar depths in order to estimate relative salt load cannot be made for these wetlands because depths were either estimates (T5 Fig 2a) or not comparable (ITL1, T1 Fig. 2b-c). However, T1 had a lower salinity at a lower depth in February 2012 than was recorded in October 2006 (Fig 2b) suggesting that the salt load was lower at this wetland in 2012. In both March and October 2006 there was a trend of decreasing salinity moving downstream through the wetland chain from ITL1. In February 2012, ITL1 had comparatively lower salinity than other wetlands in the chain and the trend of decreasing salinity only held downstream of T1.

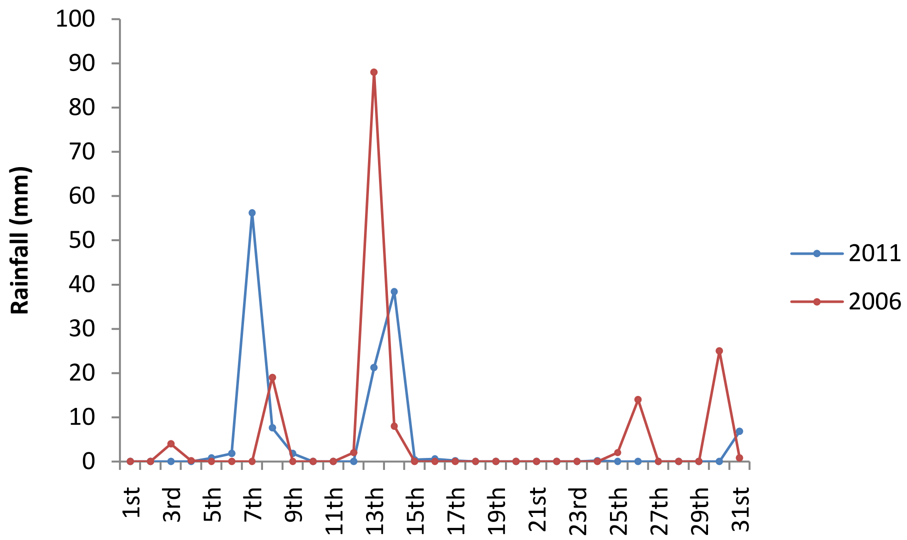

Figure 1 Daily rainfall data for January 2006 and December 2011 at the Newdegate Research Station (station 10692) approx 27 km north of Lake Bryde (Bureau of Meteorology 2012).

Field measurement of pH (Table 1) indicated slightly more alkaline conditions in Lake Bryde in February 2012 (8.33) than in March 2006 (7.81), however the difference was substantially less than the peak pH of 10.35 observed in October 2006. All wetlands surveyed had alkaline pH but only T5 was as variable as Lake Bryde and experienced a similar increase in alkalinity (to 9.24) in October 2006.

Turbidity was higher in Lake Bryde in February 2012 than on any previous occasion (Table 1) and coupled with increased 'colour' resulted in much lower water clarity than has been observed during monitoring of Lake Bryde since 1997 (DEC unpublished data).

In 2012, nutrient levels, i.e. concentrations of dissolved nitrogen and phosphorus, were lower at all wetlands, except Lake Bryde, than following the filling of wetlands in March 2006. At Lake Bryde, nitrogen concentrations were higher (2700µg/L compared to 2100µg/L) in 2012 and while phosphorus concentrations were lower than in March 2006 they were higher than other occasions following lake filling in 2006. The nutrient sampling protocol filters water samples to determine the concentration of nutrients available for further biological processes. This makes the data unreliable for gauging the extent of nutrient enrichment where nutrients are incorporated in primary production or adsorbed to sediments.

The pattern of nutrient concentration across the wetland chain was mirrored in the concentration of photosynthetic pigments (Chlorophyll and phaeophytin are measured as an analogue of primary productivity). That is, all wetlands except Lake Bryde displayed lower concentrations of photosynthetic pigments in 2012 than in March 2006. In Lake Bryde the concentration of photosynthetic pigments was higher than recorded at any time following the filling event of 2006.

A classification (UPGMA) of all site/dates based on water chemistry (Fig 3) reveals that, despite the differences detailed above, Lake Bryde samples were more similar to each other in February 2012 and March 2006 than to other wetlands or to Lake Bryde samples from October 2006 or March 2007.

A full listing of values for all measured water chemistry variables is given in Table 1.

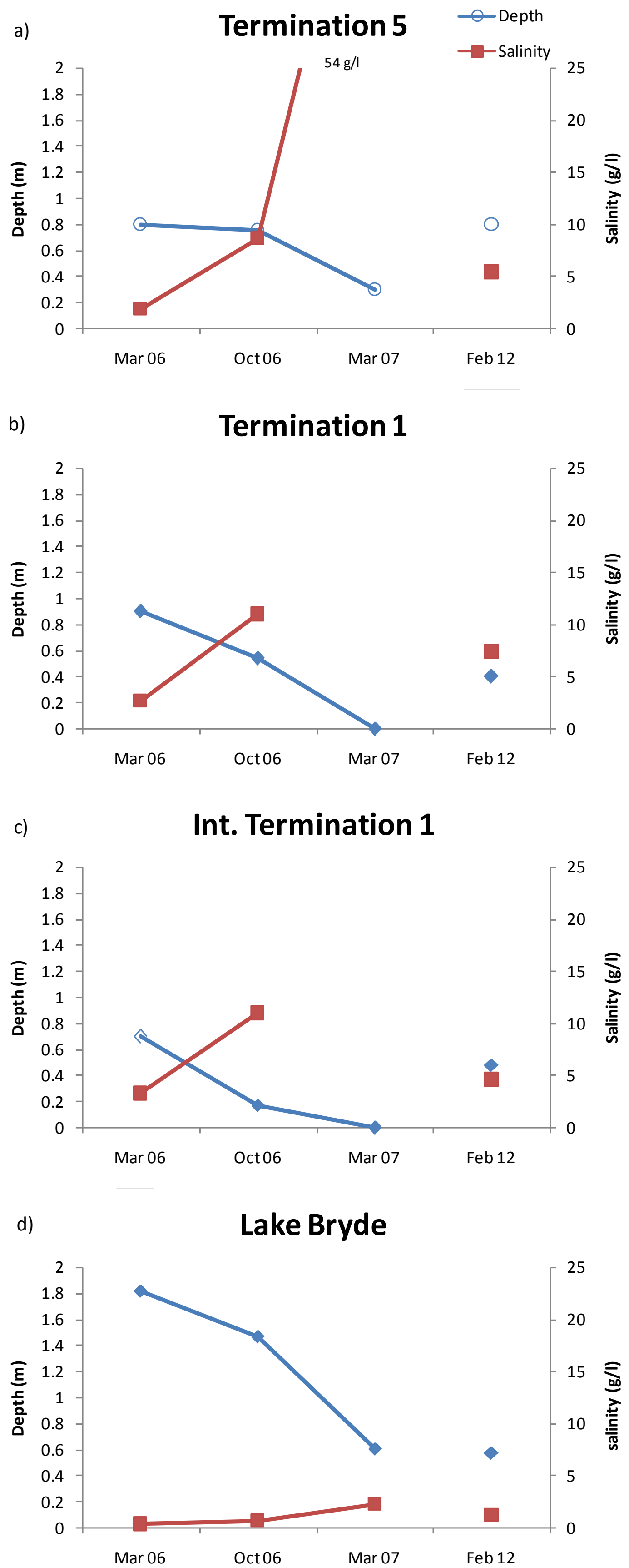

Figure 2 a-d Depth and salinity for the four wetlands with 2006 and 2012 data. Figures are ordered with the most downstream at the top of the page, open symbols indicate depth was estimated.

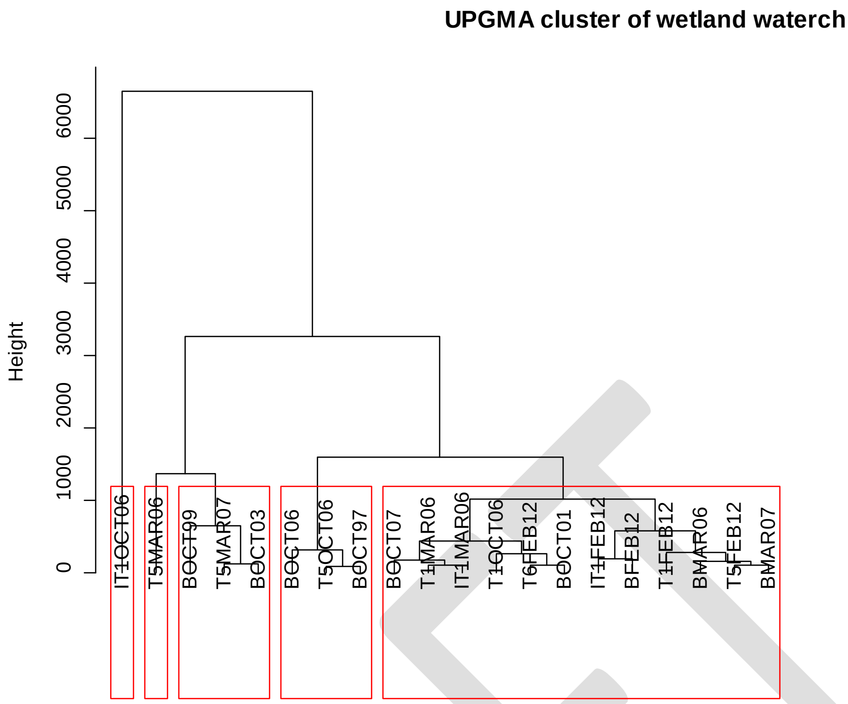

Figure 3 UPGMA classification of sites based on similarity (Euclidean distance) of water chemistry. Water chemistry from Table 1 with chlorophyll fractions summed, depth range standardised within site and TDS dropped.

