Biodiversity and Conservation Science

# Waterbird and invertebrate communities at Toolibin and Walbyring lakes during the 2021 fill event

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May 2024

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The recommended reference for this publication is:

Pinder AM, Venarsky MP, Cale DJ, Barrett A 2024 Waterbird and invertebrate communities at Toolibin and Walbyring lakes during the 2021 fill event, Department of Biodiversity, Conservation and Attractions, Perth.

Cover image:
Flooded swamp sheoak at the southern end of Toolibin Lake in November 2021,
(photographed by Maria Lee)

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# Key points

- Aquatic invertebrates, waterbirds and water quality were surveyed in Nov 2021 and Jan 2022, following the filling of Toolibin and Walbyring Lakes in July 2021.
- Aquatic invertebrate richness in Toolibin Lake was somewhat lower than for spring 2017 and so continues to be lower than expected. Contributing factors may include low dissolved oxygen concentrations, reduced viability of drought tolerant crustacean egg banks and few sources of freshwater colonists in the surrounding landscape. Invertebrate species richness in Walbyring Lake was about the same as for Toolibin and higher than in spring 2017. While the invertebrate communities appear to be somewhat depressed, they remain an important component of the lake's ecology, supporting numerous waterbird species.
- Waterbird richness and abundance in Toolibin Lake were within the range recorded by numerous surveys in the 1980s and comparable to data from 1996. Some species present in the 1980s continue to be absent reflecting current habitat features and absence of some prey species. Richness in Walbyring continues to be higher than in the 1980s. There was no evidence of compositional change in either lake since 1996. In Jan 2022 abundance in Toolibin Lake was the second highest on record, including the highest count of Hoary-headed Grebe. Walbyring Lake had an unusually high diversity and abundance of endemic shorebirds.
- Four of the six target waterbird species were present in Toolibin Lake in 2021/22 and three were breeding. The two absent species were Freckled Duck and Black-winged Stilt, but the former was present in low numbers at Walbyring Lake. Target species that were present (Grey Teal, Eurasian Coot, Australian Shelduck and Pink-eared Duck) were present in numbers within the ranges recorded during the 1980s, except that the number of Pink-eared Duck in Jan 2022 exceeded all previous counts.

# Summary

### 2021/22 fill event and sampling

- More than 150 mm was recorded across the central Wheatbelt in July and early August 2021, with 188 mm recorded at Wickepin and 189 mm in Narrogin. This resulted in the second fill event at Toolibin Lake in five years. Surveys of waterbirds, water quality and aquatic invertebrates were undertaken in early November 2021 and in mid-January 2022.
- This report presents analyses of waterbird and invertebrate communities present during the 2021/22 inundation of both lakes, with the aim of 1) comparing diversity with data from surveys in 1996 and 2017, and with information about earlier community structure, and 2) assess results against management goals.

### Hydrology and water quality

- Inundation of the lake from 15 July 2021 resulted in a peak depth of >2.12 m, with actual maximum depth for the fill event not known due to lake water overtopping gauges. The extent of the 2021/22 event is thus commensurate with the 2017 event (maximum depth at least 2.24 m) but starting in winter rather than summer. Depth during the 1996 event was not measured prior to September, when it was 1.15 m, but it would have been deeper earlier in the year after flooding in July.

- Toolibin Lake was fresh during both 2021/22 surveys, with conductivity up to 2734 µS/cm in Nov 2021 and up to 3719 µS/cm in Jan 2022. The Nov 2021 value was double that measured in Oct 2017 (up to 1327 µS/cm). Conductivity values in 2017 and 2021/22 were much lower than in Dec 1996 (up to 20200 µS/cm). Dissolved oxygen concentration was very low in 2017 and this was again the case in Nov 2021 but had moderately increased by Jan 2022. Phosphorus concentrations in Toolibin in Jan 2022 were similar to concentrations measured in 2017, with both years having higher concentrations than in Dec 1996. Elevated phosphorus concentrations in 2017 and 2022 may have been associated with low dissolved oxygen, but there may also be more entering the lake during fill events. Total nitrogen concentrations in Toolibin Lake have not changed over the 1996 to 2022 period, which also suggests an effect of oxygen on phosphorus concentrations.
- Conductivity in Walbyring Lake in Nov 2021 was lower (up to 1979 µS/cm) than in Toolibin, but the difference was not as great as in past years, and by Jan 2022 conductivity Walbyring had the higher salinity (up to 5134 µS/cm). Dissolved oxygen was low in Nov 2021, but recovered significantly by Jan 2022. Total filterable phosphorus concentrations were much lower in Jan 2022 than in Oct 2017 and lower than in Toolibin, but still higher than for 1996. The concentration of total filterable nitrogen was twice that in Toolibin, and higher than recorded in Walbyring in previous years.
- The concentrations of metals in the water were analysed for the first time but none were of concern in either lake.

### Invertebrates

- Toolibin Lake supported 51 and 47 species of macroinvertebrate in Nov 2021 and Jan 2022 respectively, with an average of 31 species/sample in both months. This brings to 118 the number of species recorded from this lake from 1996 to 2022. Species richness was lower than in Oct 2017 (where 57 species in total and an average of 41 per sample were present). Snails were recorded in Toolibin for the first time since the 1970s (an estuarine species). Other salt-sensitive groups including annelids, hydrozoans and flatworms (Turbellaria) were absent, even though they had been present in 2017, and mites remained in low diversity. There was some increase in diversity of ostracods and cladocerans after Cale and Pinder (2019) expressed concern about their low diversity in 2017.
- The invertebrate fauna present in Toolibin from 1996 is likely very different from that present in the 1970s when a range of fauna, including fish, bivalves and crayfish, were present that would have reflected very fresh conditions, frequent inundation and presence of submerged macrophyte beds. The fauna present in Toolibin Lake from 1996, with seemingly low richness in some sensitive groups, may reflect a combination of elevated salinity (at least in 1996, but perhaps an ongoing legacy effect despite now fresher conditions), less frequent inundation, loss of macrophytes and low dissolved oxygen. Infrequent inundation may have reduced diversity drought resistant egg banks of microinvertebrate groups, and there may be fewer sources of aerial and aquatic colonisation in good condition.

- Comparisons were made between Toolibin Lake and five moderate to good condition tree dominated Wheatbelt wetlands sampled by Pinder *et al.* (2004). These had an average sample richness of 54 species and range 43 to 73[1], compared to an average of 34 (range 27 to 43) for Toolibin between Oct 2017 and Jan 2022. Cale and Pinder (2019) noted that richness in Oct 2017 was low compared to the average of other Wheatbelt wetlands of similar salinity and this continues to be the case. Nonetheless, both wetlands continue to support functioning invertebrate communities supporting populations of predatory waterbirds.
- Walbyring Lake supported 52 and 49 species of macroinvertebrate in Nov 2021 and Jan 2022 respectively, with average sample richness of 35 in Nov and 37 in Jan; slightly higher than for Toolibin. This brings to 112 the number of species recorded from this lake from 1996 to 2022. In contrast to Toolibin, species richness in Walbyring was higher in 2021/22 than in Oct 2017 (43 species in total and 26 per sample). Hydra were collected for the first time in Jan 2022, but these tiny cnidarians are very easy to miss when sorting through samples. Amphipods were collected again (last collected in 1996) but annelids were absent and mites largely so. Microcrustacean diversity was about the same as in 2017, but with fewer copepods and more ostracods (in Nov) and cladocerans (both months).

### Waterbirds

- During 2021/22, 17 waterbirds species were recorded at Toolibin Lake and 20 at Walbyring Lake. The richness of individual surveys in 2021/22 was within the range recorded during numerous surveys in the 1980s and comparable to data from 1996, but at the lower end of the range of diversity recorded during ‘reference’ surveys from the 1970s and 1980s. Twenty-nine species have been present across the six 1996 to 2022 surveys. This is within the range of richness values from any six randomly selected surveys up to 1990 (21 to 34), or any six of the 12 reference[2] surveys (26 to 34).
- Waterbird richness in Walbyring Lake has shown a different pattern, with the number of species present in 1996 to 2022 (10-17) mostly exceeding the number present prior to 1996. In Nov 2021 and Jan 2022, 14 and 17 species were present respectively.
- There has been some shift in waterbird communities at Toolibin Lake compared to most of the comprehensive ‘reference’ surveys from the 1970s and 1980s. Australasian bittern and purple swamphen were affected by the loss of reed habitat and were no longer using the lake in the 1980s. Changes in community composition since the 1980s include reduced diversity of the diving guild (cormorants and grebes), already noted in 1996 and persisting in 2017 and 2021/22. It is likely that the loss of large prey species including fish, tadpoles, crayfish and shrimp has been responsible for reduced presence of this guild. Cale and Pinder (2019) also noted reduced diversity within the larger wader guild (herons etc.) in 2017, but diversity of this guild increased in 2021/22.
- Of the six target waterbird species listed in the Toolibin Lake Management Plan (Department of Biodiversity, 2017a), all except Black-winged Stilt were present 2017,

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[1] Excluding rotifers and protozoans because these were not identified in 1996 and 2021/22.

[2] See Methods for how ‘reference’ surveys were selected.

although Freckled Duck was represented by just one individual. Black-winged Stilt and Freckled Duck were absent in 2021/22. However, only two-thirds of the reference surveys recorded Freckled Duck and then often only 1 or 2 individuals, so its absence in 2021/22 may not be significant. Black-winged Stilt are more likely to be present when the wetland is shallower, so their absence in 2017 and 2021/22 is not surprising. The count of 372 Pink-eared Ducks in Jan 2022 was higher than for any previous survey of Toolibin.

- The total numbers of waterbirds counted at Toolibin Kake in Nov 2021 and Jan 2022 were 478 and 2472 respectively. Total abundances for the five 1996 to 2022 surveys were within the range of values for the 1970s and 1980s reference surveys. Grey Teal were the most abundant species in 2021/22, and the Jan 2022 count included record numbers of Hoary Headed Grebe.
- The total numbers of waterbirds counted at Walbyring Lake in Nov 2021 and Jan 2022 were 358 and 619 respectively. Much greater abundance of waterbirds, especially ducks and grebes, have been counted at the lake from 1996. Shorebirds constituted nearly a third of birds present in Jan 2022 (Black-winged Stilt, Black-fronted Dotterel, and Red-kneed Dotterel) but these species have not previously been recorded at this lake.
- During 2021/22 there was evidence of breeding for seven species at Toolibin Lake; one more than in 2017. These are comparable to the number of species reported breeding in many other surveys, with 1 to 9 species breeding (average 4) in the 1980s reference surveys reported by Jaensch *et al*. (1988). At Walbyring Lake, breeding was detected for five species, two more species than in 2017.

# Introduction

Toolibin Lake lies 180 km south-east of Perth within the Wheatbelt Region of Western Australia. Together with the similar Walbyring Lake, immediately downstream, Toolibin lies within a 1230 ha system of Class “A” nature reserves at the headwaters of the Northern Arthur River (Department of Biodiversity, 2017b). The wetlands in these reserves are actively managed by the Western Australian Department of Biodiversity, Conservation and Attractions for their significant biodiversity value, and Toolibin Lake is listed under the Ramsar convention.

Toolibin Lake is the most important example of the threatened ecological community (TEC) comprising “perched wetlands, in the Wheatbelt region, with extensive stands of living swamp sheoak (*Casuarina obesa*) and paperbark (*Melaleuca strobophylla*) across the lake bed” (Hamilton-Brown & Blyth, 2000). This community type is listed as critically endangered under the Biodiversity Conservation Act 2016. This wetland type is characterised by an undulating lake bed with gilgai sediments, with an overstorey of *Melaleuca* and taller sheoak and a dependence on seasonal, temporary inundation with freshwater. While once widespread, salinisation as a result of land clearing has degraded at least 90% of the area and occurrences of this TEC (*op.cit*).

Land clearing for agriculture has caused salinization of many Wheatbelt wetlands and has long been recognised as a primary threat to the persistence of Toolibin Lake’s fauna and flora (Northern Arthur River Wetlands Committee, 1987). Toolibin Lake is the last major natural wetland, within a chain of wetlands in the headwaters of the Arthur River, that has not become saline (McMahon, 2006)[3]. Most of the wetlands in this chain are significantly degraded by secondary salinity, which has resulted in increased salt loads from surface inflows and direct interaction with groundwater. Salinisation had already affected some overstorey vegetation elements at Toolibin Lake by the 1980s when capillary action from rising groundwater increased soil salinity when the lake was dry and caused a loss of vigour amongst even the most tolerant species (Froend *et al.*, 1987). The loss of some fringing beds of sedges may have occurred during the 1970s (Casson & Atkins, 1989; Froend, Halse & Storey, 1997). Before land clearing in the catchment Toolibin Lake was an ephemeral fresh to brackish wetland and believed to fill in seven out of ten years (Stokes & Sheridan, 1985; Rutherford *et al.*, 2016). The lake typically filled with seasonal rain and then retained water, even in the absence of further inflow, into a second year, albeit with a decline in depth and breeding of waterbirds (Casson & Atkins, 1989).

Engineering solutions for the management of saline water in the Lake Toolibin catchment were implemented from 1994 (Department of Biodiversity, 2017a) and include:

- Groundwater pumping to maintain the water table below the root zone of trees and reduce the interaction of saline groundwater with the lake bed and surface water.
- A diversion bank which can allow entry of high volume, fresh surface inflows (<2000 μS/cm) to the lake, but divert saline flows past Toolibin and Walbyring Lakes into saline wetlands further downstream.

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[3] This may also be true of the very similar Walbyring Lake, in terms of actual salinity, though tree condition is worse in the latter.

- A system of sump, channels and a pump on the lake bed which can be used to remove surface water in the drying phase of the lake, before evapo-concentration increases salinity above 10 mS/cm, thus preventing the accumulation of salt.

However, maintenance of water quality has come at some cost. The diversion bank has successfully diverted all but the freshest inflows since 1994 which, in conjunction with declining rainfall has meant a reduced volume and frequency of inflows (e.g. Muirden & Coleman, 2014; Table 4.9). While there have been a few small fill events since 1994 (e.g. 2008 and 2012) these have inundated only portions of the lake bed and persisted for only a few months. Sufficient inflow to raise lake levels and maintain them for a period approaching 12 months occurred in 1996, 2006, 2017 and 2021 when the wetland was filled to a depth of ca 1 m (Bowra & Wallace, 1997), 0.96 m (Bourke & Rutherford, 2018), 2.25 m (Cale & Pinder, 2019) and >2.12 m respectively. In each of these events the wetland dried within 12 months of filling compared to hydroperiods sometimes approaching 2 years for earlier fill events (Casson & Atkins, 1989 pg5; Lane, Clarke & Winchcombe, 2017). Consequently, rather than the wetland being inundated 70% of the time (e.g. Froend *et al.*, 1987) inundation occupied < 15% of the 20 year period from 1996 to 2021 including two decade-long periods without significant inundation. The inundation that commenced in July 2021 came five years after the previous inundation event but did not alter the proportion of the time the wetland has held water since 1996.

The conservation value of the TEC, the waterbird assemblages and the importance as a breeding site were integral to the listing of Toolibin Lake as a wetland of international importance under the Ramsar Convention. At Toolibin Lake, data for the occurrence of waterbird species have been collected since the 1970s (see Froend & Storey, 1996 for a review), with 50 species recorded in total (McMahon, 2006). A series of 49 surveys of waterbirds conducted between 1981 and 1985 as part of the "Waterbirds in Nature Reserves Study" (Jaensch, Vervest & Hewish, 1988), recorded 41 species, ranking Toolibin Lake as 13th when compared with 197 other wetlands surveyed during the same period. Twenty-two species were recorded breeding by these authors, ranking 1st amongst the 197 studied wetlands and representing the highest published richness of breeding species in wetlands of the south-west region of Western Australia. Walbyring Lake was included in these surveys but supported a less diverse assemblage of species; total richness was 19 species with 7 species breeding, giving ranks of 55 and 23 respectively (Jaensch *et al.*, 1988). Halse (1987) attributed the importance of Toolibin Lake as a breeding site to three factors: 1) the stands of inundated paperbark and sheoak, 2) water quality sufficiently fresh to support this vegetation and very young waterbirds and 3) periodic drying which again supported the vegetation and also increased the production of food for breeding birds.