<u>Waterbirds</u>

A total of 15 waterbird species (Table 2) were recorded from the study sites in 2012. All of these species had been recorded in previous years; however two species, Australian shelduck and Australian white ibis, were not recorded in March 2006. Four species (blue-billed duck, little grassbird, red-kneed dotterel and straw-necked ibis) were recorded with low abundance during March 2006 but not recorded at all in 2012. At Lake Bryde species richness and total abundance were higher in 2012 than in March 2006 and a greater number of broods were recorded.

In 2012, breeding was recorded for three species; grey teal, Pacific black duck and hoary-headed grebe with a total of 26 broods across four wetlands, including 19 broods (all grey teal) on Lake Bryde. In 2006, breeding intensity was highest in March with twenty broods from four species (grey teal, pink-eared duck, Eurasian coot and hoary-headed grebe), declining to 9 broods in October and none in March 2007. Lake Bryde supported 4 and 5 broods for March and October 2006 respectively, compared to the 19 broods recorded in February 2012. There was no evidence of breeding birds at Termination Lake 5 in 2012; although three species were breeding (total 8 broods) in March 2006. The number of broods recorded in March 2006 and February 2012 were equivalent in T1 (3 and 3 broods respectively) and IT1 (5 and 4 broods respectively).

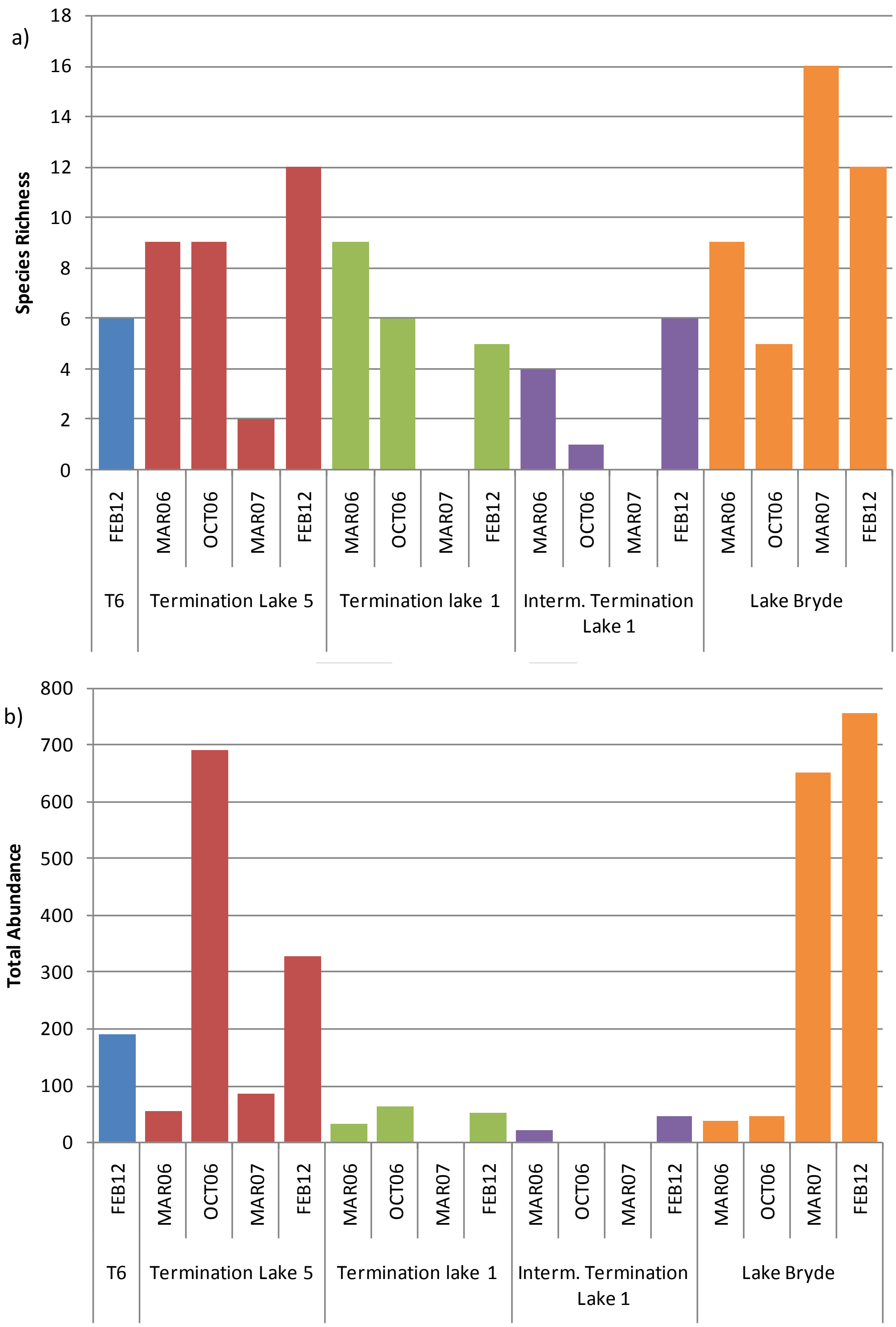

Figure 4. Waterbird a) species richness and b) total abundance at the five wetlands sampled in 2012

In 2012, species richness of waterbirds (Fig 4a) was higher in T5 (12 species) and ITL1 (6 species) than had previously been recorded. In T1 richness was lower (5 species) than had previously been recorded when water was present. At Lake Bryde, species richness (range 5 – 16 species over all 2006/7 and 2012 sampling dates) was greater in 2012 (14 species) than in March 2006 (9 species) but less than the peak richness of 16 species achieved in March 2007.

Waterbird abundance at Lake Bryde was high in 2012 and more similar to values recorded in March 2007, 14 months after the lake filled, than to any of the 2006 dates (Fig 4b). T5 also supported greater than modal abundance in 2012 but lower than the highest abundance recorded for the wetland which occurred in October 2006. At T1 and ITL1 waterbird abundance was generally low (< 100 birds) and similar between 2012 and previous surveys.

The distribution of species richness amongst feeding guilds (Fig. 5) gives an indication of the diversity of trophic interactions within waterbird assemblages. The Dabbler guild was dominant in terms of both species richness and abundance following filling in both March 2006 and February 2012 (and on most other occasions). All other guilds were represented by one or two species at any one time and only the diver-vegetation guild achieved the same magnitude of abundance as dabblers. At Lake Bryde the same 5 guilds were present on all occasions except October 2006 when species richness was lower and guild structure simpler. In 2012, T5 had a guild structure very similar to Lake Bryde and slightly more diverse than the guild structure on the same lake in March 2006. There were some compositional differences in guild structure at ITL1 particularly with an increased dominance of dabblers in 2012 but with low species and guild richness and low abundance these differences may be trivial. At T1, guild structure was simpler in 2012 than had been recorded previously because of the absence of the diving species (i.e. Musk duck, Hoary headed grebe and Eurasian coot) which were present in both March and October 2006. These species were present elsewhere during 2012.

Differences in waterbird community structure across the four survey dates can be summarised using waterbird presence/absence to perform an ordination of wetland samples (Fig. 6). Data are complete for Lake Bryde (LB) and Termination Lake 5 (TL5) with water present on all sampling occasions and by including lines to link sampling dates sequentially a trajectory of community composition can be followed, although it must be remembered that there are large time differences between consecutive surveys (ranging from weeks to years). For Lake Bryde, this trajectory suggest that February 2012 species composition was most like that recorded in March 2007 and not particularly similar to that observed in March 2006. The difference between February 2012 and March 2006 surveys is the result of 7 species (50%) not shared. However, there is no suggestion of a sustained directional change from any of the previously recorded assemblages, but rather a 'see-sawing' between alternative compositions. A similar pattern is observed at Termination Lake 5, but the March 2007 assemblage (when salinity was greatest) is singled out as being most different from other sampling occasions.