Breeding of several waterbird species at Toolibin Lake during the 1980s was particularly significant because there were few breeding sites for these species throughout the south west. These included Great Cormorant for which Toolibin Lake was the only recorded breeding site, Freckled Duck which bred in only 4 wetlands, and Little Pied Cormorant, Little Black Cormorant, Blue-billed Duck, White-necked Heron, Great Egret, Rufous Night Heron and Yellow-billed Spoonbill, all of which bred in <10 of the 197 studied wetlands (Jaensch *et al.*, 1988).

During the 2017 fill event, 19 species of waterbirds were recorded at Toolibin Lake and 16 at Walbyring (Cale & Pinder, 2019). The richness of individual surveys in 2017 was within the range recorded by numerous surveys in the 1980s and comparable to data from 1996. There was evidence for six species breeding across the two wetlands.

There has been some compositional change in waterbird communities since the 1970s. Australasian Bittern and Purple Swamphen were affected by the loss of reed habitats and were no longer using the lake in the 1980s. Changes in community composition since the 1980s include reduced diversity of the diving (cormorants and grebes) and large wader (herons, egrets and spoonbills) guilds. The reduced number of species in these guilds was already established in 1996 and persisted in 2017 and it is likely that the loss, since at least the early 1990s, of large prey species including fish, tadpoles and freshwater crayfish and shrimp was critical. There is no evidence that differences in the invertebrate communities between 1996 and 2017 further restricted the development of waterbird communities.

Three previous studies have documented the community structure of aquatic invertebrates at Toolibin Lake and Walbyring Lake. Doupé and Horwitz (1995) collected 36 species at Toolibin Lake in September 1992 and 31 species at Walbyring Lake. The collected fauna was dominated by aquatic insects and a large proportion of the richness at each lake was not collected in the other. In December 1996, Halse *et al*. (2000) collected 52 and 63 species at Toolibin Lake and Walbyring Lake respectively and suggested that the higher richness (a product of greater sampling effort compared to 1996) was a better reflection of the conservation value of the wetlands. Toolibin Lake supported 35 and 57 species of macroinvertebrate in April and October 2017 respectively (Cale & Pinder, 2019). This was higher than the richness observed at Walbyring Lake (22 and 42 species recorded for the same periods). Invertebrate richness was lower than would be expected for a fresh Wheatbelt wetland and Cale and Pinder (2019) suggested this was due to a combination of low dissolved oxygen, especially in April 2017 (only 2 months after filling), depletion of resting egg banks after the 20 year dry period, and poor condition in neighbouring wetlands that would have been sources of colonising invertebrates.

# Methods

## Field visits

Both wetlands were visited on November 1-2, 2021 (3.5 months after filling) and January 10-11, 2023 (6 months after filling), except that the western site at Walbyring Lake was not sampled until 16 Nov in spring. Invertebrates and water quality were sampled at the same sites as were sampled in 2017 and 1996 (see Cale and Pinder (2019))

## Water chemistry

Field measurements of electrical conductivity, pH and temperature were collected at each invertebrate sampling location on each survey. Dissolved oxygen was measured only in Nov 2021 and turbidity was measured in the field only in Jan 2022 at two sites within each wetland. Water quality samples for analyses of nutrients, metals, ionic composition, plus colour, total dissolved solids, alkalinity and hardness were also collected in January at the same two sites per wetland. For nutrients, total nitrogen, total Kjeldahl nitrogen and total phosphorus were analysed from unfiltered water samples. Other nutrient analyses were performed on water filtered through a 0.45 µm filter. All water samples were processed by Eurofins ARL Pty Ltd.

*Table 1. Invertebrate and water quality sampling Locations in Toolibin and Walbyring Lakes*

| Site | Description of habitats in 2021/22 | Coordinates |
|---|---|---|
| Toolibin West (TW) | Open water with dead Tecticornia and filamentous algae and underneath dense Casuarina. ~50% cover of coarse organic matter (leaves, sticks) and 5% logs. Fine sediment (silt/clay/sand). No submerged macrophytes. | 32.91944082˚ S 117.5992981˚ E |
| Toolibin South (TS) | Open water and beneath live and dead Casuarina and Eucalypt trees. No submerged macrophytes. Fine sediment (silt/clay/sand) covered by thin benthic algal mat. 95% cover of organic matter (particulate, leaves, sticks) and 5% cover of logs. | 32.92983572˚ S 117.6095301˚ E |
| Toolibin East (TE) | Open water and beneath live and dead Casuarina and a few eucalypt saplings. No submerged macrophytes. Fine sediment (silt/clay/sand) covered by thin benthic algal mat. 90% cover of organic matter (mostly particulate, few leaves and sticks) and 10% logs. | 32.92149˚ S 117.6166˚ E |
| Walbyring East (W1b) | Open water with sparse dead trees (other than fringe of live trees). Fine sediment (silt/clay/sand) with thin benthic algal mat. ~60% cover of organic matter (mostly particulate, few leaves and sticks) and 5% logs. No submerged macrophytes. | 32.93628023º S 117.5961924º E |
| Walbyring South (W2) | Open water with sparse dead trees (other than fringe of live trees). Fine sediment (silt/clay/sand) covered with benthic algal mat. ~60% cover of organic matter (mostly particulate, few leaves and sticks) and 5% logs. No submerged macrophytes. | 32.93902882o S 117.5939556o E |
| Walbyring West (W3) | Amongst dead trees and terrestrial shrubs with coating of filamentous algae. Fine sediment (silt/clay/sand). ~50% cover of coarse organic matter (mainly sticks). No submerged macrophytes. | 32.9343627o S 117.5877944o E |

## Waterbirds

### Historical waterbird surveys

There have been numerous surveys reported on in previous publications, but the origin and availability of these have not been adequately documented in one place. These are:

**1965 to 1975.** A species list compiled by Goodsell (1978, in Northern Arthur River wetlands Rehabilitation Committee 1978). This list, with some annotation of habitats was compiled from records collated over the period 1965 to 1975, but the results of individual surveys are not presented or known to be available. Northern Arthur River Wetlands Rehabilitation Committee (1978) note that 40 aquatic bird species had been recorded using “Toolibin Lake and environs”, which likely means Taarblin through to Dulbinning. Goodsell (1978) lists 37 species of waterbird, but it is clear that the list refers to the regional lakes not just Lake Toolibin, though most would have occurred at Lake Toolibin. Froend *et al.* (1997) cite this as the number recorded at Lake Toolibin and this figure is similarly used in Froend and Storey (1996).

**1974**. In a file kept by Jim Lane (DBCA Busselton, retired) (file 4 part II), is a note by a K.D. Morrison on a survey of Lake Toolibin conducted on 16 Dec 1974. Twenty four species are listed including reed warblers, making this the richest individual survey. This was a comprehensive survey by boat over two days. Given that the survey was undertaken in a dinghy we assume the lake was reasonably deep.

**1975**. Munro (1975) compiled a report as background to a visit to Lake Toolibin by the West Australian Bird Committee. In this, he reports on a waterbird survey undertaken in late October 1975, recording 18 species. No abundance data is provided. Munro’s description suggests this survey was reasonably comprehensive, covering much of the lake including the lake centre.

**1976**. In the same Jim Lane file (file 4 part II) is a note on a survey of Lake Toolibin undertaken by (Jim?) Rolfe on 29-30 Dec 1976, recording 14 waterbirds. No information on the extent of the survey is provided but the fact that 5000 grey teal were counted suggests much of the lake was surveyed. On the same pages are notes from observations by Don Munro with results of other surveys including 9 species on 15 Dec 1976, with 1 species not recorded by Rolfe. This extra species is added to the Rolfe list for analysis. This file also contains numerous other individual waterbird observations from the 1970s.

**1981 to 1987.** Sixty one surveys of Toolibin Lake and Walbyring Lake were undertaken as part of a citizen science project (Waterbirds in Nature Reserves of Southwestern Australia) run by RAOU (BirdLife WA) and CALM (DBCA) and reported in Jaensch *et al*. (1988). The consistency of these is not clear but participants were asked to note where they believed all species had been observed. This was the case for just five surveys. Jim Lane’s files have a numerous other ad-hoc waterbird observations over this period.

**1988 and 1990.** Two surveys undertaken at Lake Toolibin (Aug 1988 and Sep 1990) by Stuart Halse and colleagues are unpublished, but data is available. A survey of Walbyring was also undertaken in Sep 1990. These surveys are assumed to have been reasonably comprehensive.

**1990**. Froend *et al*. (1997) note a survey undertaken by “Blyth” in March 1990 but we have not been able to source this data.

**1993**. Froend *et al*. (1997) note a survey undertaken by “Mitchell” in March 1993 but we have not been able to source this data.

**1996.** Surveys of Toolibin and Walbyring were undertaken on 4 July and 21 August (by “Silvester and Nicol’ – data held by DBCA), by DBCA’s Grant Pearson on 4 December (as recorded in Jim Lane Toolibin file 1) and 18 December (DBCA’s Stuart Halse). Data from the latter two surveys were published by Halse *et al*. (2000).

**2017**. Cale and Pinder (2019) report on surveys in April and October 2017.

### 2021/22 waterbird survey

Waterbirds were surveyed on 1 Nov 2021 and 10 Jan 2022 at Toolibin Lake and on 2 Nov 2021 and 11 Jan 2022 at Walbyring Lake. All surveys were conducted by boat, starting adjacent to the pumping station, with two observers and a skipper. Care was taken to investigate all areas of the lakes and observers were reasonably confident that all species present were recorded; however, abundance within dense stands of live trees in Toolibin Lake was likely underestimated. All broods and active nests were recorded as evidence of breeding, however no active searching for nests or other signs of breeding was attempted.

### Reference waterbird communities

Froend *et al.* (1997) examined trends in waterbird communities in Toolibin Lake using just those surveys that were undertaken when the lake was relatively deep (>0.76m). These included five surveys from Jaensch *et al*. (1988), the 1975 survey by Munro, the 1988 and 1990 surveys by Stuart Halse and colleagues, plus the two surveys (Blyth and Mitchel) for which we now lack the data. For our analyses we also add the 1974 survey by Morrison, the 1976 survey by Rolfe and two additional Jaensch *et al*. (1988) where surveyors believed they had recorded all surveys and depth was >1.0m. These twelve ‘reference’ surveys are contrasted with surveys undertaken from 1996. Reference surveys were not identified for Walbyring Lake as few of the Jaensch *et al*. (1988) surveys were scored as complete and there were fewer surveys overall.

## Invertebrates

### Sampling methods

Three sites were sampled for invertebrates in each of Toolibin and Walbyring lakes (Figure 1). The sites are those used by Halse *et al*. (2000) and Cale and Pinder (2019) in October 2017. Site 1A was only sampled by Cale and Pinder (2019) in April 2017. Coordinates are provided in Table 2.

*Table 2. Invertebrate sampling locations.*

| Wetland | Site code | Latitude | Longitude |
|---|---|---|---|
| Toolibin | W | -32.91944082 | 17.5992981 |
| Toolibin | E | -32.92149 | 117.6166 |
| Toolibin | S | -32.92983572 | 117.60953 |
| Walbyring | 1B | -32.93628023 | 117.596192 |
| Walbyring | 2 | -32.93902882 | 17.5939556 |
| Walbyring | 3 | -32.9343627 | 17.5877944 |

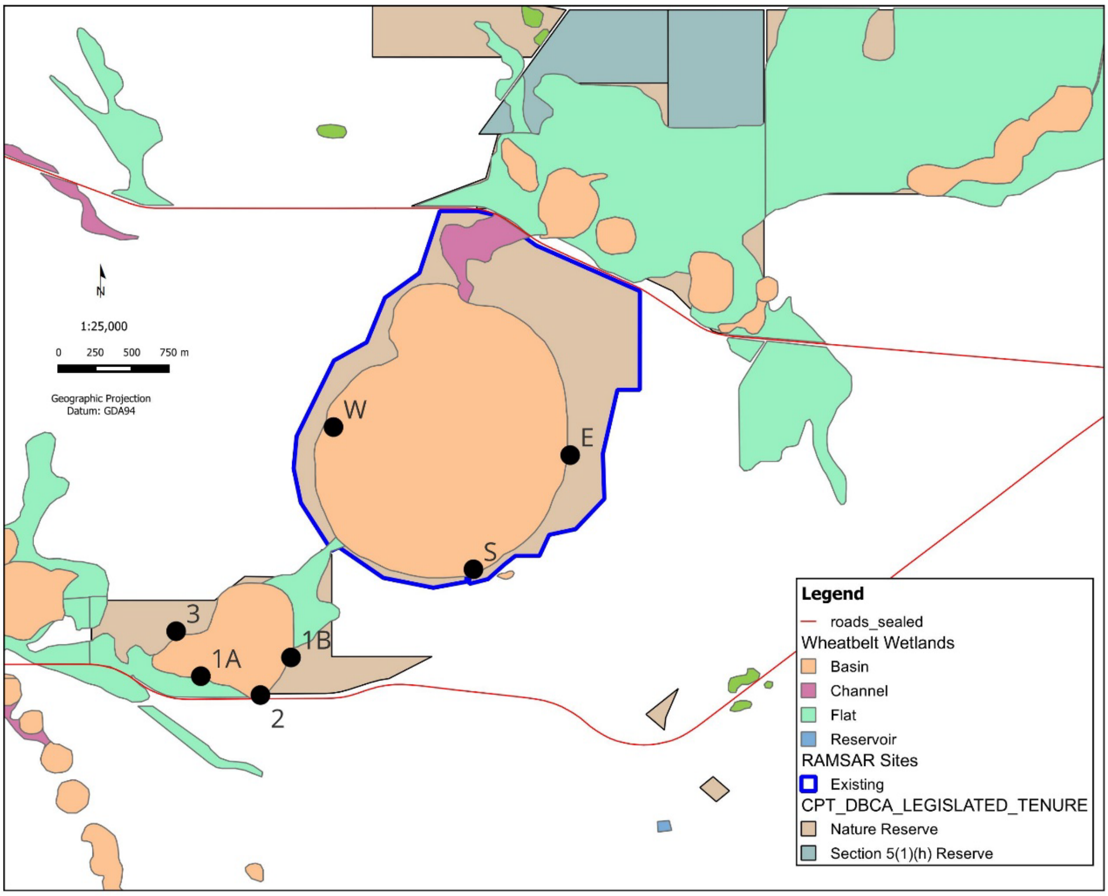

*Figure 1. Map of Toolibin and Walbyring Lakes showing invertebrate sampling locations.*

Two invertebrate samples were collected at each site. Firstly, a sample was collected using a standard FBA D-framed net with a 53 µm mesh to gently sweep the water column and submerged surfaces over a disjunct 50 m sampling path that included all recognisable microhabitats over an area of approximately 200 m. A second sample was collected with a net 250 µm mesh net on the same type of frame using vigorous sweeping of surfaces and ‘heal kicks’ of benthic substrates to collect larger, faster species and ensure collection of sediment dwelling species. These samples were preserved in the field in 100% ethanol and processed in the laboratory. Laboratory processing involved 1) sieving samples with a graded series of sieves to assist in the detection of all species under a binocular microscope at 10-50x magnification and 2) the removal of sufficient representative specimens of each taxonomic group to ensure identification of all species. Specimens from the two subsamples were combined to yield a single sample of community structure for each site. The efficacy of this sampling protocol has been described elsewhere (Halse *et al.*, 2000; Pinder *et al.*, 2010). The 2017 and 2021/22 sampling protocol only differs from the methods used at Toolibin Lake by Halse *et al*. (2000) in the use of a 53 µm rather than 110 µm mesh size. A 53 µm is standard for DBCA plankton sampling. The use of a 110 µm mesh net in 1996 would not have affected results since the smallest animals (rotifers and protozoans, were not being examined. The sampling protocol represents a much greater sampling effort than reported by Doupé and Horwitz (1995) who took a single sample with a 500 µm mesh size over a much smaller area. Invertebrate data is entirely presence/absence because abundance estimation is too time consuming and actual area of sampling too difficult to estimate.