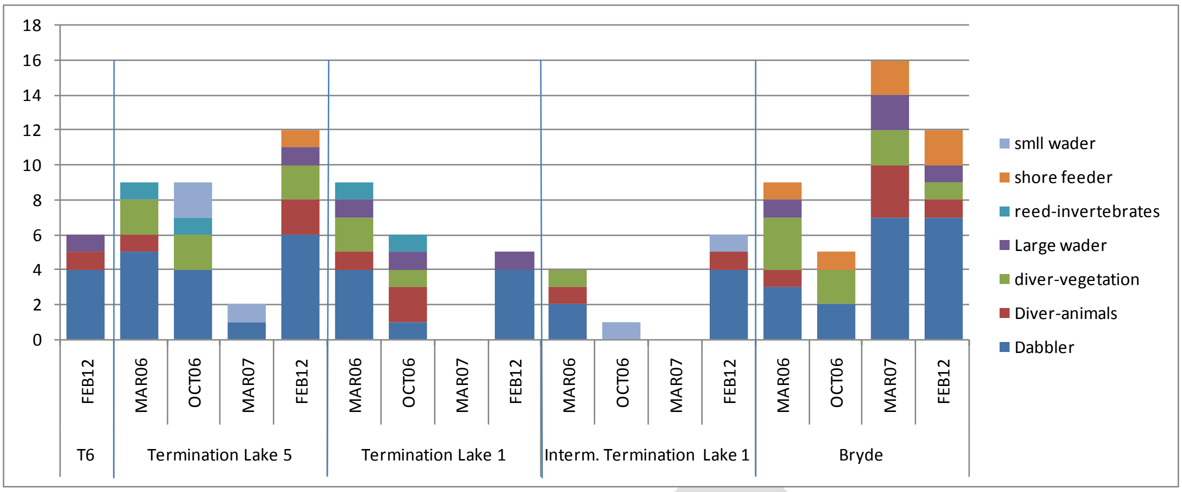

Figure 5 Waterbird species richness by guild membership for the 5 wetlands surveyed in 2012.

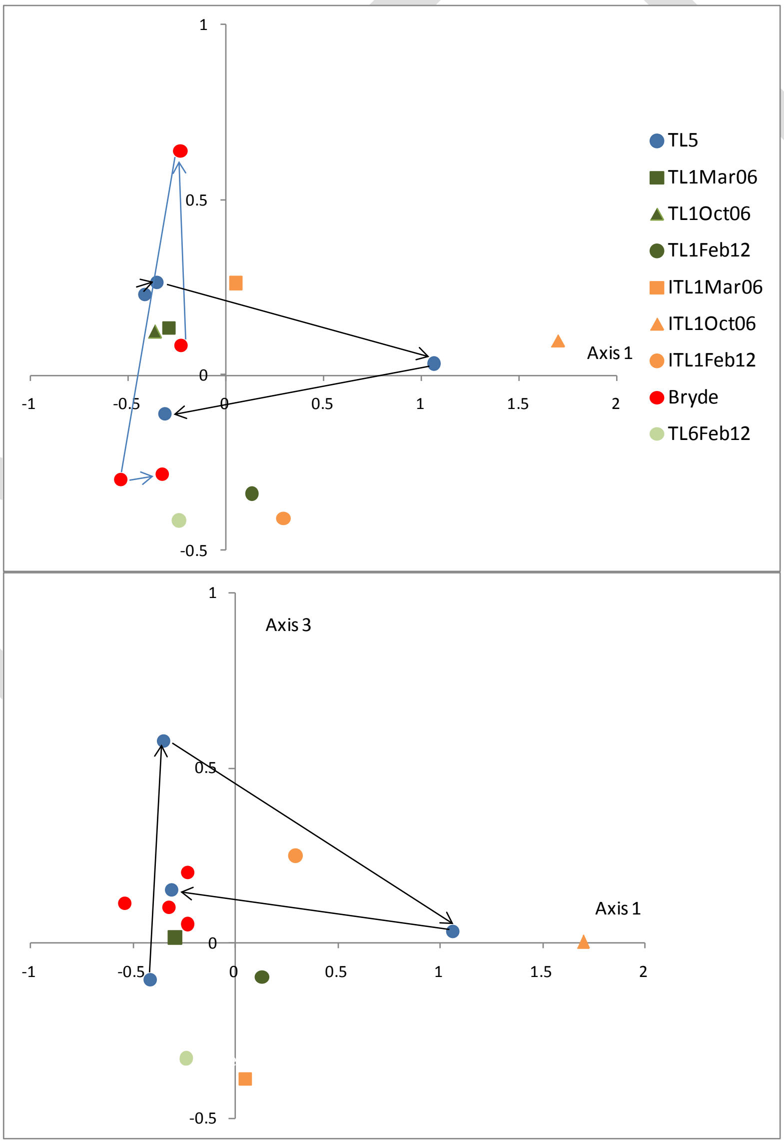

Figure 6 Ordination (nMDS) of waterbird presence/absence. For Bryde and TL5 arrows progress from March 2006 through October 2006 and March 2007 to February 2012.

Invertebrates

Species richness of invertebrates at Lake Bryde (which does not include Rotifera in this study) varied between 16 and 51 over the 14 year period of monitoring (data from this study and additional data from the Wheatbelt wetland monitoring program). Through this period, low richness coincided with low depth and high salinity while high richness (i.e. > 30 spp) occurred across a range of salinities from 1.4 – 13 g/L. Species richness during the hydroperiod initiated by the filling event of 2006 had a range of 30-41 species with maximum richness occurring in October 2006 and March 2007, eight and 14 months after filling respectively (Fig 7). Invertebrate species richness in February 2012 was 30 species; four species less than recorded in March 2006 shortly after filling.

In 2012, Lake Bryde supported fewer invertebrate species (30) than other wetlands in the chain (37 to 40 species) (Fig 7). The highest species richness in 2012 was recorded in T1 (40) and was greater than recorded in 2006 (29 – 33) at this wetland. At T5 species richness was constant at 37 species other than in March 2007 when this lake was drying and richness was 12 species. Termination Lake 6 (immediately downstream of T5) and lake ITL1 also supported 37 invertebrate species in February 2012, slightly less than recorded in ITL1 in March 2006.

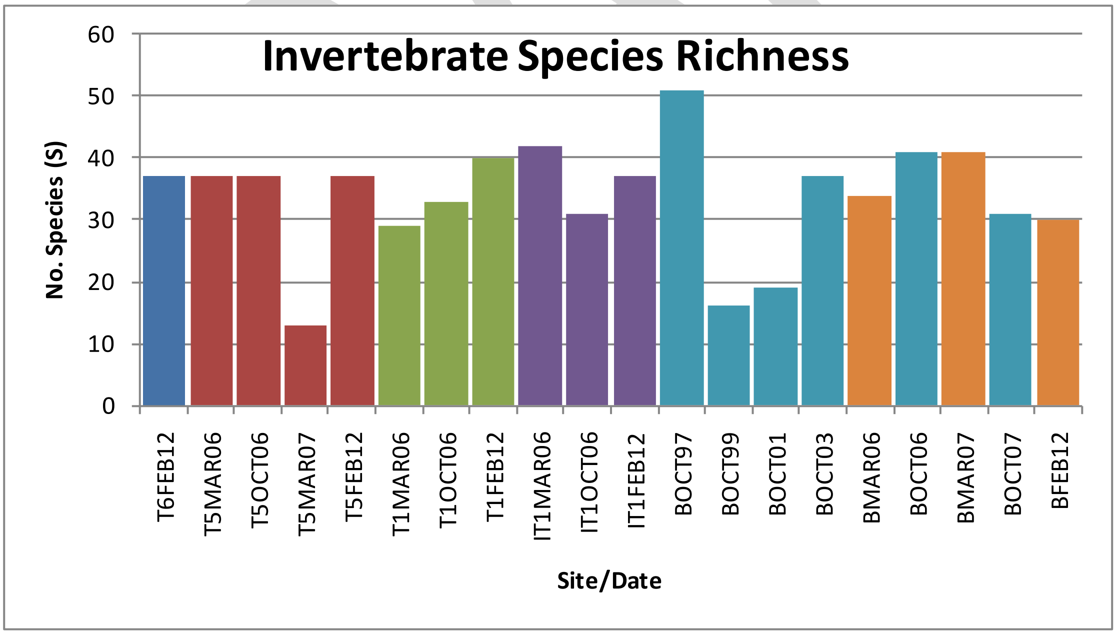

Figure 7 Species richness at the five wetlands sampled . These data don't include Rotifera which were not identified in 2012.

In 2012 total invertebrate abundance was equivalent to that in March 2006 at T5 and T1 and higher at Lake Bryde. In ITL1 abundance was an order of magnitude lower than recorded in March 2006 but greater than that recorded in October 2006. In March 2006 the majority of species in ITL1 had an abundance of less than 100 individuals and the community was dominated numerically by *Boeckella triarticulata* (> 10,000 individuals in the sample). In 2012 abundance was more evenly spread across a larger number of species, including three species with more than 1000 individuals in the sample.

Total invertebrate abundance was greater in Lake Bryde during 2012 than in March 2006 (i.e. first sample after flooding), but was less than recorded for March 2007 when the lake had a similar depth but had been flooded for a year. The distribution of abundance amongst species showed the typical strongly skewed pattern of low abundance in the majority of species (Fig 8); however it was more evenly distributed in 2012 than in March 2006. In March 2006 the most abundant species was a benthic ostracod *Bennelongia* sp. In 2012 the most abundant species (>1000 individuals) was a small pelagic copepod (*Australocyclops australis*), and the pelagic cladoceran *Daphnia carinata* and three benthic species (the chironomids *Chironomus* aff. *alternans*, *C. occidentalis* and the small ostracod *Cypricercus* sp.) had > 100 individuals in the sample. In March 2007 the most even distribution of abundance across these sampling dates was displayed, with eight benthic species and three pelagic species occurring at greater than 100 individuals per sample, possibly reflecting the length of time since inundation and a more established community. Some of these species (*Micronecta robusta*, *Mytilocypris mytiloides*, *Bennelongia* sp., *Trigonocypris globosa* and Pyralidae sp.) are large and would have contributed to a substantial standing biomass; greater than observed soon after flooding in either March 2006 or February 2012.

There were generally more benthic species (eg. Coleoptera, Odonata Chironomidae) than pelagic species (eg. Cladocera, Corixidae and Notonectidae) present in samples. However, the ratio of benthic to pelagic richness was lower earlier in the flooding cycles of both 2006 and 2012 (1.5 in February 2012 and 1.6 in March 2006 for Lake Bryde) than during the later 2006 samples (2.3 and 2.7 in October 2006 and March 2007 respectively). This probably reflects the rapid hatching of planktonic species from sediment propagule banks versus longer colonisation or development times for benthic species. This pattern of increasing benthic dominance over time extended to abundance, with 2.5 benthic individuals per pelagic individual in March 2006 compared to 7.4 – 10.3 later in the hydroperiod. In February 2012 most individuals at Lake Bryde were pelagic, with only 0.3 benthic individuals per pelagic individual recorded. *Daphnia carinata* (a water flea), and 4 species of corixid (water boatmen) and notonectid (backswimmer) insects were responsible for most of the abundance in February 2012. In T6 a high proportion of benthic individuals (18.1/pelagic) suggested benthic dominance in this wetland when it was sampled.

Invertebrate species composition was investigated by determining the number of species in each of the assemblages defined by Pinder *et al.* (2004). These assemblages are defined by the frequent co-occurrence (association) of species under particular environmental conditions. Assemblage E (mostly ubiquitous insects with a preference for fresh to sub-saline waters) was the most species rich assemblage in all wetlands on all sampling dates (Fig 9). Assemblages were rarely represented by more than one species in a wetland and never more than three species, although numerous species cannot be assigned to one of these assemblages and are shown in Fig. 9 as ‘U’ (unassigned). In T1, the addition in 2012 of species from assemblages H, I and D with sub-saline to saline distributions and the loss of a single species (the cladoceran *Simocephalus victoriensis*) from assemblage C, which is typical of freshwater swamps, suggest a more salt-tolerant fauna than was present in March 2006. A similar pattern is observed in IT1 and in T5; while no assemblages were added the loss of single species representing assemblages C and A also indicated a more salt tolerant fauna in 2012.

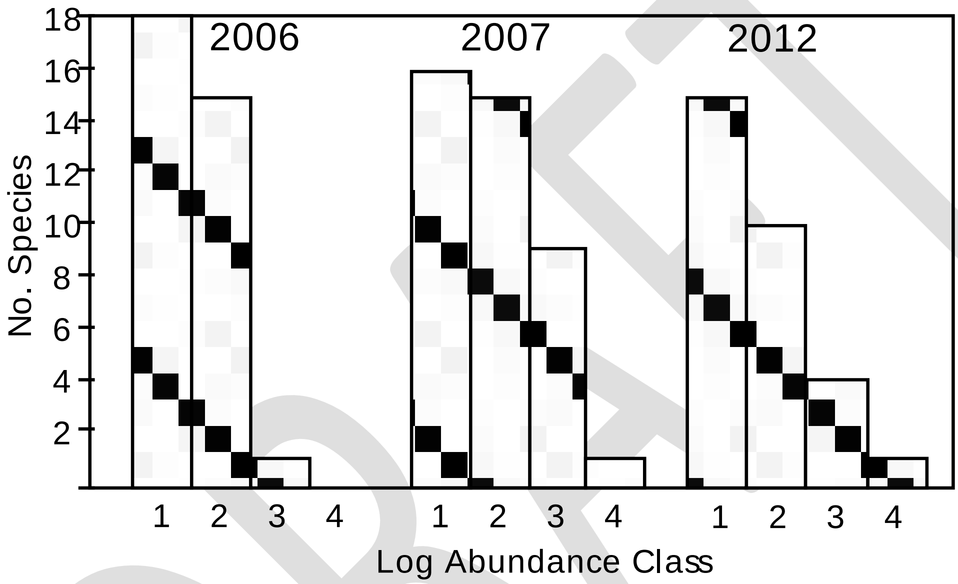

Figure 8. Distribution of abundance across species at Lake Bryde in March 2006, 2007 and February 2012. Abundance is estimated during sample processing using abundance classes 1 = 1-10 individuals per sample, 2 = 11-100, 3 = 101-1000 etc.

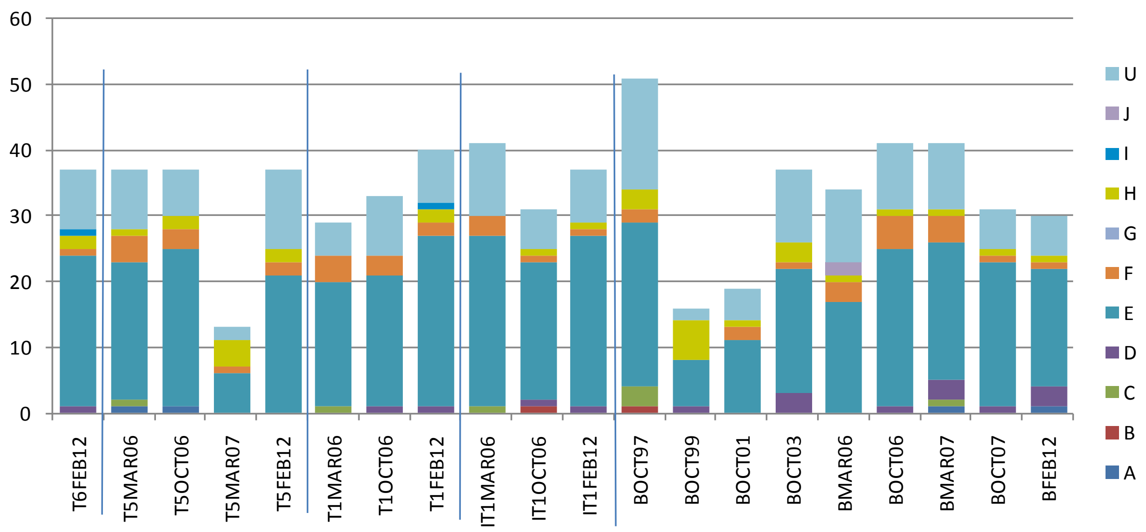

Figure 9. Species richness within the invertebrate assemblages defined by Pinder *et al*. (2004).

Constrained ordination (RDA) of wetland samples using invertebrate community composition (from Table 3 but as species presence-absence) and environmental variables (Table 1) did not yield any statistically significant constraining terms. Without constraining terms this ordination (Fig. 10), which includes monitoring data for Lake Bryde from October 1999, 2001, 2003 and 2007, reveals two patterns of community composition that are of interest. Firstly, Lake Bryde invertebrate communities outside the 2006 and 2012 filling events (i.e. those sampled as part of the State Salinity Strategy monitoring) have a different composition from the communities observed in all study lakes following the filling events (see green polygon on Fig 10). Secondly, following a filling event there is (with one exception) a greater similarity across wetland samples from the same date than between samples from the same wetland on different dates. That is, temporal changes in composition are greater than spatial differences between lakes. In Lake Bryde, composition in February 2012 is more like the composition of any of the wetlands sampled in March 2006 than other wetlands sampled in 2012. February 2012 samples from the remaining wetlands, while most similar to each other, have a composition more like those recorded in October 2006 (when depth and salinity were more similar) than in March 2006.