### Comparison invertebrate data

Five additional freshwater tree dominated wetlands with clear water that remained in good condition were used to place the current aquatic invertebrate communities of Toolibin into a broader regional context. These were sampled as part of the Wheatbelt Biological Survey (Pinder *et al.*, 2004) using the same methods as used at Toolibin since 1996. These wetlands were dominated by either Yate (*Eucalyptus occidentalis*) or *Melaleuca* and sedges (SPS111) (Figure 2 and Table 2). These are the best condition wetlands with trees across their bed in the agricultural zone for which we have comparable data, but it should be noted they are all on the edge of, or beyond, the Avon Wheatbelt IBRA region, and they may not be expected to have a similar fauna to each other or to Toolibin Lake. We have used the term ‘comparison’ wetlands rather than ‘reference’ because they are not entirely the same types of wetlands, either as each or in comparison to Toolibin and Walbyring, and some may not have been pristine themselves.

*Table 3. Locations of the comparison wetlands used in the invertebrate analyses.*

| Site Code | Location | Latitude | Longitude |
|---|---|---|---|
| SPS049 | 70km NE of Hyden | -31.953 | 119.3 |
| SPS072 | 35km ENE of Southern Cross | -33.13 | 119.679 |
| SPS082 | 10km E of Lake Magenta NR | -33.636 | 119.353 |
| SPS083 | 6km W of Lake Magenta NR | -33.652 | 118.79 |
| SPS111 | 29km WNW of Cranbrook | -34.232 | 117.247 |

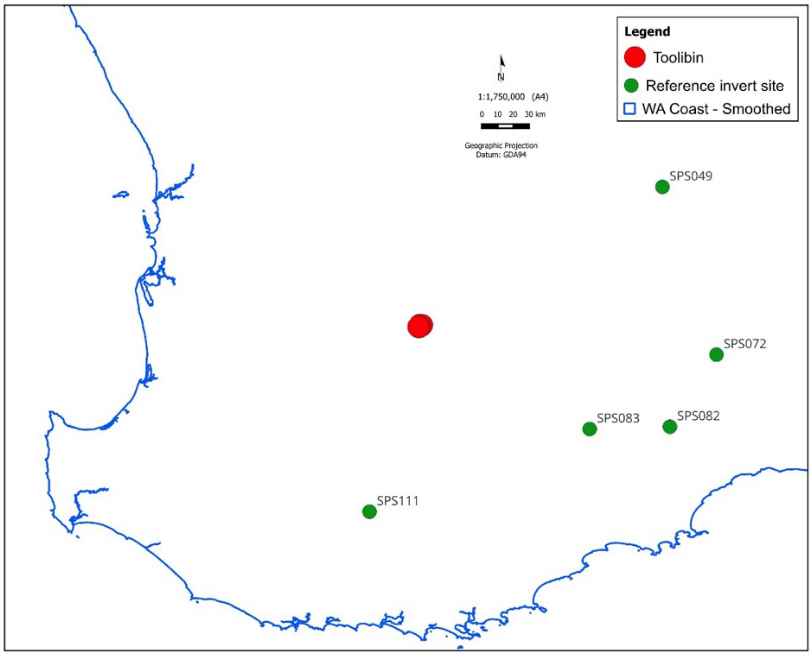

*Figure 2. Locations of the five comparison wetlands used in the invertebrate analyses, from Pinder et al (2004).*

## Analyses

All analyses were performed using R v.4.3.1 (R Development Core Team, 2023) in RStudio. Multivariate analyses were performed using the vegan package (Oksanen *et al.*, 2022). Ordinations were non-metric multidimensional scaling, based on Bray-Curtis dissimilarities calculated from presence/absence data (invertebrates) or Hellinger transformed abundance data (waterbirds). Dendrograms were based on agglomerative hierarchical clustering using Bray-Curtis dissimilarity of invertebrate presence/absence data and average linking (also known as Un-Paired Group Mean Averaging or UPGMA).

The multi-year invertebrate dataset was edited to ensure consistency in taxonomic scope and resolution across surveys and to reflect improved taxonomic knowledge. This means richness values used in this report may not match those quoted in previous reports. Rotifers and protists were not included in the invertebrate analyses because they were only identified in 2017. Some invertebrate groups that could not be identified to species (such as nematodes, flatworms, sponges and hydrozoans) are excluded from multivariate analyses.

# Results

## Water chemistry

Table 2 has all field measured water quality data collected during the Nov 2021 and Jan 2022 surveys and Table 3 and Appendix 1 has original laboratory water quality results for Jan 2022. Table 4 and Table 5 contain selected water quality variables associated with waterbird surveys from the 1980s to 2021/22. Depths quoted for Lake Toolibin are either from the SWMMP gauge boards on the eastern side of the lake or the DWER gauge at monitoring location 609009 (with the latter increased by 0.4 metres to be comparable with the contemporary and historical SWMMP gauge board readings).

Toolibin Lake filled to a maximum depth of more than 2.12 m by late July/early August following removal of the diversion gates on 14 Jul 2021. Unfortunately, all depth gauges were submerged from this time until September, so the maximum depth of the inundation is unknown, but is likely to have been similar to the 2017 event when a maximum of 2.48 metres was reached. The minimum recorded conductivity was 1236 µS/cm on 4 Aug and conductivity increased from then on, indicating that maximum depth may have been reached on or before then, although salts dissolving from sediment may have confounded this. By the time depth could be again recorded from the DWER gauge board on 8 September, at 2.11 metres, conductivity was 2190 µS/cm. Depth on 28 October immediately prior to the November fauna sampling was 2.05 metres (DWER gauge) and conductivity 2150 µS/cm measured during the regional monitoring program. This is somewhat lower than the 2675 to 2734 µS/cm measured during the survey on 1-2 Nov using a different meter. By mid-January 2022 depth had declined to 1.51 metres (DWER gauge) and conductivity measured by the regional monitoring program was 3490 µS/cm, which is closer to the measurement of 3710 to 3714 µS/cm measured during the fauna survey of 10-11 January. The lake was thus fresh for both surveys, if fresh is taken to be <5000 µS/cm (approx. 3 g/L).

Conductivity in Nov 2021 (when the lake had a depth of 2.05 m) was nearly twice that measured in Oct 2017 (1392 to 1483 µS/cm) when the lake was shallower (1.41m), suggesting the lake filled with more saline water in 2021 than in 2017.

Conductivity for surveys in 2017 and 2021/22 were much lower than for Dec 1996 when Halse *et al.* (2000) recorded 15200 to 20200 µS/cm at a much shallower depth of 0.66 m (5 months after filling). Doupé and Horwitz (1995) reported conductivity of 4000 to 5000 µS/cm in Sep 1992, so double the salinity in Oct 2017 and Nov 2021, but only slightly higher than for Jan 2022. No depth was reported, but Lane *et al*. (2017) recorded a depth of 1.88 metres in the middle of that month with a salinity of 2.08 g/L (approx. 3500 µS/cm using the conversion of Williams (1966)).

Water chemistry was generally not recorded during the 1980s waterbird surveys of Jaensch *et al*. (1988) but salinity measured by Lane *et al*. (2017) during Sep and Nov 1981-1985 averaged 3.1 g/L (approx. 5200 µS/cm), with a range of 0.96 to 10.2 g/L (~1.600 to 17000 µS/cm), or 2.7 g/L (= 4500 µS/cm) without the single measurement > 5g/L. No salinity or conductivity data is associated with the waterbird data from the 1970s.

Walbyring Lake was 1.23 metres deep by 29 July 2021 and conductivity 548 µS/cm. Depth peaked at 1.28 metres on 4 August (conductivity 350 µS/cm) and by the time of the November fauna survey had declined to 0.88 metres and conductivity was 1674 µS/cm (measured by the regional monitoring program). As for Toolibin, this measurement was lower than the 1925 to 1979 µS/cm measured during the November fauna survey. The January survey was undertaken when depth of Walbyring was 0.42 metres and conductivity was measured at 4593 to 5134 µS/cm (similar to the measurement of 4960 µS/cm by regional staff a week later).

Surveys of Walbyring Lake in April and October 2017 were undertaken when conductivity was just 611 to 647 µS/cm and 1113 to 1120 µS/cm respectively, so both fresher than for either of the 2021/22 surveys. Conductivity was 4200 µS/cm when the lake was surveyed in December 1996 by Halse *et al*. (2000); similar to the January 2023 values. Conductivity in Walbyring Lake was 1700 µS/cm in Sep 1992; similar to the Nov 2022 values.

As well as differences in salinity, there were major differences in water colour, total chlorophyll and dissolved oxygen between the 1996, 2017 and 2021/22 sampling events in Toolibin and Walbyring. Toolibin Lake water was darker in April and October 2017 (500 and 190 TCU on eastern shore) and in January 2023 (only 12 near the western edge but 250 near the eastern shore) than in 1996 (54 near eastern shore). Walbyring had TCU values of 700 and 440 in April and October 2017 respectively, compared to 250 and 260 in January 2022, with both of these periods having more coloured water than December 1996 (89). Cale and Pinder (2019) attributed the higher colour in 2017 to 20 years of accumulated organic matter build up and this may still have been the case with some organic matter remaining after the 2017 fill and more accumulating in the following years.

In December 1996, dissolved oxygen (DO) was in excess of 200% of saturation at Toolibin Lake, a condition which typically occurs in the presence of substantial photosynthetic activity, especially by submerged macrophytes. Chlorophyll concentrations in the water column (a surrogate for algal photosynthetic activity) were low (<7 µg/l) suggesting that the oxygen generating photosynthesis was occurring on substrates or from submerged macrophyte beds (Halse *et al*. (2000) hinted at the presence of submerged macrophytes). Similar conditions prevailed at Walbyring Lake in 1996 although DO was lower (154%) and chlorophyll concentrations in the water column were higher (36 µg/l).

In April 2017 Toolibin Lake had substantial photosynthesis occurring in the water-column with total chlorophyll concentrations > 140 µg/l, and 14 to 44 µg/l in October. Rather than elevating dissolved oxygen concentrations, vertical profiling of the water column at Toolibin Lake on 9 May 2017 indicated that DO concentrations were 15-36% of saturation at the surface and declined with increasing depth (Bourke & Rutherford, 2018). Low DO was probably in response to the high biological oxygen demand of decomposing leaf litter and organic sediments but the algal bloom may have contributed to this if it was decaying. Negative redox potentials during a repeat of the vertical profiling in October 2017 (*op. cit.*) imply that low oxygen concentrations persisted at Toolibin Lake throughout the period of waterbird and invertebrate sampling in 2017. There are no data to determine the status of DO concentrations at Walbyring Lake in 2017. Dissolved oxygen was similarly very low in Lake Toolibin in November 2021, with 22.2 to 33.4% near the surface and only 11.5 to 22.7% near the bottom. Dissolved oxygen measured at mid-water column in January 2022 had increased to 58.1 to 64.3%.

Walbyring Lake had similarly low DO values of 29.5 to 32.4% (near the top) and 20.1 to 29.1 (near the bottom) in November 2021 but much higher saturation in January 2022 (98.6 to 85.8 % at mid-water column).

Total phosphorus (TP = filterable and non-filterable P) in Jan 2022 was 0.27 mg/L in Toolibin and 0.32 to 0.4 in Walbyring. This has not previously been measured in either lake for previous fauna surveys, but these concentrations are significantly above the ‘default trigger values’ for TP for south-west Australian wetlands of 0.06 mg/L (ARMCANZ/ANZECC 2000). In Toolibin, more than 70% of TP was filterable (= total dissolved P), with concentrations of 0.21 to 0.24 mg/L. This is slightly higher than for 2017 (0.16 to 0.21 mg/L and significantly higher than in 1996 (0.01 mg/L). Filterable reactive phosphorus (FRP or orthophosphate), which is the form most readily available for plant and algal growth, was just 0.05 mg/L in Toolibin, which is also above the ARMCANZ/ANZECC trigger of 0.03 mg/L. Elevated phosphorus in Toolibin may be associated with low oxygen concentrations resulting in phosphorus release from the sediment (Wetzel, 2001). In Walbyring, filterable phosphorus was lower than for Toolibin (0.11 to 0.14 mg/L) but FRP was about the same (0.03 to 0.05 mg/L). While oxygen concentrations had recovered in Walbyring by January, the high phosphorus concentrations in that lake may reflect lower oxygen earlier in the inundation event.

Total nitrogen (TN) in Jan 2022 was 3 to 3.3 mg/L in Toolibin and 6.6 to 8 mg/L in Walbyring. This has not previously been measured in either lake for previous fauna surveys, but these concentrations are significantly above the ‘default trigger values’ for TN for south-west Australian wetlands of 1.5 mg/L (ARMCANZ/ANZECC 2000). In both lakes, almost all nitrogen was filterable and this mostly in organic forms (Kjeldhal N minus ammonia) rather than more readily available nitrate/nitrite and ammonia. Total filterable N in Toolibin (2.9 to 3 mg/L) in Jan 2022 was similar to 2017 (2.4 to 5) mg/L and 1996 (3.6 to 4.2 mg/L). That water column nitrogen concentrations in Toolibin were not higher than they were in 1996, suggests the phosphorus concentrations are related to low DO rather than being entirely a result of increase in inflowing water, though the latter should not be discounted. By contrast, total filterable nitrogen in Walbyring Lake was about 30% higher than in 2017 and double that present in 1996.

Chlorophyll was not measured in 2021/22 but there were no signs of an algal bloom when the wetland was visited.

Both lakes were sodium chloride dominated but Toolibin Lake had a much higher proportion of sulfate amongst the anions, at the expense of bicarbonate.

The concentrations of metals were measured in both lakes in January 2022. Most metals were below detectable limits. Arsenic was 0.002 mg/L and 0.004 mg/L in Toolibin and Walbyring respectively, which is slightly above the default guideline values for protecting 99% of aquatic species (0.0008 to 0.001 mg/L depending on the form of arsenic) but well below the figure for protecting 95% of species (0.0013 to 0.024 mg/L) (https://www.waterquality .gov.au/guidelines/anz-fresh-marine). Nickel was also detectable, but only at Walbyring and at a concentration (0.003 mg/L) below the default guideline values for protecting 99% of aquatic species (0.008 mg/L).

*Table 4. Field measured water chemistry for the three sample sites in each lake in November 2021 and January 2022.*

| | | Nov-21 | | | | | | Jan-22 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Toolibin | | | Walbyring | | | Toolibin | | | Walbyring | | |
| | | W | S | E | 1b | 2 | 3 | W | S | E | 1b | 2 | 3 |
| Date | | 11/04/2017 | 12/04/2017 | 12/04/2017 | 2/11/2022 | 2/11/2022 | 16/11/2022 | 11/01/2023 | 28/10/2017 | 27/10/2017 | 28/10/2017 | 28/10/2017 | 28/10/2017 |
| Maximum depth of invertebrate sample | m | 0.95 | 0.9 | 0.8 | 0.75 | 0.7 | 0.4 | 0.6 | | | | | |
| Total dissolved solids near top* | g/L | 1.74 | 1.77 | 1.77 | 1.25 | 1.25 | 1.44 | | | | | | |
| Total dissolved solids near bottom* | g/L | 1.74 | 1.77 | 1.78 | 1.25 | 1.25 | | | | | | | |
| Electrical conductivity | (µS/cm) | 2675 | 2734 | 2733 | 1925 | 1930 | 1979 | 3710 | 3719 | | 4593 | | 5134 |
| pH near top | | 6.79 | 6.44 | 6.5 | 6.92 | 6.79 | 8.35 | | | | | | |
| pH mid depth | | | | | | | | 7.55 | 7.59 | | 8.23 | | 8.19 |
| pH near bottom | | 6.9 | 6.64 - 6.68 | 6.66 | 6.94 | 6.86 | | | | | | | |
| Dissolved oxygen near surface | % saturation | 33.4 | 22.2 | 27.6 | 29.5 | 32.4 | | | | | | | |
| Dissolved oxygen mid depth | % saturation | | | | | | | 58.1 | 64.3 | | 98.6 | | 85.8 |
| Dissolved oxygen mid depth | mg/L | | | | | | | 4.68 | 5.25 | | 8.21 | | 7.37 |
| Dissolved oxygen near bottom | % saturation | 20.3 – 22.7 | 14-19.3 | 11.5 | 20.1 | 29.1 | | | | | | | |
| Turbidity | FNU | | | | | | | 1304 | 1316 | | 1259 | | 1292 |
| Temperature near top | (°C) | 16.2 | 18.1 | 19.2 | 20.7 | 21.1 | 29.2 | 25.9 | 25 | | 23.8 | | 22.1 |
| Temperature mid depth | | | | | | | | | | | | | |
| Temperature near bottom | (°C) | 16.2 | 18.1 | 18.4 | 20.6 | 21 | | | | | | | |

*calculated in meter from conductivity – see next table for TDS in January analysed in the lab.