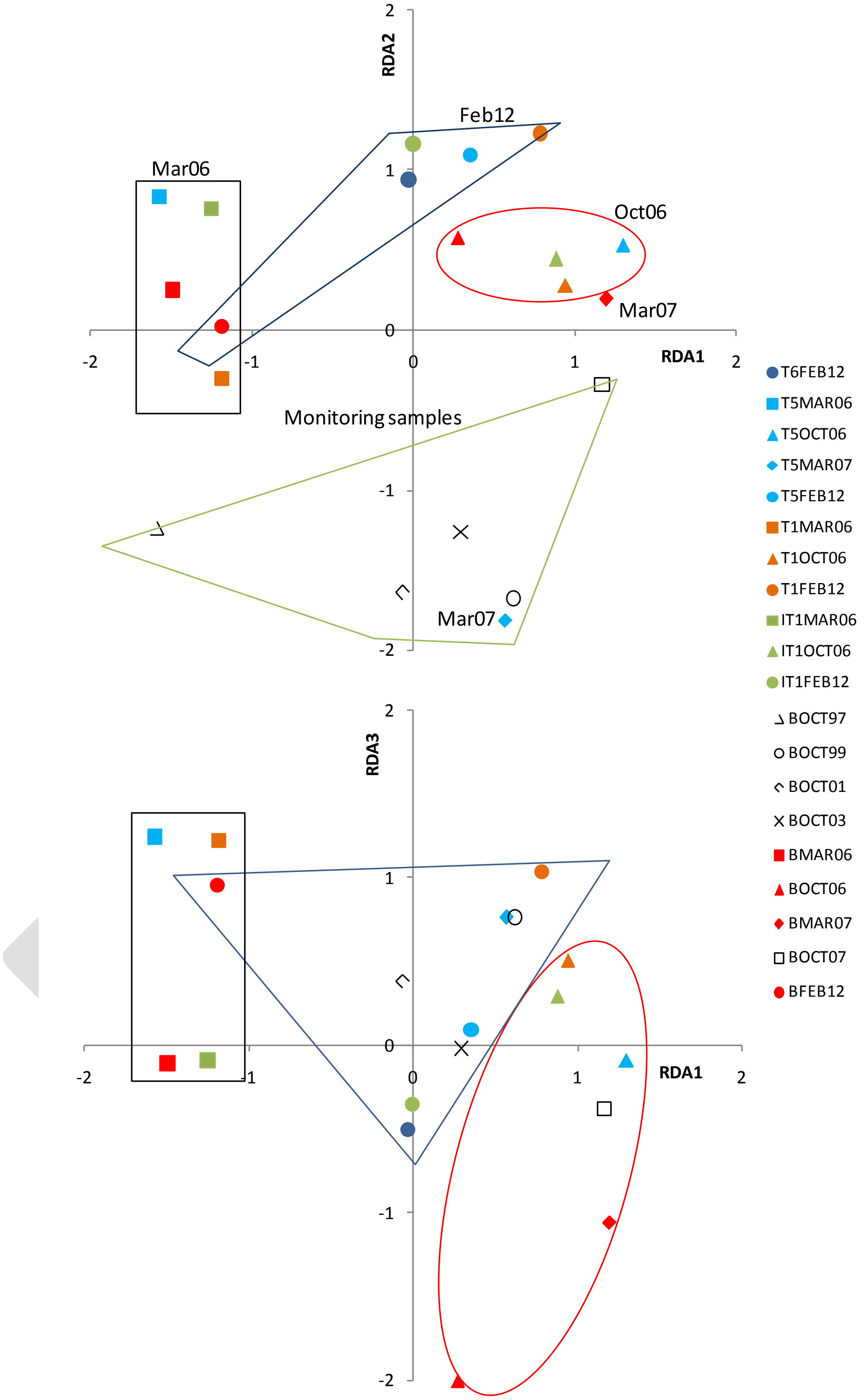

Figure 10 Ordination of wetland sites based on invertebrate community composition (i.e. species presence/absence). Samples from the Salinity Strategy Monitoring Program are un-coloured. Coloured squares are Mar06, triangles from)ct06, diamonds from Mar07 and coloured circles are Feb12, are

Discussion

Water Chemistry

The operation of the waterway was designed to result in an altered distribution of surface runoff through the wetland chain downstream of Lake Bryde. During periods of high flow the waterway drains runoff which traditionally would have accumulated and persisted on the valley floor. This moves accumulated water more immediately into downstream wetlands and prevents water logging which in turn causes vegetation damage and salinisation. This study collected invertebrate and waterbird data for comparison between two filling events to determine differences between communities that might be the product of this altered water regime. However, the filling events of 2006 and 2012 were not the same. In 2006, runoff from higher rainfall on a single day resulted in more widespread filling of wetlands and to greater depths than occurred in 2012. Peak depth in Lake Bryde in 2012 was less than half that recorded in 2006, while in Termination Lake 1 it was about half. Depth in Termination Lake 5 and Intermediate Termination Lake 1, were relatively more similar between events, but remained lower at the time of sampling in 2012. Consequently, any effect on water chemistry and fauna resulting from the functioning of the waterway is confounded with differences in water depth and salinity resulting from less runoff.

During filling in 2012, runoff was backed up at Lake Bryde Road such that a portion flowed west and into the top end of the waterway (K. Hemmings pers. com.). This would have resulted in more rapid filling of downstream wetlands. Where water backed up at Lake Bryde Road in 2006 it would not have been able to move so directly into downstream wetlands, but rather persisted on the valley floor, either entering wetlands over an extended period or not at all. While more water moved into the chain of termination lakes, lowering of the outflow height in Termination Lake 1 as part of the construction of the waterway (K. Hemmings pers. comm.) was responsible for limiting depth in this wetland at the time of sampling in 2012 and contributed, in turn, to a greater than expected depth at Termination Lake 5. To what extent the depths observed on sampling in 2012 are in response to the waterway or reduced runoff in the catchment cannot be determined, but it seems clear both factors are involved.

The limited set of water chemistry observations also suggest that water chemistry (particularly in Lake Bryde) differed between March 2006 and February 2012, reflecting the different depths. In 2012, Lake Bryde was more saline than in March 2006 and had higher turbidity and colour. While increased salinity was a direct result of relatively less inflow and less dilution of existing salt loads, it cannot be determined whether increased turbidity was due to increased sediment load during filling or a result of greater sediment disturbance (by wind and waterfowl) because of the shallower conditions. Primary production was higher in Lake Bryde in 2012 than at any stage of the hydroperiod initiated in 2006 (this may also have contributed to higher turbidity) and was probably driven by elevated (compared to March 2006) levels of dissolved nitrogen. Salinity in downstream wetlands was also higher in 2012 than in 2006, but turbidity and colour were similar. Nutrient levels and photosynthetic pigments were lower in these downstream wetlands in 2012, probably resulting in lower primary production (as indicated by chlorophyll) than during the 2006 hydroperiod.

The higher observed salinities in 2012 were concomitant with lower depths and therefore less dilution of pre-filling salt loads and do not suggest increasing salinisation of the wetlands. The salt load in Termination Lake 1 may even have been reduced: salinity in this wetland was lower in 2012 than in October 2006 despite lower depth. Modification to the height of the outflow of Termination Lake 1 has reduced the residence time of a large portion of the water entering this wetland and it seems likely this has enabled flushing of some of the wetland's salt load during the 2012 filling event. Termination Lake 5, the most downstream of the re-sampled wetlands, receives water from Termination Lake 1 and had greater salinity in 2012 than in March 2006 despite similar estimates of lake depth. While some of this increase may be the result of additional salt load from the upstream wetlands it is likely a portion of the apparent increase is the result of uncertainties in depth estimates. Given that the waterway will move greater volumes of water into these downstream wetlands it seems inevitable that salinity will increase in Termination Lake 5 in the absence of a means of flushing the wetland (and even then the increased salinity will only be moved further downstream).

<u>Waterbirds</u>

Waterbird abundance was higher in 2012 and coincided with equal or higher abundance of invertebrates than was observed after filling in 2006. In Lake Bryde dense flocks of grey teal were observed feeding from the water column and surface in 2012 at a time when large numbers of Corxidae (water boatmen) and Cladocera (waterfleas) could be observed in the water. It is notable that immediately after filling in 2006 pelagic species made up a greater proportion of invertebrate abundance than later in that hydroperiod and a similar proportion was observed in 2012. The high availability of invertebrate prey is in large part responsible for the triggering of breeding amongst waterbirds following the filling of a wetland (Maher and Carpenter 1984, Scott 1997). Breeding was more intense (more broods observed) in 2012 than in 2006 although most broods occurred in Lake Bryde. The absence of any observed breeding at Termination Lake 5 is not explained by the data, since invertebrate abundance was at least as great in 2012 as 2006 and waterbird abundance and richness were higher in 2012. Inundation of *Melaleuca* stands on the western shore occurred in 2006 but not in 2012 and this may have reduced the availability of suitable nesting sites. In addition, bird populations are mobile and many species used wetlands from the chain opportunistically. With high invertebrate abundance in Lake Bryde, birds may have been choosing Lake Bryde over other wetlands for nesting. Increased breeding observed in Lake Bryde may also be in part an artefact of sampling at lower lake depths. In March 2006 the wetland was filled to well beyond the basins boundary and many areas of cover were provided for waterbirds by inundated stands of vegetation. While this is expected to have increased the density of breeding in 2006 it would also have reduced the visibility and therefore detectability of waterbird broods; resulting in an under-estimation of the actual extent of breeding. In 2012, flooding of riparian vegetation was limited and it is likely a high proportion of all broods present were actually observed and counted.

Waterbird communities typically had higher richness in 2012 than in 2006. Termination Lake 1 was an exception, having reduced species richness and a composition that was a subset of those species recorded in 2006. As a result, the 2012 community of this lake most closely resembled that occurring in October 2006 as the lake was drying. Guild structure was simplified in this wetland by the absence of any diving species. In 2012 there was consistently fewer or no species of the diver-vegetation guild across all study sites except Termination Lake 5. This guild feeds on macrophytes (eg. *Ruppi*a spp and *Chara* spp) grazed from the lake bed suggesting insufficient of this food resource was available, although at least sparse macrophyte beds were observed in all wetlands except Lake Bryde. It is likely that high turbidity had slowed the development of macrophyte beds in Lake Bryde. The absence of diving species in Termination Lake 1 could also be a response to insufficient depth. A reduced occurrence of species of this guild has been observed in Lake Bryde at depths less than 0.7m (Cale, in prep) and Termination Lake 1 had a depth of only 0.48 m in 2012. Notably, Termination Lake 5 supported two species of this guild in 2012 which is an equivalent richness to previous years.

In Lake Bryde in 2012, waterbird richness, abundance and guild richness were greater than observed after filling in 2006 and more like the highly productive communities observed in March 2007 at a similar depth and salinity. The waterbird communities of 2012 did not have as much time to accumulate species and individuals as in March 2007 so it is likely that the recorded community structure is the result of similar depth and chemistry. Cale (2007 and in prep 2012) observed an increased waterbird richness and abundance at Lake Bryde in the depth range 0.6 - 0.7m and suggested that this depth was optimal for this component of the biota; allowing access to the greatest number of feeding habitats in the wetland at salinities low enough to enable high abundance of a range of invertebrate food species. Differences between February 2012 and March 2006 are thus likely to be the result of the higher water level in the earlier period.

Invertebrates

Salinity has frequently been observed as a primary factor determining the structure of invertebrate communities (Williams 1998, Cale *et al*. 2004, Pinder *et al*. 2005). In wetlands downstream of Lake Bryde there was a marked difference between community composition in the least saline conditions of March 2006 and the moderate saline conditions of February 2012 and later in the 2006 hydroperiod. Invertebrate community structure in these wetlands is more similar between wetlands on the same sampling date than within the same wetland across sampling dates, despite a gradient of salinity through the wetland chain. The invertebrate fauna present was salt-tolerant and it seems likely that salinity differences between wetlands were not sufficient to override temporal patterns of community development through a hydroperiod.

Lake Bryde remained fresher than other wetlands in 2012 and invertebrate community composition had strong similarities to the invertebrate communities collected from the study wetlands in March 2006 and was dissimilar from all communities sampled at Lake Bryde in the October of non-filling years. This 'post filling' community included pelagic species, such as *Caenestheriella packardi* , and species of corixidae (boatmen) and notonectidae (backswimmers), infrequently encountered at other times. Additionally this community lacked a range of ostracoda (seed shrimp) species encountered on most other sampling occasions. These ostracods, while probably present as eggs in sediments at the time of filling, are likely to have longer development times than the post-filling sampling dates allowed.

Jenkins and Buikema (1998) suggested that dispersal is an important regulator of developing zooplankton communities; limiting the proportion of the available regional species pool that becomes established in a wetland. Species with low dispersal capability will occur less frequently. Conversely, highly mobile species such as insects are more likely to be able to colonise all wetlands. The similarity, on any single date, of invertebrate communities between downstream wetlands and the high proportion of assemblage E species (mostly insects; Pinder *et al.* 2004) suggest these wetlands are dependent on colonisation of highly mobile species from outside the wetland. This is likely a result of the high proportion of dry or saline years they experience and the reduction of propagules retained within the wetland following fill years. In contrast, Lake Bryde retained similarity across both March 2006 and February 2012 and supported a higher proportion of crustacean species of assemblages D and H which are likely to re-establish from propagules persistent within the wetland. The higher diversity observed in Termination Lake 1 was comprised principally of salt tolerant species but included both hemipteran insects, which would have colonised from elsewhere and copepod crustaceans which develop very rapidly from eggs or diapause adults retained in the wetland. The reliance of the downstream wetlands on colonisation from elsewhere, may increase if the chain becomes more saline. This would have implications for the maintenance of diverse invertebrate communities and indicates the importance of maintaining the condition of wetlands such as Yate Swamp, East Lake Bryde and Lake Bryde which support in excess of the two thirds of the local species pool (Cale 2007) and would provide dispersing individuals for re-colonisation of these wetlands when conditions were suitable.

The correlated factors of depth and salinity were the most important in determining community structure of waterbirds and invertebrates. Lower depth and higher salinity occurred in 2012, resulting in lower species richness in many wetlands and reduced waterbird guild complexity in some. Differences in depth and salinity may be in part the result of the functioning of the waterway but it is clear that the two filling events (2006 and 2012) were not equivalent, with the latter filling wetlands to a lesser extent. Reduced outflow height in Termination Lake 1 appears to have increased flushing of this wetland and a richer invertebrate community was supported. However, lower depth in Termination Lake 1 may have reduced waterbird diversity and would certainly shorten the period over which both invertebrate and waterbird communities could persist. It seems likely that a filling event as large as that of 2012 would be sufficient for the species of copepod present in this wetland to produce propagules to perpetuate future populations, however, more slowly developing species such as some ostracoda may struggle to persist. In Lake Bryde, salinity and depth in 2012 matched those of March 2007 and waterbird communities showed the greatest similarity between these dates. While the composition of invertebrate communities, at Lake Bryde in 2012, was more like those of March 2006, the richness and abundance of species was more similar to March 2007, suggesting salinity had greater effect on functional aspects such as growth and productivity of the community than on composition. Continued functioning of the waterway is likely to result in increased salinity of Termination Lake 5 and possibly Termination Lake 6 as salt is carried downstream, unless this water can continue to move further downstream. Without data for salt load in these wetlands it is not clear that there has been an increase to date and current observed salinities are able to support similar biodiversity to that recorded in the past.

<u>Summary</u>

The rainfall events of 2006 and 2012 were different and gave rise to different lake depths and water chemistry.

The waterway resulted in more rapid movement of water into downstream wetlands.

The reduced outflow height of Termination Lake resulted in flushing of some salt from this wetland and presumably into Termination Lake 5. While this may have enabled the development of a more diverse invertebrate fauna it also resulted in reduced depth with some impacts on fauna anticipated.

In Termination Lake 5 waterbird and invertebrate communities were similar after filling in 2006 and 2012, except for the absence of waterbird breeding in 2012. It is suggested that the lack of breeding waterbirds may have causes un-related to the waterway.

Lake Bryde had similar waterbird and invertebrate community composition after filling in both 2006 and 2012. However, species abundances were more similar between 2012 and dates in 2006 with similar depth and salinity.

Differences in lake depth and salinity between the 2006 and 2012 filling explain the observed differences amongst invertebrate and waterbird communities.

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Table 1 Water chemistry for the five wetlands surveyed in February 2012 and March 2006.

Wetland	Date	Depth	Electrical Conduct. Ec	pH	Total Filtered N	Total Filtered P	Chlphyll-a	Chlphyll-b	Chlphyll-c	Phaeo-a	Temp.	Turbidity	Colour	Total Dissolved Solids
Term. 6	FEB12	0.25*	8310	8.83	3300	5	0.5	0.5	0.5	0.5	2	30.5	1.8	4.7**
Term. 5	MAR06	0.8*	2870	7.56	4800	70	0.5	0.5	1	3	22.3	7.2	98	1.9
Term. 5	OCT06	0.75*	14380	9.24	1400	5	1	1	1	2	19.7	2.2	21	8.7
Term. 5	MAR07	0.3*	79100	8.52	6000	30	6	6	9	11	28.9	18	40	54
Term. 5	FEB12	0.8*	9580	8.4	2100	5	0.5	0.5	0.5	0.5	24	1.4	37	5.4**
Term. 1	MAR06	0.9	4000	7.7	3500	30	0.5	1	2	11	23.4	5.2	110	2.7
Term. 1	OCT06	0.54	16020	8.52	3000	5	0.5	1	2	2	22.6	1.1	32	11
Term. 1	MAR07	0												
Term. 1	FEB12	0.4	12850	8.4	2400	5	0.001	0.5	0.5	0.5	23	0.7	33	7.4**
ITL1	MAR06	0.7*	5150	8.13	3600	50	0.5	0.5	9	8	22.9	4.8	80	3.3
ITL1	OCT06	0.17	18970	8.77	9900	20	2	2	2	3	15.1	1.6	39	11
ITL1	MAR07	0												
ITL1	FEB12	0.48	8400	8.47	2700	10	0.5	0.5	0.5	0.5	17.3	5.2	55	4.6**
Bryde	MAR06	1.82	549	7.81	2100	130	6	1	6	3	21.6	31	75	0.37
Bryde	OCT06	1.47	1445	10.6	1100	10	1	0.5	1	1	20.6	2.1	20	0.73
Bryde	MAR07	0.61	4480	9.41	2200	10	1	1	3	5	22.9	0.8	21	2.3
Bryde	FEB12	0.58	2630	8.33	2800	40	14	1	2	9	27.5	120	160	1.2**

*depth estimated, ** field measurement as ppt

Table 2 Waterbird species abundance for the 2006 and 2012 sampling events (bold figures indicate species observed breeding)

wetland	Termination Lake 5				Termination Lake 1				Intermediate Termination Lake 1				Lake Bryde				Termination Lake 6
Date	22/3/06	31/10/06	20/03/07	7/02/12	22/3/06	31/10/06	20/03/07	7/02/12	22/3/06	31/10/06	20/3/07	7/02/12	21/3/06	31/10/06	20/3/07	6/02/12	7/02/12
Australasian Grebe						6									9		
Australasian Shoveler	2	3		34											44	33	7
Australian Shelduck		**7**		2								7			27	42	4
Australian White Ibis															5	1	
Australian Wood Duck				4									3	2		4	
Black Swan	1			1	1			1	2					5	8	37	3
Black-fronted Dotterel			2							2		2					
Black-winged Stilt		7															
Blue-billed Duck													3				
Eurasian Coot	15	**318**		34	**2**	**10**			**6**				**17**	**31**	70	10	
Grey Teal	**18**	338	85	197	2	39		**39**	**2**			6	**4**	**7**	214	**514**	**164**
Hardhead	2														4	4	
Hoary-headed Grebe	**5**			4	**1**	2			**10**			**28**	2		217	45	1
Little Grassbird	2	1			4	2											
Little Pied Cormorant				5											11		
Musk Duck	3	6		5	3								2	**2**	2		
Pacific Black Duck		10		5	1			3				**2**	3		26	21	
Pink-eared Duck	**8**			10	**4**			1				2	3		2	36	
Red-kneed Dotterel		1															
Straw-necked Ibis															1		
White-faced Heron				26	14	4		7					1		6	8	12