*Table 5. Laboratory measured water quality variables for Toolibin and Walbyring Lakes sampled in January 2022.*

| | | **Toolibin E** | **Toolibin W** | **Walbyring 1b** | **Walbyring 3** |
|---|---|---|---|---|---|
| **Metals** | | | | | |
| Arsenic (filtered) | mg/L | 0.002 | 0.002 | 0.004 | 0.004 |
| Chromium (filtered) | mg/L | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Copper (filtered) | mg/L | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Lead (filtered) | mg/L | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Mercury (filtered) | mg/L | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |
| Zinc (filtered) | mg/L | < 0.005 | < 0.005 | < 0.005 | < 0.005 |
| Nickel (filtered) | mg/L | < 0.001 | < 0.001 | 0.003 | 0.003 |
| Cadmium (filtered) | mg/L | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |
| **Nutrients** | | | | | |
| Ammonia-N | mg/L | 0.25 | 0.17 | 0.04 | 0.05 |
| Nitrate-N | mg/L | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| Nitrite-N | mg/L | < 0.01 | 0.03 | < 0.01 | < 0.01 |
| NOx-N | mg/L | < 0.01 | 0.03 | < 0.01 | < 0.01 |
| Total Kjeldahl Nitrogen | mg/L | 3.3 | 3 | 6.6 | 8 |
| Total Nitrogen | mg/L | 3.3 | 3 | 6.6 | 8 |
| Total Nitrogen (Filtered) | mg/L | 3 | 2.9 | 6.5 | 7.4 |
| Filterable Reactive Phosphorus | mg/L | 0.05 | 0.05 | 0.03 | 0.05 |
| Total Phosphorus | mg/L | 0.27 | 0.27 | 0.4 | 0.32 |
| Total Phosphorus (filtered) | mg/L | 0.21 | 0.24 | 0.11 | 0.14 |
| **Major ions** | | | | | |
| Calcium (filtered) | mg/L | 87 | 86 | 98 | 110 |
| Potassium (filtered) | mg/L | 20 | 20 | 32 | 35 |
| Magnesium (filtered) | mg/L | 73 | 72 | 79 | 89 |
| Sodium (filtered) | mg/L | 490 | 480 | 630 | 710 |
| Chloride | mg/L | 910 | 940 | 1400 | 1500 |
| Bicarbonate | mg CaCO3/L | 220 | 220 | 360 | 390 |
| Carbonate | mg CaCO3/L | < 5 | < 5 | < 5 | < 5 |
| Sulfate | mg/L | 47 | 48 | 9.3 | 11 |
| Hydroxide | mg CaCO3/L | < 5 | < 5 | < 5 | < 5 |
| **Other** | | | | | |
| Alkalinity | mg CaCO3/L | 220 | 220 | 360 | 390 |
| Hardness | mg CaCO3/L | 520 | 510 | 570 | 640 |
| Total Suspended Solids | mg/L | 8 | 8 | 50 | 30 |
| Turbidity | NTU | 6.7 | 6.8 | 48 | 27 |
| Total Organic Carbon | mg/L | 48 | 47 | 110 | 120 |
| Total Dissolved Solids | mg/L | 2000 | 2000 | 2500 | 2700 |
| Conductivity | µS/cm | 3700 | 3600 | 4500 | 5000 |
| Colour | PCU(=TCU) | 12 | 250 | 250 | 260 |

*Table 6. Water quality data associated with waterbird surveys at Toolibin Lake.*

| | 1981-1985 Sep/Oct (average) | Sep 1992 | Dec 1996 | Apr 2017 | Oct 2017 | Nov 2021 | Jan 2022 |
|---|---|---|---|---|---|---|---|
| Depth (m) | - | ~1.88 (3, 4) | 0.66 (4) | 1.54 (4) | 1.41 (4) | 2.05 (5) | 1.51 (5) |
| Conductivity (µS/cm) | 4500 | 4000-5000 | 15200-20200 | 1083-1327 | 1392-1406 | 2675-2734 | 3710-3714 |
| TDS meter (g/lL) | 2.7(1) | 2.4-3.0 (1) | | | | 1.74-1.77 | |
| TDS lab (g/L) | | | 9.4-12.5(7) | 0.63 | 0.78 | | 2.0 |
| Dissolved oxygen (%) | | | 217 | 15-37 (2)<br>5-6 | | 22.2-33.4 (2)<br>11.5-22.7 | 58.1-64.3 |
| Total dissolved phosphorus (mg/L) | | | 0.01 | 0.16-0.21 | 0.069-0.61 | | 0.21-0.24 |
| Total dissolved nitrogen (mg/L) | | | 3.6-4.2 | 3.6-5 | 2.4-2.6 | | 2.9-3.0 |

*Table 7. Water quality data associated with waterbird surveys at Walbyring Lake.*

| | 1981-1985 Sep/Oct (average) | Sep 1992 | Dec 1996 | Apr 2017 | Oct 2017 | Nov 2021 | Jan 2022 |
|---|---|---|---|---|---|---|---|
| Depth (m) | | | | | | 0.88 | 0.42 |
| Conductivity (µS/cm) | | 1700 | 4700 | 611-647 | 1113-1120 | 1925-1979 | 4953-5134 |
| TDS meter (g/lL) | | 1 (1) | | | | 1.25-1.44 (1) | |
| TDS lab (g/L) | | | 2.8 | 0.52 | 0.61 | | 2.5-2.7 |
| Dissolved oxygen (%) | | | 154 | | | 29.5-32.4 (2)<br>20.1-29.1 | 85.8-98.6 |
| Total dissolved phosphorus (mg/L) | | | 0.03 | 0.53-0.61 | 0.66 | | 0.11-0.14 |
| Total dissolved nitrogen (mg/L) | | | 3.0 | 5.1-5.8 | 3.9 | | 6.5-7.4 |

(1) calculated using the formula of Williams (1966).
(2) At surface (upper value) and bottom (lower value) of water column.
(3) Lane *et al.* (2017) during the same month.
(4) Measured from the SWWMP depth gauge on the eastern shore which is known to be measure 0.4 m higher than the DWER gauge.
(5) Measured at DWER gauge 609009 but converted to an equivalent depth at the SWWMP gauge by adding 0.40m.
(6) Upper range estimated from higher conductivity on the western side of the lake (Halse *et al.* 2000).
(7) 9.4 measured in lab – range proportionally estimated from conductivity.

## Aquatic invertebrates

### Diversity

Eighty-five species of aquatic invertebrate were collected during the 2021/22 surveys of Toolibin and Walbyring, bringing to 143 the number of species recorded from these lakes between 1996 and 2022. Twenty-two were recorded for the first time in 2021/22. No species are of conservation significance. Snails of the genus *Hydrococcus* (most likely *H. brazieri*[4]) are an unusual find, occurring in Walbyring Lake in Jan 2022. This is largely an estuarine snail in WA, except for one other record[5] in a lake near Wagin, which is on another tributary of the Blackwood River (Atlas of Living Australia[6]). This may be a species that has moved upstream with the salinising Blackwood River.

### *Toolibin Lake*

During the 1970s a freshwater fauna at Toolibin Lake was indicated by the presence of two species of fish, tadpoles, aquatic insects, bivalves, snails, shrimps and gilgies (Goodsell *et al.*, 1978), at a time when salinity was 1-2 g/l (approx.1600 – 3200 µS/cm conductivity). It has been suggested that the fish were probably *Pseudogobius olorum* and *Atherinisoma wallacei* (Froend & Storey, 1996). These authors suggested that the bivalve may have been the now threatened *Westralunio carteri*, which is no longer known from the Wheatbelt (Klunzinger *et al.*, 2015), the shrimp was likely *Palaemonetes australis*, and the 'gilgie' may have been the introduced *Cherax destructor*. Some of these species were probably reliant on regular colonisation into the Toolibin wetland chain from source populations in the Arthur River. Of these groups, only the insects have been collected in Lake Toolibin subsequently. Other groups, such as microcrustaceans (copepods, ostracods, cladocerans), various worm groups (particularly annelids and turbellarians) and water mites are ubiquitous in freshwater wetlands in the Wheatbelt and would almost certainly have been present in Lake Toolibin in the 1970s, but these are not as conspicuous and were undoubtedly missed by the qualitative collecting of Goodsell.

In 1992, Doupé and Horwitz (1995) collected 28 aquatic invertebrate taxa from Lake Toolibin. Twelve microcrustacea were present, including copepods, ostracods and cladocerans, but annelids, molluscs and water mites were not collected. Nine of these species have not been collected since, but this includes some dubious identifications such as *Australphilus montanus* which is a south-eastern Australian beetle found in running waters and *Hygrobia australasiae* which is also an eastern Australian beetle. *Hygrobia* are rare in WA, with just one species in strictly freshwater wetlands in good condition, especially peat swamps. There are no other records of *Hygrobia* in the Wheatbelt. Salinity (2.4-3.0 g/L) was slightly elevated compared to the 1970s, but not to concentrations that would have eliminated these groups. However, sampling effort was very low: 1 metre-squared of sampling for macroinvertebrates with a 500 µm mesh net, and 5 linear metres of sampling for zooplankton with a 63 µm mesh net, at each of two sites.

Richness within higher taxonomic groups for samples collected from Lake Toolibin in 1996, 2017 and 2021-22, plus the five comparison sites mentioned above, is shown in Figure 3. Data

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[4] Corey Whisson pers. Comm.

[5] There is another ALA record from the town of Cue in WA which is likely a misidentification.

[6] https://api.ala.org.au/occurrences/occurrences/4d72a62a-c327-4c51-bc12-a3a0eb92f7f4

from the 1970s and 1992 are not included because the sampling effort was not comparable. Figure 4 shows richness summed for all samples within a sampling period.

Halse *et al*. (2000) employed a much greater sampling effort in 1996 (50 linear metres of sampling with each of 110 and 250 µm mesh nets at each of three sites) than was used in 1992, collecting 49[7] species in total and 36 to 41 per sample (Figure 3, Figure 4). Thirteen species of microcrustacean were present, plus insect groups not collected in 1992, including caddisflies (*Notalina spira* and *Triplectides australis*) and pyralid moth larvae (Lepidoptera). The latter require submerged aquatic macrophytes which Halse *et al*. (2000) noted to be present. The continued absence of water mites, annelids and molluscs may have been related to the elevated salinity (9.4 g/L) although there are a few mites and annelids that would tolerate this salinity. The latter includes the *Ainudrilus* worms found in Walbyring at the lower salinity of 2.8 g/L and which has been recorded in Wheatbelt lakes with salinity as high as 22 g/L (Cale, Halse & Walker, 2004).

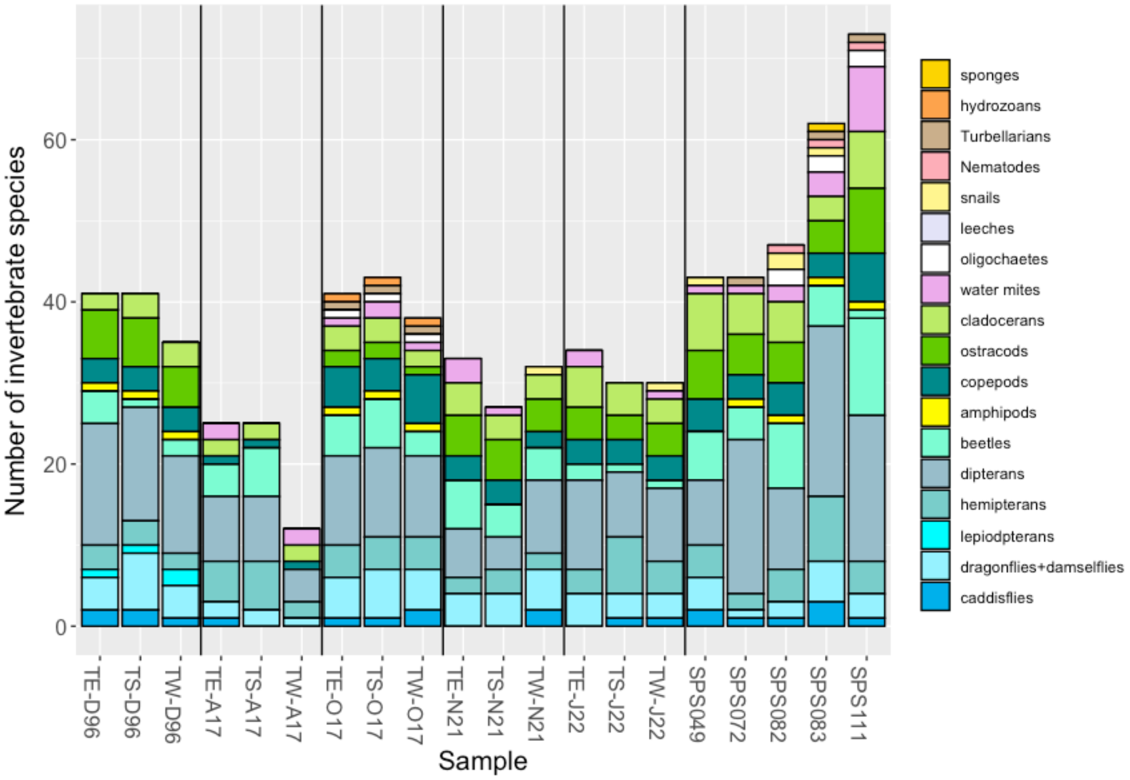

*Figure 3. Richness within taxonomic groups 1996 to 2021-22 for Toolibin Lake and for five comparison sites (SPS…). Black vertical lines separate sampling periods. Sample labels TE = East, TS = South, TW = West. D96 = Dec 1996, A17 = Apr 2017, O17 = Oct 2017, N21 = Nov 2021, J22 = Jan 2022.*

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[7] Halse *et al*. (2000) cite 52 species but for this report we have used 49 for taxonomic consistency and accuracy

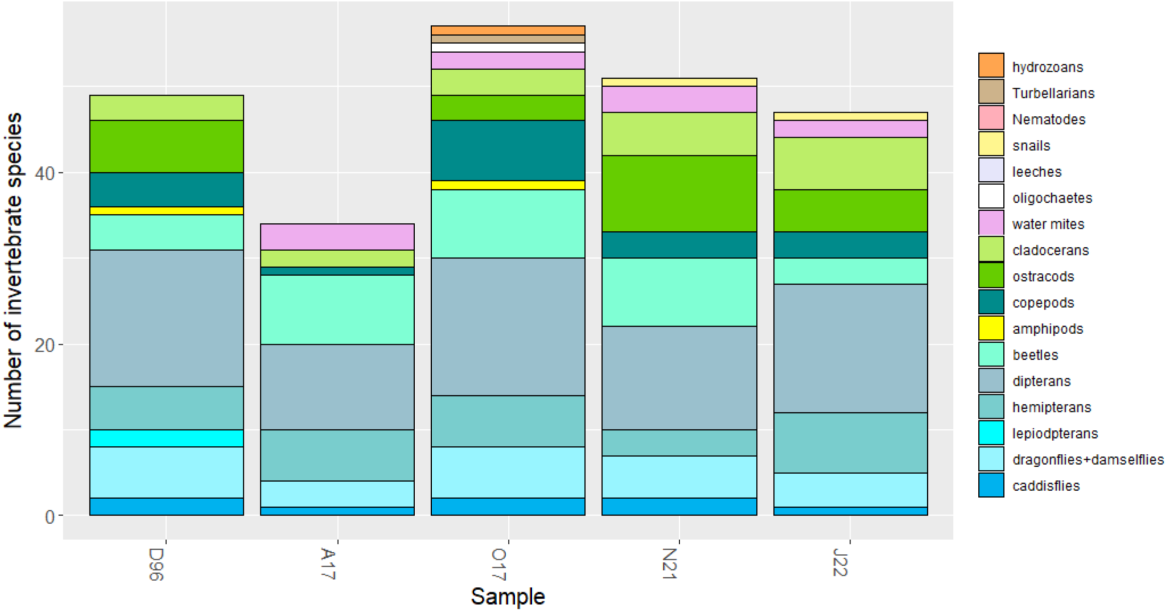

*Figure 4. Richness within taxonomic groups 1996 to 2021-22 for Toolibin Lake summed across samples in a sampling period. D96 = Dec 1996, A17 = Apr 2017, O17 = Oct 2017, N21 = Nov 2021, J22 = Jan 2022.*

In 2017, Cale and Pinder (2019), using the same methods as Halse *et al*. (2000), collected 34 and 57 species in April and October respectively, with 12 to 25 per sample in April and 38 to 43 per sample in October (Figure 3, Figure 4). Mites were recorded for the first time in April at a salinity of 0.63 g/L and both mites and annelids (one species of oligochaete) were present in October at a salinity of 0.78 g/L, but snails remained absent. Hydrozoans and turbellarians were also noted for the first time in October. Total microcrustacean richness was just three species in April but increased to 12 in October. Cale and Pinder (2019) noted that the diversity of some microcrustacean groups was lower in 2017 than would be expected given the lower salinity compared to 1996. Six species of ostracod were present in Lake Toolibin in 1996, with 5-6 species per sample. In 2017, ostracods were absent in April and only 3 species were present in October, with just 1 or 2 species per sample, despite the lower salinity. Pinder *et al.* (2004, 2005) show that ostracod diversity in water <1 g/L salinity ranges from 1 to 14 in the Wheatbelt, so Toolibin was at the lower end of that range in 2017. Cale and Pinder (2019) suggested the low diversity of ostracods may have been related to reduced egg bank viability in the sediments, as a result of less frequent inundation over the previous 20 years, and fewer good condition neighbouring wetlands that can act as sources of passive colonisation. The latter is supported by analyses undertaken by Atkinson *et al.* (2021) showing a decline in aquatic invertebrate diversity generally across the Wheatbelt during 1996 to 2011 as wetlands filled less frequently. Caddisflies were present in 2017, though *Notalina spira* was replaced by *Oecetis* sp., but pyralid moth larvae were absent, reflecting the absence of submerged aquatic vegetation.

Totals of 51 species (27 to 32 per sample) were collected in Nov 2021 and 47 species (30 to 34 per sample) in Jan 2022 (Figure 3, Figure 4), somewhat lower than the values for Oct 2017 (57 species and 38 to 43 per sample). Sixty-eight species were collected in the 2021/22 samples bringing the total number of species collected from Toolibin Lake between 1996 and 2022 to 118. Snails were recorded for the first time since the 1970s, with mites and snails present in Nov 2021 and Jan 2022, but diversity remained low (one species of snail at one site, two species of mite at 1 or 2 sites). Annelids, hydrozoans and flatworms (Turbellaria) were absent even though they had been present in 2017. Ostracod diversity was higher in Nov 2021 (8 species, 4-5/site) than in Oct 2017, but had declined by January (4 species, 3-4/site). Six species of cladoceran (3-5 per site) were present in Jan 2022 (compared to 3 to 4 for previous sampling occasions and 2-4 per site). By contrast, copepod diversity was lower in 2021/22 (same three species in Nov 2021 and Jan 2022) than in Oct 2017 (7 species) and the same as in Dec 1996. Caddisfly diversity was the same as in 2017 and pyralids remained absent.

Of the five comparison wetlands, two had richness much higher than ever recorded at Toolibin Lake. The other three had richness similar to values recorded in Toolibin in 1996 and 2017 (Figure 3) but substantially higher than was recorded in 2021/22. These wetlands tended to have more oligochaetes, ostracods and cladocerans, even compared to 1996 and 2017, but fewer odonates. The site with highest richness (SPS111) had salinity bordering on brackish (3.2 g/L, 5650 µS/cm), with some tree death (so like Toolibin), but with substantial areas of mixed submerged macrophytes which tend to support higher numbers of invertebrate species. The other high richness site was a good condition yate and *Melaleuca* swamp which lacked aquatic plants other than trees.

Figure 5 shows invertebrate richness per sample versus salinity for 198 wetlands of the south-west agricultural zone sampled by Pinder *et al*. (2004) and Jones et al. (2009) that had salinity ≤ 25 g/L. It also shows richness for the Toolibin Lake samples collected from 1996 to 2022 (excluding April 2021) and the five comparison wetlands. Pinder *et al*. (2005) showed that invertebrate richness in Wheatbelt wetlands was not correlated with salinity below 4.1 g/L. The average richness (excluding rotifers and protozoans) below this salinity is 48 species. This graph shows that the 1996 samples were about average for the salinity (9.4-12.5 g/L). With salinity in 2017 and 2021/22 being substantially lower than in 1996, an increase in richness might have been expected, but this was not the case and, moreover, there was a decline in richness in 2021/22. Sample richness in 2017 was about 8 to 13 species below the average for fresh wetlands, but was commensurate with three of the comparison wetlands, and in 2021-22 richness was 13 to 16 species below average.

The low richness of some groups in Toolibin Lake, such as oligochaetes, molluscs, ostracods, cladocerans and lepidopterans, combined with continued absence of species know to have occurred in Toolibin since in the 1970s (*Cherax*, prawns and bivalves), suggests current richness is below what it would have been present in the lake prior to the 1990s. This may reflect a combination habitat factors such as low oxygen, absence of emergent and submerged aquatic plants, and the 20-year absence of major fill events. In 1996, oxygen was high, submerged aquatic plants were present and the lake had had more regular fill events in preceding years. In 2017, low oxygen concentrations, absence of macrophytes and prolonged drying may be the reason why richness did not respond to the significantly reduced salinity, and in fact declined in 2021/22.

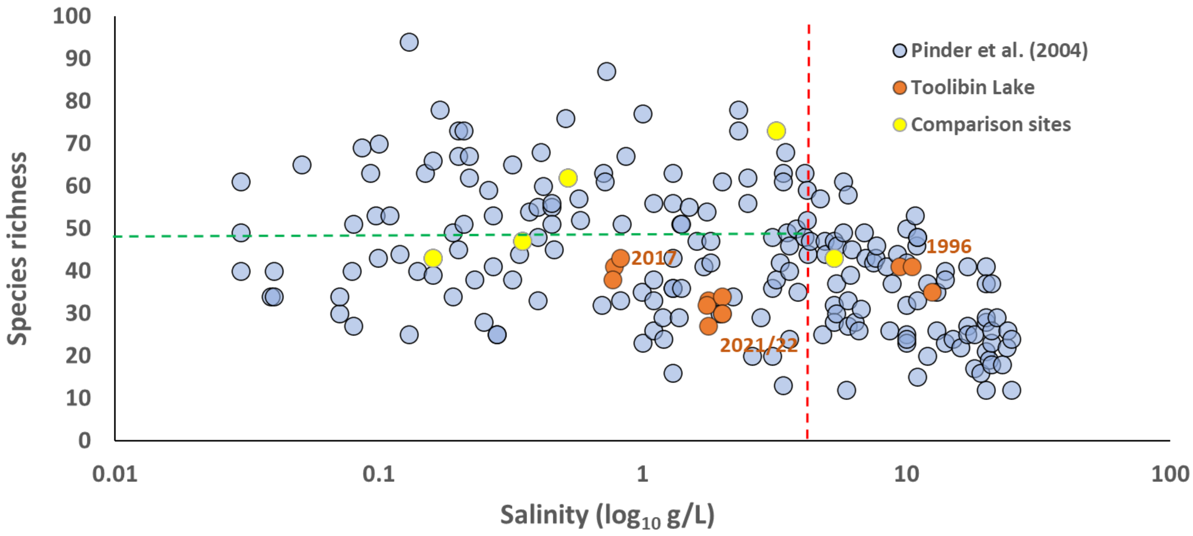

*Figure 5. Salinity versus richness of invertebrate samples for 158 wetlands sampled by Pinder et al. (2004) and Jones et al. (2009), nine samples from Toolibin Lake from Dec 1996, Oct 2017, Nov 2021 and Jan 2022, plus the five comparison wetlands. Some Toolibin salinity values are estimated from salinity measured at one of the sites and conductivity measured at all sites. Richness values exclude rotifers and protozoans (cf. the equivalent graph in Pinder et al. (2005) which included those groups). The red vertical line is the salinity (4.1 g/L) above which total richness declines with increasing salinity. The green horizontal line is the average richness for wetlands with salinity ≤4.1 g/L.*

### Walbyring

In 1992, Doupé and Horwitz (1995) collected 29 aquatic invertebrate taxa from Walbyring Lake (from a single sample versus two samples from Toolibin). In contrast to Toolibin, the fauna included flatworms, annelids, and water mites, reflecting the lower salinity at this lake (1700 μS/cm ≈ 1 g/L) compared to Toolibin (4.0 to 5.8 μS/cm ≈ 2.4 to 3 g/L). Molluscs were absent, but were present in a supplementary sample collected from this wetland in April 1993 when salinity had risen to 1.6 g/L.

Richness within higher taxonomic groups for samples collected from Walbyring Lake in 1996, 2017 and 2021-22, plus the six comparison sites mentioned above, is shown in Figure 6. Data from the 1970s and 1992 are not included because the sampling effort was not comparable. Figure 7 shows richness summed for all samples within a sampling period.

In 1996, following a much greater sampling effort (Halse *et al.*, 2000), Walbyring Lake had 45 to 48 species per sample and 62 in total. Unlike Toolibin, snails were present (*Isidorella* and *Bayardella*) as were annelids (oligochaetes and leeches) but not water mites. The higher richness and the presence of these taxa reflected the much lower salinity at Walbyring (4700 µS/cm) compared to Toolibin (15200 to 20200 µS/cm).

In 2017, Cale and Pinder (2019) collected 22 and 43 species in April and October respectively, with 11 to 19 per sample in April and 27 to 37 per sample in October (Figure 4, Figure 5). The former represented an early stage in community development, but the October richness was a 30% decline compared to 1996. As for Toolibin, low salinity was likely the reason for presence of water mites and annelids in October. In addition, the October sampling collected flatworms (Turbellaria) and snails (at one site) whereas these groups were absent from Toolibin.

Totals of 52 species (31 to 41 per sample) were collected in Nov 2021 and 49 species (34 to 39 per sample) in Jan 2022. This is a small increase on the number of species collected in 2017. Seventy-one species were collected in the 2021/22 samples bringing the total number of species collected from Walbyring Lake between 1996 and 2022 to 112, about the same as for Toolibin. *Hydra* (Hydrozoa) were collected for the first time, in Jan 2022, but these tiny cnidarians are easy to miss when sorting samples. Amphipods were collected again whereas they were absent in 2017, but annelids were absent and mites were largely so. Microcrustacean diversity was about the same as in 2017, but with fewer copepods and more cladocerans.

The 1996 samples from Walbyring had richness similar to three of the comparison wetlands (Figure 5). Some of the 2017 to 2022 samples came close to the comparison wetland richness but most were 10 or more species lower.

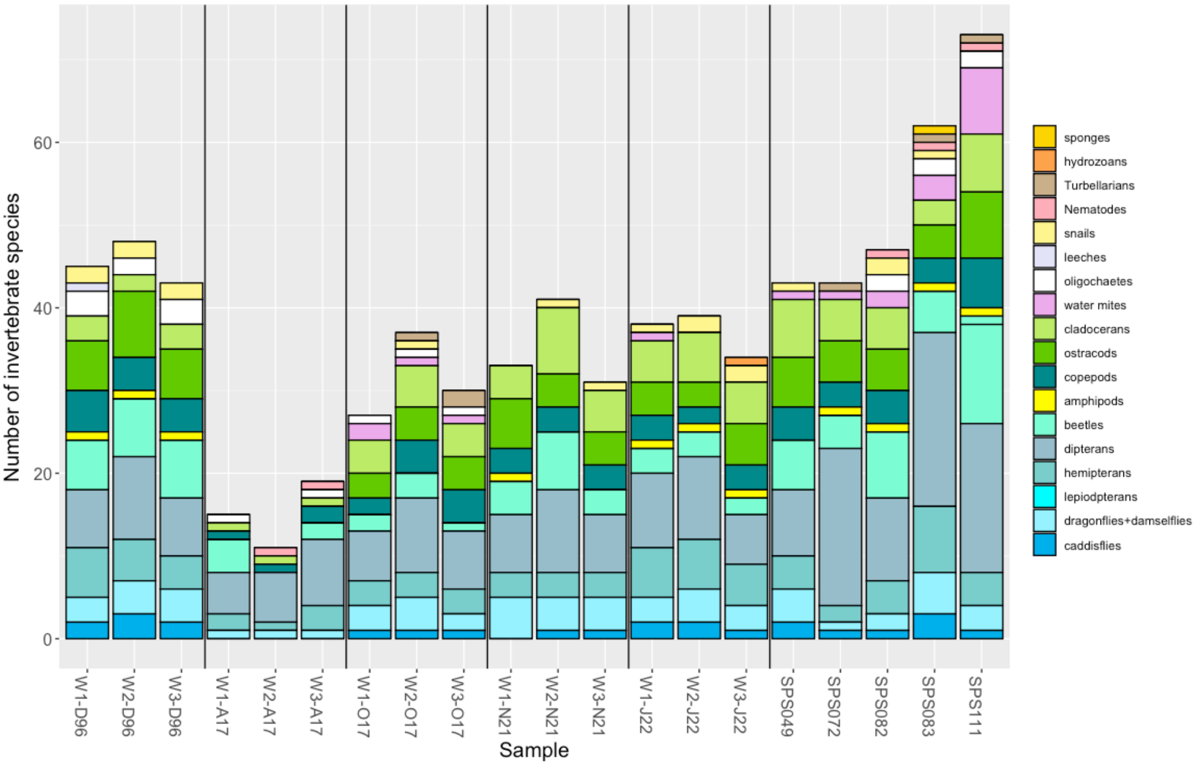

*Figure 6. Richness within taxonomic groups 1996 to 2021-22 for Walbyring Lake and for six comparison sites (SPS…). Black vertical lines separate sampling periods. Sample labels W1 = South, W2 = East, W3 = West. D96 = Dec 1996, A17 = Apr 2017, O17 = Oct 2017, N21 = Nov 2021, J22 = Jan 2022.*