Table 2 Waterbird species abundance for the 2006 and 2012 sampling events (bold figures indicate species observed breeding)

wetland	Termination Lake 5				Termination Lake 1				Intermediate Termination Lake 1				Lake Bryde				Termination Lake 6
Date	22/3/06	31/10/06	20/03/07	7/02/12	22/3/06	31/10/06	20/03/07	7/02/12	22/3/06	31/10/06	20/3/07	7/02/12	21/3/06	31/10/06	20/3/07	6/02/12	7/02/12
Yellow-billed Spoonbill														4			
Richness	9	9	2	12	9	6	0	5	4	1	0	6	9	5	16	12	6
Total Abundance	56	691	87	327	32	63	0	51	20	2	0	47	38	47	650	755	191
No. Spp Breeding	3	2	0	0	3	1	0	1	3	0	0	2	2	3	0	1	1

Table 3 The abundance (log_{10}) of invertebrate species from the five wetlands sampled in 2006 and 2012 with additional data for Lake Bryde from the State Salinity Strategy Biodiversity Monitoring Program (Cale *et al*. 2004)

Wetland			**T6**	**T5**				**T1**			**IT1**			**BRYDE**								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
Turbellaria	U	IF999999	1				4		1			1		1						1		
Nematoda	U	II999999					2			2	1		2	4		2	1	2	1	1		
Gastropoda																						
Ferrissia petterdi	F	KG060101																1				
Glyptophysa sp	U	KG070299	1																			
Gyraulus sp.	U	KG070799									1											
Oligochaeta																						
Naididae	U	LO049999															1		1		2	
Dero nivea	F	LO050202									1											
Rhyacodrilus sp. WA30	U	LO0519A1																1				
Ainudrilus nharna	U	LO052101												3		3				2		
Enchytraeidae	U	LO089999				1					1			2								
Acarina																						
Hydrachna sp.	U	MM010199								1												
Eylais sp.	E	MM030199								1												
Acercella falcipes	E	MM170101																				
Arrenurus balladoniensis	A	MM230101			1																	
Mesostigmata	U	MM9999A2																1				
Trombidioidea	U	MM9999A6															2					
Anostraca																						
Branchinella sp.	U	OD030199									1							1				

Table 3 The abundance ($\log_{10}$) of invertebrate species from the five wetlands sampled in 2006 and 2012 with additional data for Lake Bryde from the State Salinity Strategy Biodiversity Monitoring Program (Cale *et al*. 2004)

Wetland			T6	T5				T1			IT1			BRYDE								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
Conchostraca																						
Caenestheria sp. (nr. *lutraria*)	B	OF0102A0												2								
Caenestheriella packardi	U	OF010302	1										1	1				1				1
Eocyzicus sp.	U	OF010499									1											
Limnadopsis sp.	U	OF020399																2				
Cladocera																						
Alona longinqua	U	OG030210												1								
Alona clathrata	U	OG030211																				
Alona rigidicaudis	E	OG030212	1			1				2				3						2		
Alona sp. *nov*. a (Bryde)	U	OG0302A7												3								
Alona cf. *rectangula novaezelandiae*	E	OG0302B5							1													
Dunhevedia crassa	F	OG031201				1										2				3		
Leberis cf. *diaphanus*	U	OG0317A4	1											3								
Leydigia cf. *leydigii*	D	OG0318A2	2																2		3	
Plurispina cf. *chauliodis*	U	OG0324A0												3				1				
Pleuroxus foveatus	D	OG032501															2			3		
Pleuroxus inermis	E	OG032502									2								1			
Australospilus elongatus	U	OG033001												3								
Pseudomonospilus diporus	U	OG033101												3								

Table 3 The abundance ($\log_{10}$) of invertebrate species from the five wetlands sampled in 2006 and 2012 with additional data for Lake Bryde from the State Salinity Strategy Biodiversity Monitoring Program (Cale *et al*. 2004)

Wetland			**T6**	**T5**				**T1**			**IT1**			**BRYDE**								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
Daphnia carinata	E	OG040201		3				1			1		3	4		3	4	2			4	3
Daphniopsis queenslandensis	H	OG040302												2								
Daphniopsis truncata	H	OG040305													3							
Daphniopsis wardi	D	OG040306													3		2					
Simocephalus victoriensis	C	OG040507		2				1						4								
Macrothrix breviseta	E	OG060201			3		3		1	1		2	3				3		2		4	
Macrothrix cf. *rosea*	E	OG0602B0					2			2												
Ostracoda																						
Platicypris baueri	H	OH082601				3																
Limnocythere mowbrayensis	E	OH010203			1		2							3	2		2		3	2		
Ilyocypris australiensis	E	OH060101	1		1		2				2	1	3	4					3			
Alboa worooa	F	OH080101		3	3		2	2	3	3	1	1										
Bennelongia sp.	U	OH080399	2	4			2				2			3				3	3	3		1
Candonocypris novaezelandiae	U	OH080403												2								
Cypretta baylyi	E	OH080501	2								1			3				2	3			1
Cyprinotus cingalensis	H	OH080602	3	3	3		2			2		1	4							2	4	2
Diacypris sp.	U	OH080799				3																1
Heterocypris sp.	U	OH081099		1			2															
Mytilocypris ambiguosa	E	OH081201	2		3							2		1	3		3				4	

Table 3 The abundance (log_{10}) of invertebrate species from the five wetlands sampled in 2006 and 2012 with additional data for Lake Bryde from the State Salinity Strategy Biodiversity Monitoring Program (Cale *et al*. 2004)

Wetland			T6	T5				T1			IT1			BRYDE								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
Mytilocypris mytiloides	U	OH081204	2		3	3	2		3	3		3	3		3		1			3	4	
Reticypris clava	H	OH081501												2								
Trigonocypris globulosa	U	OH081701											2						3	3		
Ilyodromus amplicolis	F	OH081901																	2			
Cypricercus sp.	U	OH082199												1					2	2		3
Sarscypridopsis aculeata	E	OH090101	4		1		3		3	4		2	3	1	3		2			2	3	
Copepoda																						
Boeckella triarticulata	E	OJ110101	1	4						1	5		4	2		3		2	2			
Calamoecia sp. 342	E	OJ1102A1	2		1		3					3	4	2			3	2	2		3	
Metacyclops sp. 442	E	OJ3102A0										3	2	3		3	2		1	1	3	
Metacyclops sp. 434	E	OJ3102A2									1											
Australocyclops australis	E	OJ310301	2	3			2	4			1		2	3			1	2	1			4
Mesocyclops brooksi	F	OJ310703			3				3										2	2	3	
Eucyclops australiensis	C	OJ311001									1			3								
Apocyclops dengizicus	H	OJ311201	2		2	3	2			4					2	2	2					
Mesochra nr *flava*	H	OJ6103A1													2							
Amphipoda																						
Austrochiltonia subtenuis	E	OP020102			2	4			2	1	2	4	3	3	2	5	1		2	1	4	1
Malacostraca																						
Cherax destructor	U	OV010101									1											
Coleoptera																						

Table 3 The abundance ($\log_{10}$) of invertebrate species from the five wetlands sampled in 2006 and 2012 with additional data for Lake Bryde from the State Salinity Strategy Biodiversity Monitoring Program (Cale *et al*. 2004)

Wetland			T6	T5				T1			IT1			BRYDE									
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
Haliplus sp.	U	QC060199	1		1		2				1	1				1						
Hyphydrus sp.	U	QC090499		1			1	1		2										1		
Allodessus bistrigatus	E	QC091101		1				1	1	1	2	2	1	1			1					1
Antiporus gilberti	E	QC091603		1				1	1		1	1		3		1	2	1				
Sternopriscus multimaculatus	E	QC091805		1	1		1	1		1	2	2	1	3					1	1	2	
Necterosoma penicillatus	E	QC092001					1	1	2	2		1			1							
Megaporus howitti	E	QC092103			1			2	1		1								1			
Rhantus suturalis	E	QC092301		2				1														1
Lancetes lanceolatus	E	QC092401							1													
Hyderodes crassus	E	QC092802		1																		
Eretes australis	D	QC092901																				1
Onychohydrus scutellaris	F	QC093401						1														
Berosus sp.	U	QC110499	3	2	2		2	2	1	1	2	1	1	1	2		2	2	1		1	1
Enochrus elongatus	D	QC111101																				1
Limnoxenus zelandicus	F	QC111401		1														1				
Diptera																						
Anopheles sp.	U	QD070199		1													1					
Aedes camptorhynchus	H	QD070502													1							
Culex (Culex) australicus	D	QD070706															2					
Bezzia sp.	E	QD090499																	1			