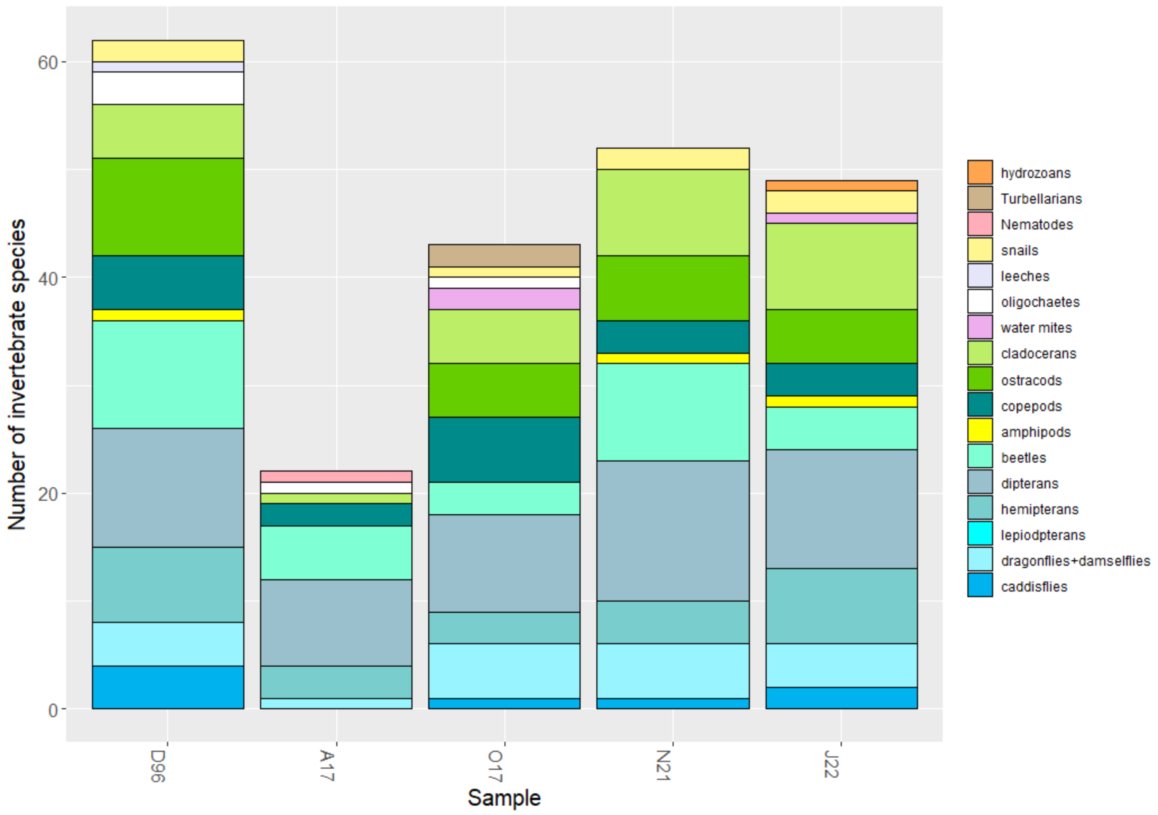

*Figure 7. Richness within taxonomic groups 1996 to 2021-22 for Walbyring Lake summed across samples in a sampling period. D96 = Dec 1996, A17 = Apr 2017, O17 = Oct 2017, N21 = Nov 2021, J22 = Jan 2022.*

## Community composition

### *Toolibin and Walbyring composition*

Figure 8 is an ordination of community composition within samples from 1996, 2017 and 2021/22, from Toolibin and Walbyring. Earlier invertebrate data is not included due to inconsistency in sampling effort. Within a sampling period, Walbyring (blue symbols) and Toolibin (pink symbols) communities tended to occur in the same part of the ordination plot, with minimal overlap between other periods, but mostly separated from each other, suggesting the lakes maintain somewhat different faunas but are broadly responding to the same interannual variation in conditions and timing of sampling. The April 2017 samples for both lakes lie in the far right of the plot, separate from remaining samples. These likely reflect an early stage in development of the invertebrate community, with these depauperate samples being collected only two months after the lake filled. The December 1996 samples lay to the bottom left of the plot, the Jan 2022 samples to the mid-left and Oct 2017 and Nov 2021 samples towards the top left, suggesting more minor differences between survey periods compared to the contrast between these surveys and April 2017.

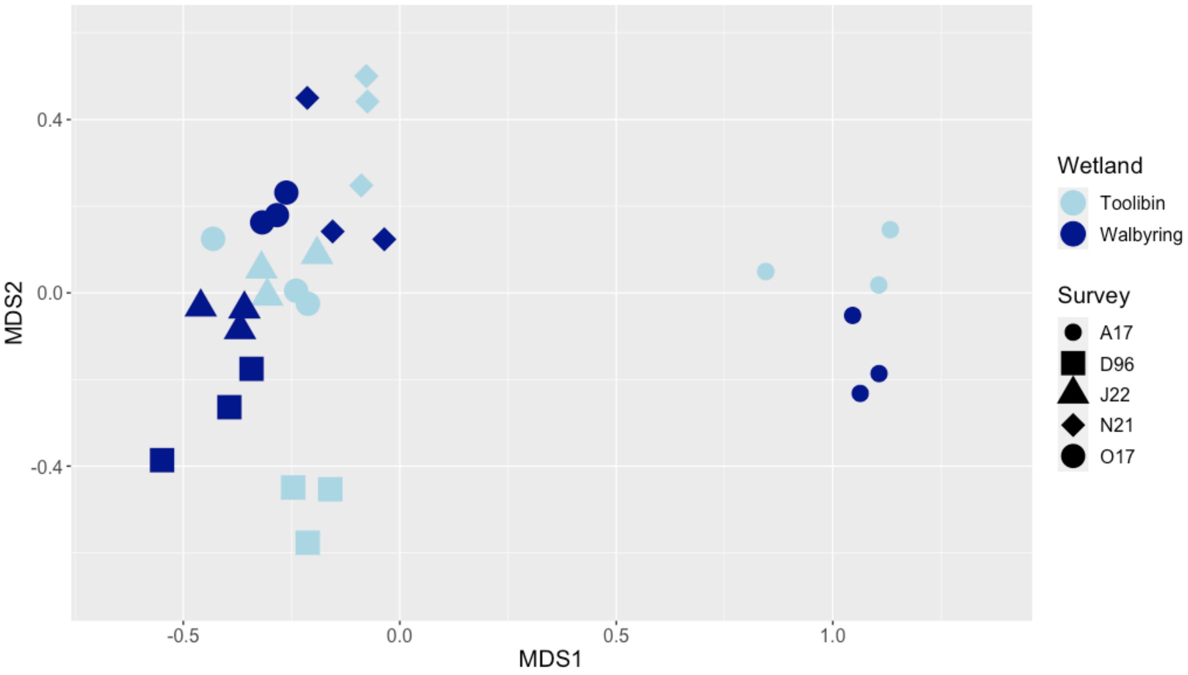

*Figure 8. Axes 1 and 2 of a 3-dimensional ordination of invertebrate samples from Toolibin Lake and Walbyring Lake. Symbol levels represent surveys, e.g. A17 = April 2017. Light blue = Toolibin, dark blue = Toolibin. Stress = 0.10.*

Figure 9 is a plot of a 2-dimensional ordination of invertebrate samples collected from Toolibin and Walbyring from 1996 to 2022 (excluding the April 2017 samples), with the five 'comparison sites for comparison. The comparison sites plotted just outside of the cloud of Toolibin and Walbyring samples though they were not themselves a homogenous group. In fact, the differences in composition between these six sites were of a similar scale to differences between some of the samples collected from Toolibin and Walbyring. To better understand the contrasts in composition between samples from the comparison sites, and those from Toolibin and Walbyring,a cluster analysis was undertaken (Figure 8). This shows samples from two of the comparison sites (SPS…) grouped separately (to the far right of the plot), from all other samples, then the 1996 samples clustering separately from the rest, then the remainder of the comparison sites grouping separately to all of the 2017 to 2022 samples (far right). These analyses suggest some differences in composition between the comparison and Toolibin and Walbyring sites, but there is not a clear-cut contrast. It may be that Toolibin and Walbyring are just additional examples of the same sort of tree dominated fresh(ish) Wheatbelt wetlands, but with slightly depauperate faunas.

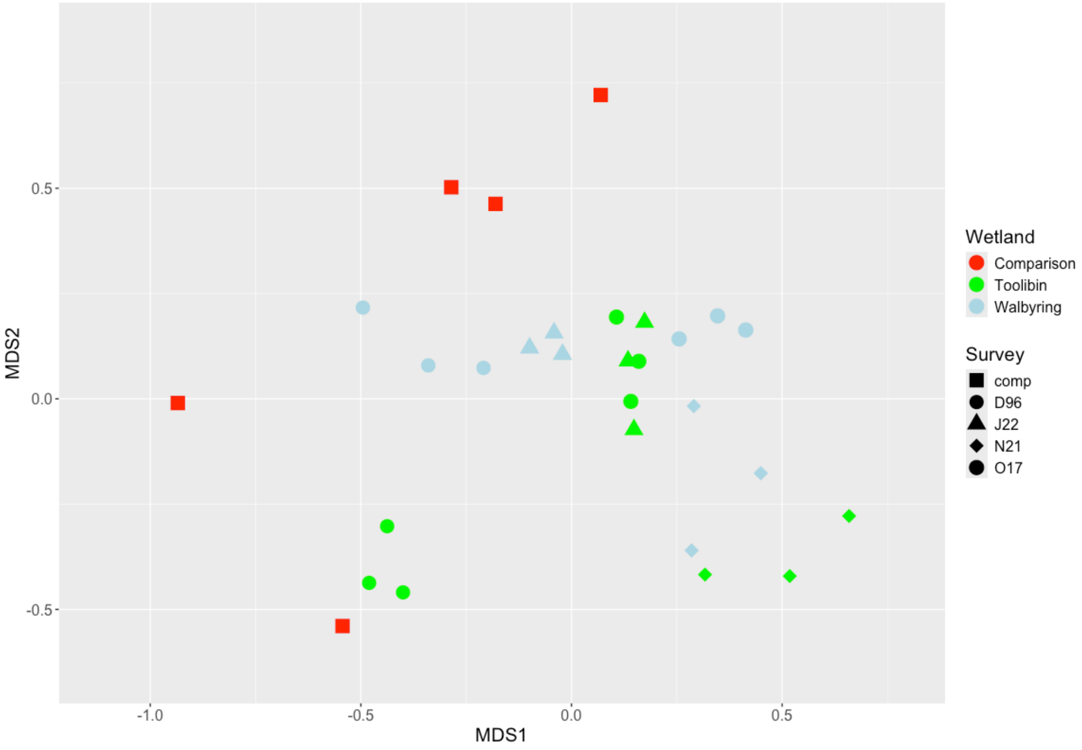

*Figure 9. A 2D ordination of 1996 to 2022 Toolibin (dark blue) and Walbyring (light blue) invertebrate samples and samples from five comparison sites (red) from Pinder et al. (2004). Stress = 0.12.*

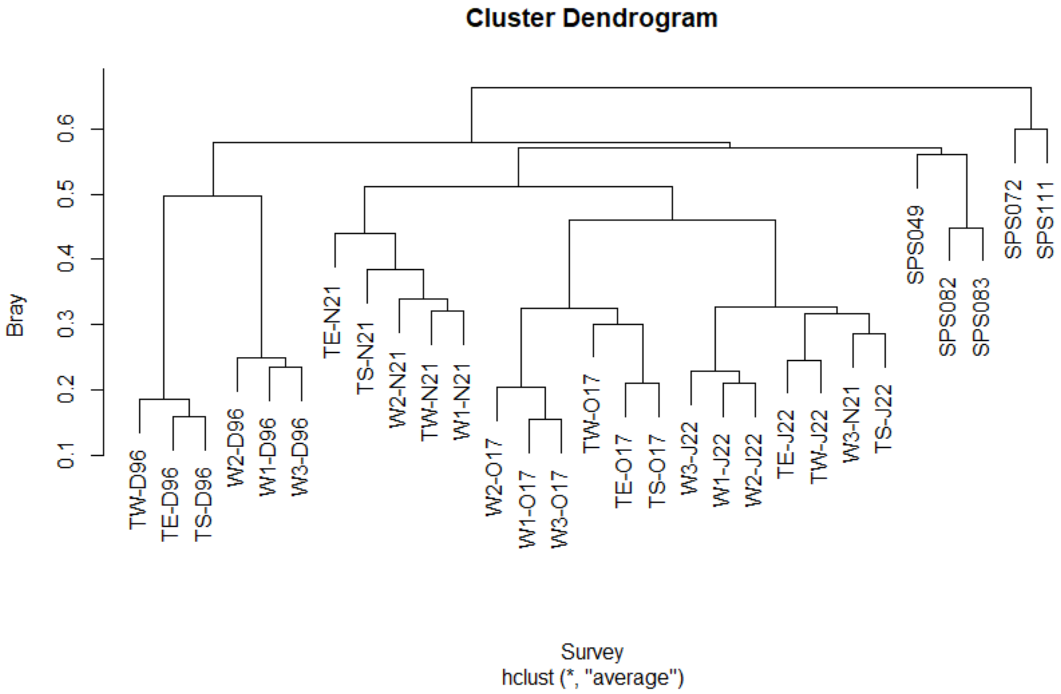

*Figure 10. Dendrogram from agglomerative cluster analysis using the average linkage method, based on Bray-Curtis dissimilarity. Sample labels TE = East, TS = South, TW = West. D96 = Dec 1996, A17 = Apr 2017, O17 = Oct 2017, N21 = Nov 2021, J22 = Jan 2022, SPS… = comparison sites.*

### Invertebrate management targets for Toolibin Lake

No management targets or limits of acceptable change were set for aquatic invertebrates in the Toolibin Lake Management Plan, but the plan did have the following goal:

*Assess the feasibility of aquatic invertebrate surveying and monitoring and, if acceptable, develop LoAC and a monitoring plan.*

The methods used from 1996 to 2022 constitute standard surveying and monitoring protocols suitable for monitoring aquatic invertebrates of Toolibin Lake and associated wetlands and are described in ther Methods section and in Appendix 4. The sampling methods are the same as used during many other DBCA surveys. These monitoring methods could be applied to future fill events, with surveys preferably conducted about three months after filling and again after about six months if the fill lasts long enough.

Froend *et al.* (1997) suggested a recovery criterion of:

*Based upon available data, the lake supports sufficient species richness and numbers of invertebrates to assure waterbird food resources.*

The waterbird communities (see below) remain diverse, and total abundance and abundance of most target species is within reference ranges, but the poor representation and abundance of predatory diving species, which would be looking for larger prey, suggests this criterion is only partly met if the goal was to return waterbird communities to their pre-1990s composition.

Now that we have results from two more recent inundation events it is possible to suggest an additional interim target:

*Maintain or improve the diversity of aquatic invertebrate communities using Lake Toolibin recorded during the 2017 and 2021/22 surveys (at least 45 species) when the lake has freshwater.*

To increase invertebrate diversity towards the average for freshwater Wheatbelt wetlands, and to what diversity would likely have been present in Toolibin Lake prior to the 1990s, would require improvement in aquatic habitat such as re-establishment of submerged and emergent macrophytes and improved oxygenation of the wetlands, acknowledging it may not be possible to re-establish these conditions with infrequent fill events.

## Waterbirds

### Richness

During the Nov 2021 and Jan 2022 waterbird surveys at Toolibin Lake 13 and 17 species were recorded respectively (Figure 11), with 24 species in total. The Nov 2021 value is the same as was recorded in April 2017 and the Jan 2022 value is the same as recorded in Oct 2017 and Dec 1996, suggesting an increase in the number of species present over a filling event. These values are within the range of richness recorded during the 1970s and 1980s, but in the lower half of the range for the ‘reference’ surveys (see Methods).

A total of 49 species were recorded up to 1990, from 50 surveys plus the Goodsell species list. Twenty nine of these species were present across the six 1996 to 2022 surveys. The latter is well within the range of richness values from any six randomly selected surveys up to 1990 (21 to 34), or any six of the 12 reference surveys (26 to 34).

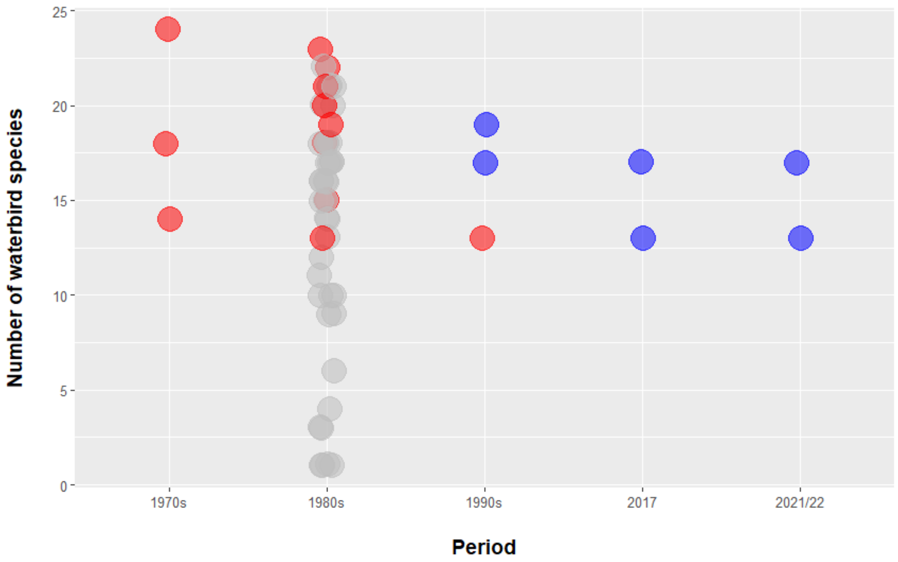

*Figure 11. Number of waterbird species recorded for Toolibin Lake over five periods. Points are 'jittered' so that surveys with identical or similar richness are more visible. Red symbols represent 'reference' surveys undertaken between 1974 and 1990 when depth was >0.7m and surveys were likely to have been comprehensive. Blue symbols are surveys from 1996 to 2022.*

Waterbird richness in Walbyring Lake has shown a different pattern, with the number of species present in 1996 to 2022 (10-17) mostly exceeding the number present prior to 1996 and higher than all but one of the four 1996 and 2017 surveys (Figure 12). In Nov 2021 and Jan 2022, 14 and 17 species were present respectively.

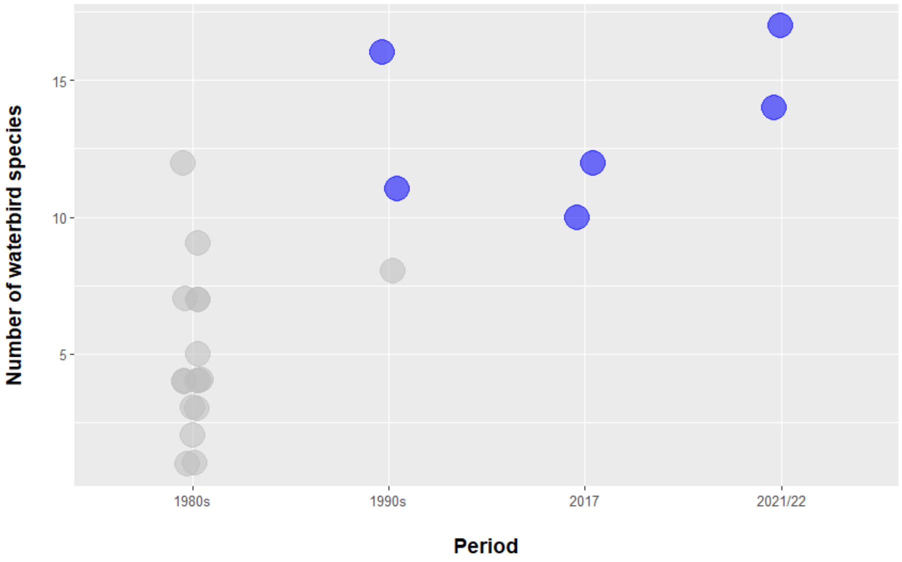

*Figure 12. Number of waterbird species recorded for Walbyring Lake over five periods. Points are 'jittered' so that surveys with identical richness are more visible. Grey symbols are surveys prior to 1996. Blue symbols are those undertaken between 1996 and 2022.*

### Guild richness at Toolibin Lake

Eight feeding guilds were defined by Halse (1987) to describe the bird community at Toolibin Lake. For this report we have changed "Divers – vegetation" to "Divers – mixed" for Musk Duck, Blue-billed Duck, Eurasian Coot and Dusky Moorhen, reflecting their varied diet. These were present despite a lack of submerged vegetation in 2017 and 2021/22. We have also added "Terrestrial – animal" for Clamorous Reed Warbler and Purple Swamphen. The number of species within each of these guilds is shown in Figure 13 for the reference surveys and the 1996 to 2022 surveys.

Dabblers was the most species rich guild in both time periods, with 6 to 8 species present on any one survey (out of nine in the guild) and richness of this group was not different between the two periods. The Nov 2021 and Jan 2022 surveys had 6 and 7 species respectively from this guild. The only other guild with more than 5 species ever present was predatory divers (cormorants, grebes and Pelicans), with 5 or 6 present in several of the reference surveys (average 3.9) but only 1 to 3 in the 1996+ surveys (average 2). Only Hoary-headed Grebes and Little Pied Cormorants were present in 2021/22. Divers generally prefer depths > 1 m (Halse, 1987) and the lowest richness in some of the reference surveys, and in 1996, may reflect lower depths (depth in 1996 was 0.66m). However, depth was well above 1 metre for the four 2017 and 2021/22 surveys so low diver richness in those surveys must be due to other factors; most likely insufficient food resources, such as fish and larger invertebrates, for predatory species. The cormorants (Little Black, Little Pied, Pied and Great), none of which were present in 2017 and few present in 2021/22 (just a few Little Pied Cormorant), might be expected to be influenced by food availability and forced to seek alternative wetlands with greater food resources. These are the larger species of the guild and likely require more and larger food items than the grebes. In contrast, the hoary headed grebe (the smallest and only member of the guild occurring in all time periods) not only has a less size dependent diet but also higher rates of occurrence regionally and occurs in a wider range of inland wetland types than the cormorants (e.g., compare waterbird group 2 and 1 of Halse *et al.*, 1993). Consequently, this species will more readily find, colonise and prosper in a newly filled wetland such as Toolibin Lake.

The large wader guild (herons etc.) was consistently represented by 4 of the 5 member species prior to the 2017 surveys. In 2017 the guild was represented by just the white-faced heron (12 individuals in April and 13 in October) and white-necked heron (2 individuals in October) (Cale & Pinder, 2019). In 2021/22, these species were also present, but we also recorded Nankeen Night Heron and a single Great Egret in Jan 2022. Yellow-billed Spoonbills, common during the reference surveys and present in 1996, have not been present during the 2017 and 2021/22 surveys. Absence of the latter is not easily explained given the returned presence of other large wading species, but it has only ever been present in low numbers and was absent from many 1980s surveys.

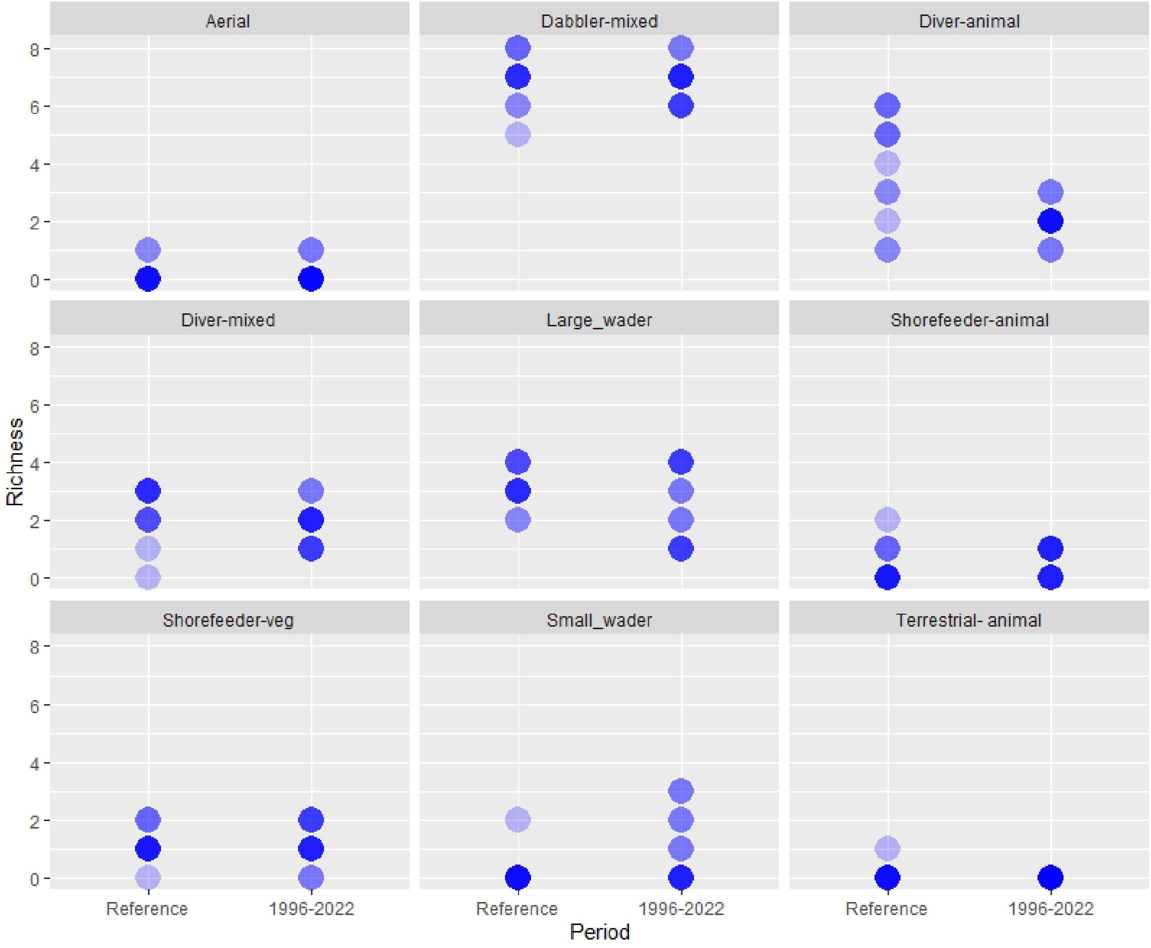

*Figure 13. Scatterplots of richness within eight feedings guilds for surveys of Toolibin Lake prior to 1996 (reference surveys) and those undertaken from 1996. Depth of colour represents number of surveys with that richness value. Colour depth indicates the proportion of surveys within a period with the recorded richness. i.e. where a point represents two of the twelve reference surveys it will have the same colour as a point representing one of the six 1996 to 2022 surveys.*

Small waders are naturally rare in Toolibin Lake and the only records in pre-1996 surveys were a Wood Sandpiper and 5 Black-fronted Dotterels from Aug 1988. Three species were recorded in 1996 (Black-winged Stilt, Marsh Sandpiper and Red-kneed Dotteral), one species was present in 2017 (Black-fronted Dotterel) and none were seen in 2021/22.

For other guilds there were no clear differences in richness between the two periods, except that the single terrestrial animal feeder, Clamorous Reed Warbler, was present only in 1974 when the fringes of the lake had dense fringing rushes.

## Abundance

### *Toolibin*

Abundance of waterbirds by taxonomic group, for reference surveys and 1996 to 2022 surveys is shown in Figure 14 . The Nov 2021 total count was 478, compared to 2472 in Jan 2022. Total abundances for the five 1996 to 2022 surveys were within the range of values for the

1970s and 1980s reference surveys, and counts were generally higher (median 818) in the 1996 to 2022 period than for the reference surveys (median 413). Abundance in Jan 2022 was exceeded only by one previous count[8] (6358 in 1976). Grey Teal were the most abundant species in 2021/22, and the Jan 2022 count included record numbers of Hoary Headed Grebe (832) with the previous highest count being 135 in Sep 1982.

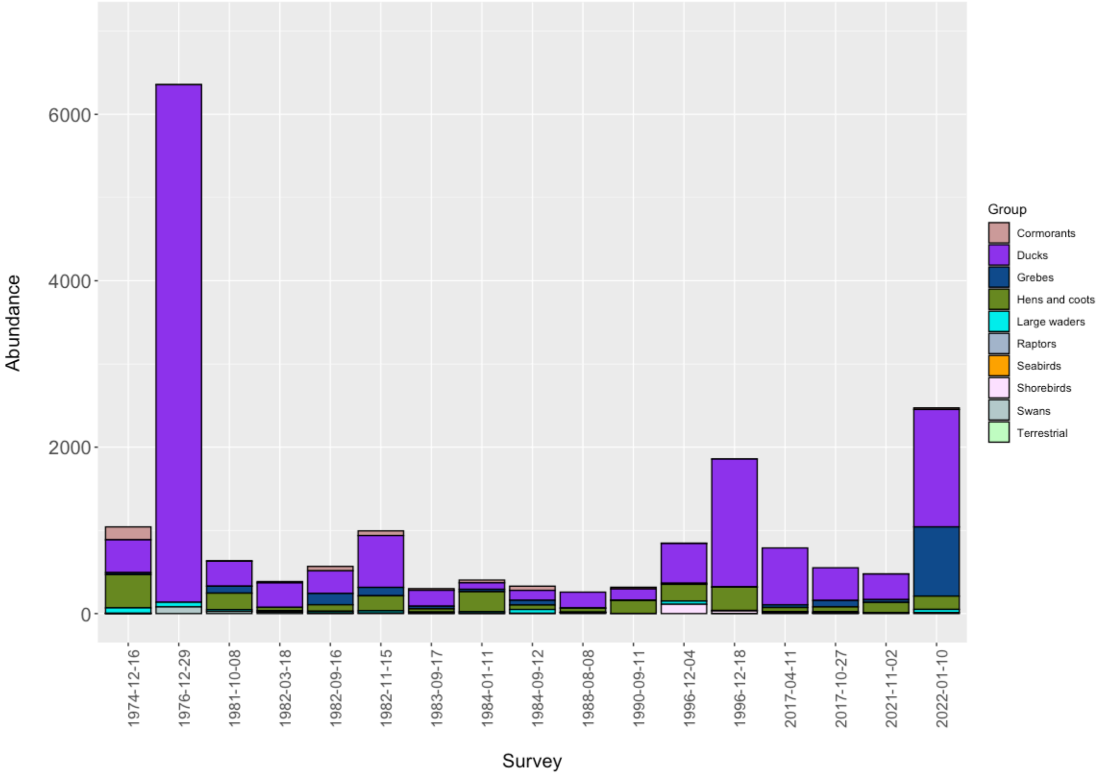

*Figure 14. Abundance of waterbirds using Toolibin Lake for reference surveys and more recent (1996 to 2022) surveys)*

### *Walbyring Lake*

Abundance of waterbirds by taxonomic group for all Walbyring Lake surveys where at least 5 species were recorded, are shown in Figure 15. The count in Nov 2021 was 358 birds, and in Jan 2022 it was 619. This graph shows much greater abundance of waterbirds, especially ducks and grebes, counted at the lake from 1996. Shorebirds constituted nearly a third of birds present in Jan 2022 (Black-winged Stilt, Black-fronted Dotterel, and Red-kneed Dotterel) but these species have not previously been recorded at this lake. The two Dotterel species included juveniles.

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[8] Including any of the non-reference surveys prior to 1996.