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Wetland			T6	T5				T1			IT1			BRYDE								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
Culicoides sp.	E	QD090899									1			1			1					
Monohelea sp. 1	E	QD0919A0	1			1							1								2	
Nilobezzia sp. 1	E	QD0920A0	1		1	1	1		1	1	1	2	1						1	2	3	
Atrichopogon sp. 2	A	QD0927A0																				1
Forcypomyia sp. 3	J	QD0928A0																1				
Stratiomyidae	U	QD249999	1	2	1		1	1	1	1	2	1	1				1	2	1			2
Dolichopodidae	U	QD369999															1					
Ephydridae sp. 3	H	QD7899A7															2					
Ephydridae sp. 4	I	QD7899A8	1							1												
Muscidae sp. A	H	QD8999A0																	1			
Procladius paludicola	E	QDAE0803	3	3	2	2	2			3	3	3	2		2			2	1	2		1
Procladius villosimanus	E	QDAE0804			2			2	3					3			2				3	
Ablabesmyia notabilis	E	QDAE1102																1	1	3		
Paramerina levidensis	F	QDAE1201												3					2			
Paralimnophyes pullulus	F	QDAF1202												3								
Cricotopus albitarsus	C	QDAF1501												2								
Cricotopus 'parbicinctus'	J	QDAF15A0																2				
Orthocladiinae sp. A	E	QDAF99A0												2								
Tanytarsus barbitarsis	H	QDAH0402				1											3					
Tanytarsus bispinosus	F	QDAH0405																	1	3		
Tanytarsus	U	QDAH04D8	3	2	2		2		3	3	2	3	3	3		1		1			4	

Table 3 The abundance (log_{10}) of invertebrate species from the five wetlands sampled in 2006 and 2012 with additional data for Lake Bryde from the State Salinity Strategy Biodiversity Monitoring Program (Cale *et al*. 2004)

Wetland			**T6**	**T5**				**T1**			**IT1**			**BRYDE**								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
fuscithorax/semibarbitarsus																						
Harrisius sp.	U	QDAI0199																	1			
Chironomus occidentalis	F	QDAI0408		3				3								1						3
Chironomus tepperi	E	QDAI0414			2				3								2		1			
Chironomus aff. *alternans*	E	QDAI04A0		3			3	3		2			2	3		1	2	2			3	3
Dicrotendipes conjunctus	E	QDAI0603	2		2		3		2	2	1	2	2				2		2	2	3	
Dicrotendipes 'CA1'	D	QDAI06A4																		4		
Kiefferulus intertinctus	E	QDAI0701						2			1									2		
Polypedilum nubifer	E	QDAI0804	3	3	1		2		2	3	2		4				2		2	3	4	2
Cryptochironomus griseidorsum	E	QDAI1901	2	3			1	2			2		3	3				2	1			
Cladopelma curtivalva	E	QDAI2201			1	2										1					2	
Hemiptera																						
Saldula brevicornis	U	QH600201		1													1					
Diaprepocoris barycephala	A	QH650101																		1		
Sigara truncatipala	A	QH650204		1																		
Sigara mullaka	D	QH650206							1	1		2	2							1		
Agraptocorixa eurynome	E	QH650301								1												2
Agraptocorixa parvipunctata	E	QH650302	2	2			1			1	2		2			1						2
Agraptocorixa hirtifrons	D	QH650303																				2

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Wetland			**T6**	**T5**				**T1**			**IT1**			**BRYDE**								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12
Micronecta robusta	E	QH650502		1			1			2		1	2					2			3	2
Micronecta gracilis	E	QH650503		3				1			2			1						1		1
Anisops thienemanni	E	QH670401	2	2	2			2		3		2	2					1	1	1	2	2
Anisops hyperion	E	QH670402	2				4	2						3							1	
Anisops gratus	E	QH670403	2							2	2		2					1		2		2
Lepidoptera																						
Pyralidae nr. sp. 39/40	U	QL0199A0								1										3		
Odonata																						
Xanthagrion erythroneurum	E	QO021301			1					2						1				1	2	
Austrolestes analis	F	QO050101	1	1	1		2	1	1	2	1		1				1	1	1	1		
Austrolestes annulosus	E	QO050102	2	1	2		2	2	2	3	1	2	1	1	1	2	1	1		2	2	
Austrolestes io	E	QO050105		1	1			1	1		1	2						1				
Hemianax papuensis	E	QO121201	1	2	1		1	2	1	1	1		1	1			1					1
Orthetrum caledonicum	E	QO171601					2		1	1										1	1	
Hemicordulia tau	E	QO300102	1	1	1		1	1	2	1		1	1	2				1	1	1	1	1
Trichoptera																						
Ecnomus pansus/turgidus	C	QT0804A0																		1		
Notalina spira	E	QT250504			2				1			1				2			1	2	3	
Oecetis sp.	U	QT250799		1	1		1		1		1		1	1		1		1	2	2	2	
Triplectides australis	E	QT251103	1	2	2				1	1	2	1	2					2	1	1		2

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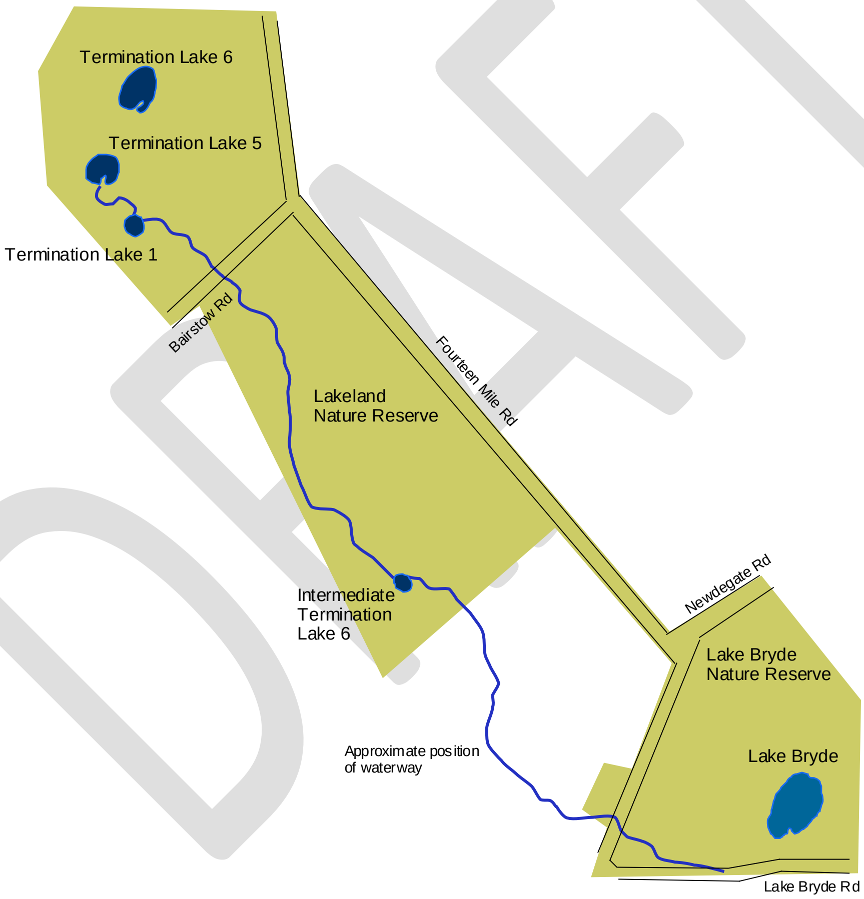
Wetland			**T6**	**T5**				**T1**			**IT1**			**BRYDE**								
LowestID	**A**[1]	LowestIDNC	FEB12	MAR06	OCT06	MAR07	FEB12	MAR06	OCT06	FEB12	MAR06	OCT06	FEB12	OCT97	OCT99	OCT01	OCT03	MAR06	OCT06	MAR07	OCT07	FEB12

[1] The assemblage assigned to the species by Pinder *et al*. 2004

Appendix 1 Study Wetlands, sampling dates and relative locations

Parameter	Site Name *(Cale 2007)*	2006	2006	2007	2012
		Mar	Oct	Mar	Feb
Lake Bryde (LB)	Bryde 6	1	1	1	1
Intermediate Termination Lake 1 (ITL1)	Bryde 3	1	1	1	1
Termination Lake 1 (TL1)	Bryde 2	1	1	1	1
Termination Lake 5 (TL5)	Bryde 1	1	1	1	1
Termination Lake 6 (TL6)					1



Approximate location of Wetlands and the waterway

Appendix 2 water chemistry parameters and their units of measurement

Parameter	Chem Centre Methodology	Units
Field Depth		metre
Field Conductivity		mS/cm
Field pH		pH units
Field Temperature		° Celsius
TN	iNP1WTFIA	µg/L
TP	iPP1WTFIA	µg/L
Chlorophyll-a	iCHLA1WACO	µg/L
Chlorophyll-b	iCHLA1WACO	µg/L
Chlorophyll-c	iCHLA1WACO	µg/L
Phaeophytin-a	iCHLA1WACO	µg/L
Turbidity	iTURB1WCZZ	NTU
Colour	iCOL1WACO	TCU
TDS	iSOL1WDGR	mg/L