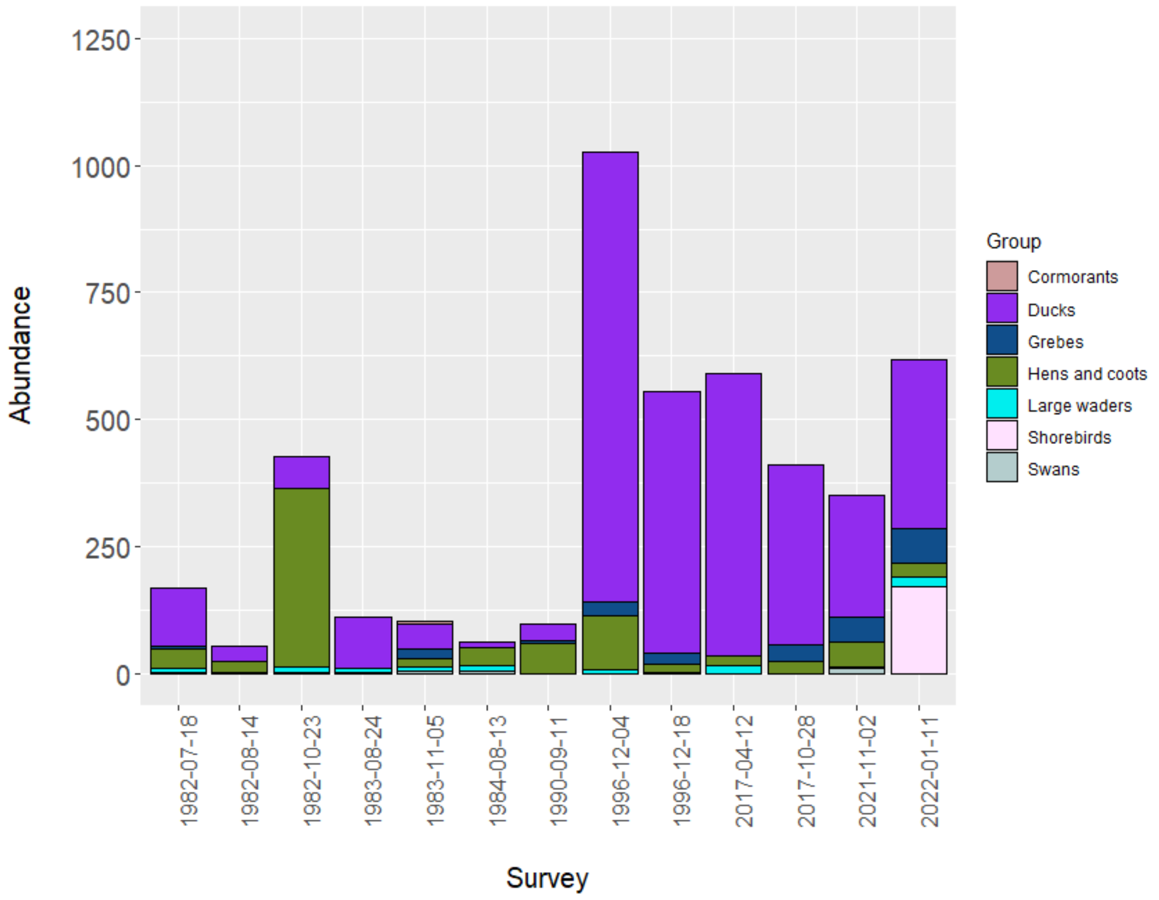

*Figure 15. Abundance of waterbirds by taxonomic groups for all surveys of Walbyring Lake for which at least 5 species were recorded.*

## Waterbird community composition

### *Toolibin Lake*

Figure 16 is an ordination plot portraying similarities in composition of waterbird communities of Toolibin Lake surveyed since the 1970s. Data from 1975 is excluded as it is presence/absence only. This shows the 1996 to 2022 surveys (blue symbols) near the edge of most surveys undertaken from 1974 to 1990 but not separate. The reference surveys are coloured red, showing the 1996+ surveys had composition not dissimilar to most of the reference surveys. An ordination using only the reference and 1996+ surveys showed a similar pattern. The 1996+ surveys appear to be relatively similar in composition compared to earlier periods and there is no evidence of ongoing change.

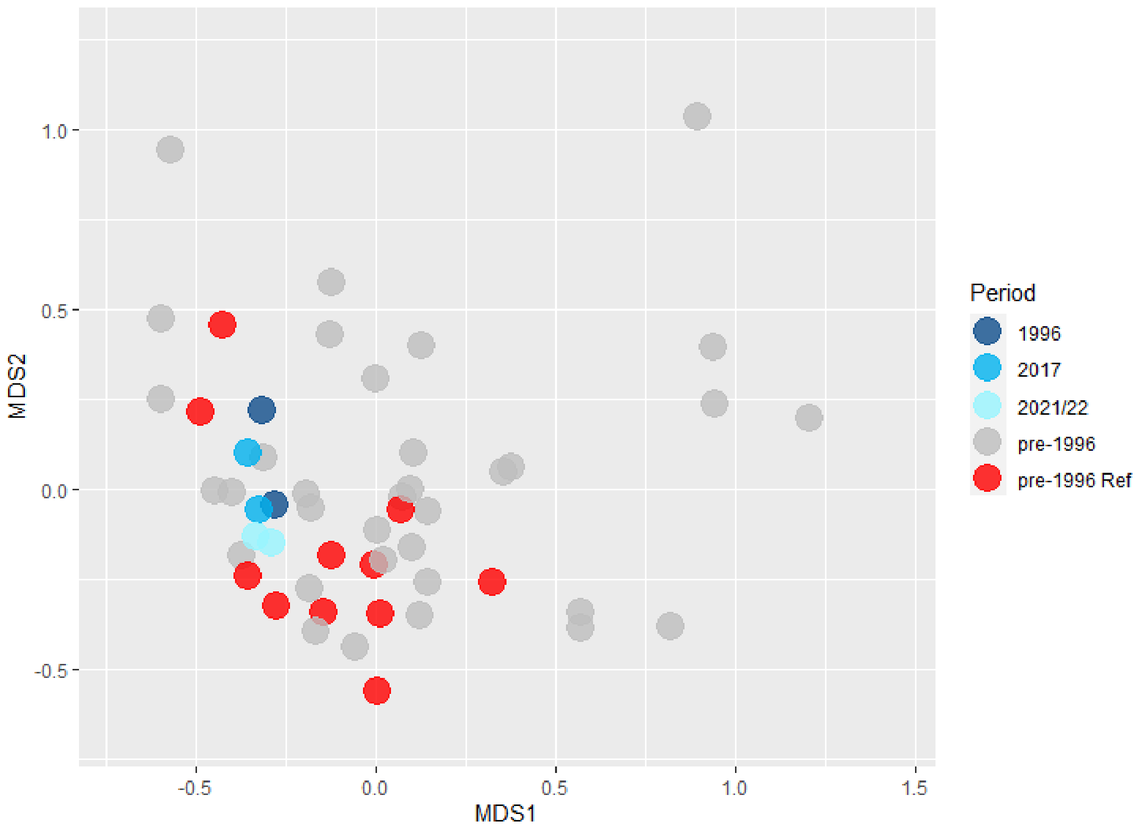

*Figure 16. Axes 1 v 2 of a 3D ordination plot based on Helinger transformed species abundance values for surveys at Toolibin Lake undertaken during periods as indicated. 1975 data excluded because it was presence/absence. Stress = 0.13.*

Figure 17 shows the relative abundance of waterbird species during reference surveys (dates in black text on the y axis) and those undertaken from 1996 to 2022 (blue text). There are few strong patterns. Grey Teal are more consistently more abundant (>200 individuals) in the later surveys. Freckled Duck were mostly in low abundance across the dataset other than in 1982 and 1983 (during which 4 surveys recorded more than 100). Surveys in the 1970s, 1981 and from 1984 rarely recorded more than 10 of this species. Of the six 1996 to 2022 surveys, half had Freckled Duck present (1 to 25 individuals), indicating that this species continues to use Toolibin Lake and probably not in significantly lower numbers than historically. All three species of cormorant, great-crested grebe, blue-billed duck, musk duck, the Nankeen Night Heron and yellow-billed spoonbill tended to be more abundant prior to 1996, though these were never in high abundance on the lake.

Low abundance of cormorants, great-crested grebes, nankeen night heron and yellow-billed spoonbills may reflect less abundant food resources such as fish, tadpoles and crayfish for these diving and larger wading species. Emergent vegetation present in the 1970s provided habitat for Clamorous Reed-warblers and a record of Australasian bittern, but these were not recorded in the 1980s.

A ‘simper’ analyses based on transformed abundances identified 8 species that together contributed 53% of the difference in composition between the reference surveys and the 1996 to 2022 surveys, but the only significant difference was for Little Black Cormorant. A simper analysis of raw abundance data found that the same top 8 species contributed 86% of differences in composition between these periods, with only Pink-eared Ducks significant (more abundant from 1996).

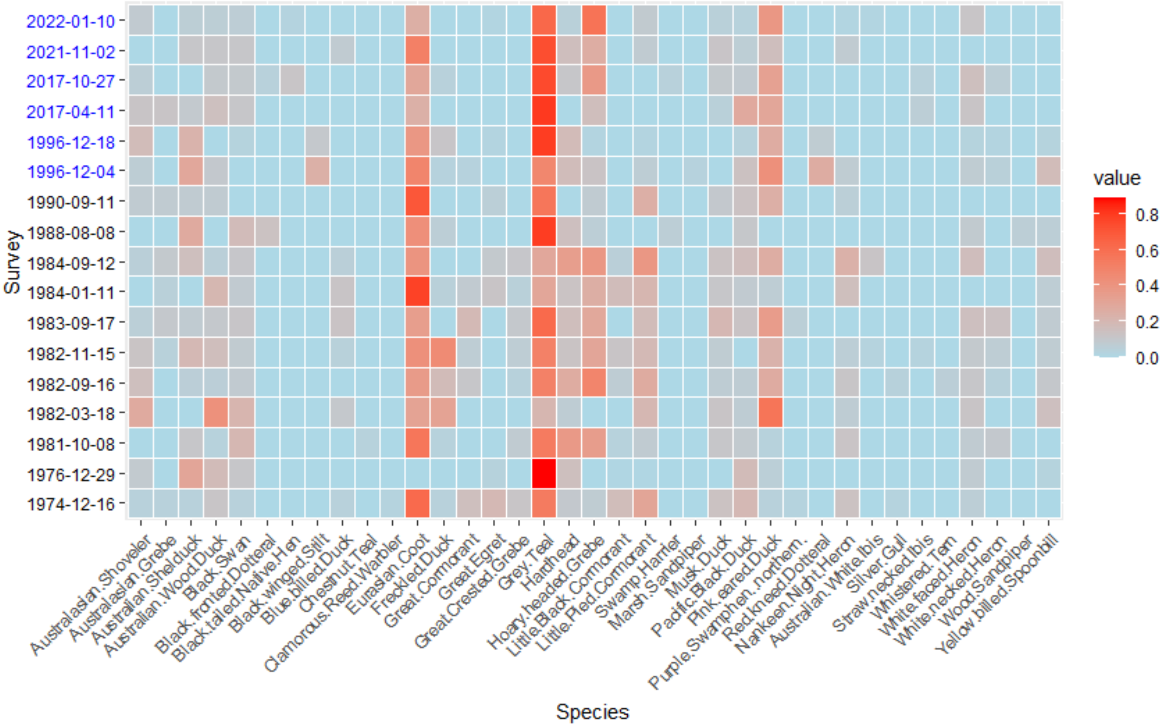

*Figure 17. Heatmap showing relative abundance of species recorded for the reference and 1996 to 2022 surveys, based on Helinger transformed abundances.*

The above analyses suggest that there has been some moderate shifts in the diversity and composition of waterbirds using Toolibin Lake, particularly compared to the 1970s, reflecting altered habitats, but there is no continuing trajectory in waterbird communities.

### *Walbyring Lake*

Figure 18 is an ordination of Walbyring waterbird communities present between 1981 and 1990 and from 1996 to 2022. Some of the Jaensch *et al*. (1988) surveys recorded only 1 or 2 species and none were noted to have been complete by surveyors. Also, some surveys were undertaken within days or a few weeks of one another so are essentially re-surveys of the same communities, so there is some temporal autocorrelation in that dataset. The ordination below was based only on those surveys for which at least 5 species were detected, which coincidentally eliminated most of the repeat surveys. This left seven surveys between 1982 and 1990 and the six from 1996 to 2022.

This ordination suggests that the communities surveyed from 1996 to 2022 at Walbyring Lake are dissimilar to those undertaken between 1981 and 1990, but there is no evidence of ongoing change. It should be noted that the 1980s surveys used in the analyses were more biased towards winter and early spring whereas the 1996 to 2022 surveys were undertaken largely from late spring to autumn so this may account for some of the difference.

A 'simper' analyses based on transformed abundances identified 8 species (Grey Teal, Eurasian Coot, Pink-eared Duck, Black Swan, Hoary-headed Grebe, Pacific Black Duck, Wood Duck and Hardhead), that together contributed 68% of the difference in composition between the 1980s surveys and the 1996 to 2022 surveys. Four of these had significantly different abundances: Grey Teal and Australian Wood Duck more abundant from 1996 ($p<0.01$ and 0.05 respectively), Hardhead (present only in 1996+ surveys, $p<0.01$) and Eurasian Coot less abundant from 1996 ($p<0.05$). A simper analysis of raw abundance data found that nearly the same top 8 species contributed 91% of differences in composition between these periods, with Red-kneed Dotterels replacing Black Swan. Of these, five (Grey Teal, Hoary-headed Grebes, Hardhead, Australian Wood Duck and Red-kneed Dotterels) had significantly higher abundances in the 1996 to 2022 surveys.

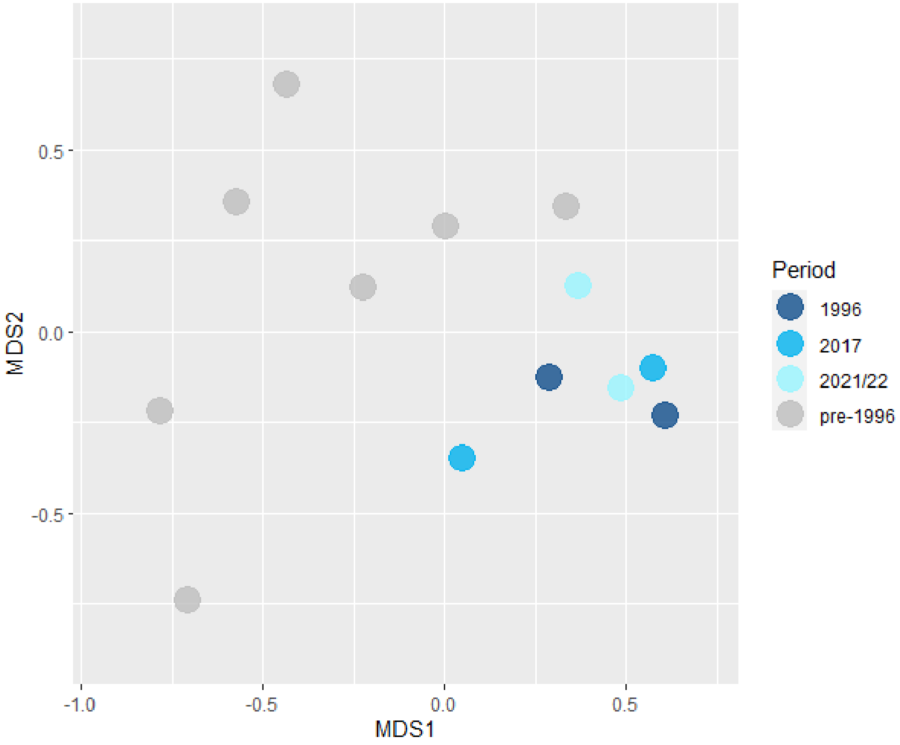

*Figure 18. Axes 1 v 2 of a 3D ordination plot based on Helinger transformed species abundance values for surveys at Walbyring Lake undertaken during periods as indicated. Stress = 0.04.*

Figure 19 is a heatmap of the relative transformed abundance of waterbird species for selected surveys of Walbyring Lake conducted in the 1980s (dates in black text on the y axis – those used in the ordination) and those undertaken from 1996 to 2022 (blue text). Some patterns in this graphic reflect the simper analysis. Notable are higher abundance (on average) of Hoary-headed Grebe, Hardhead, Australian Wood Duck, Grey Teal, but lower abundances of White-faced Heron, Black Swan and Eurasian Coot.

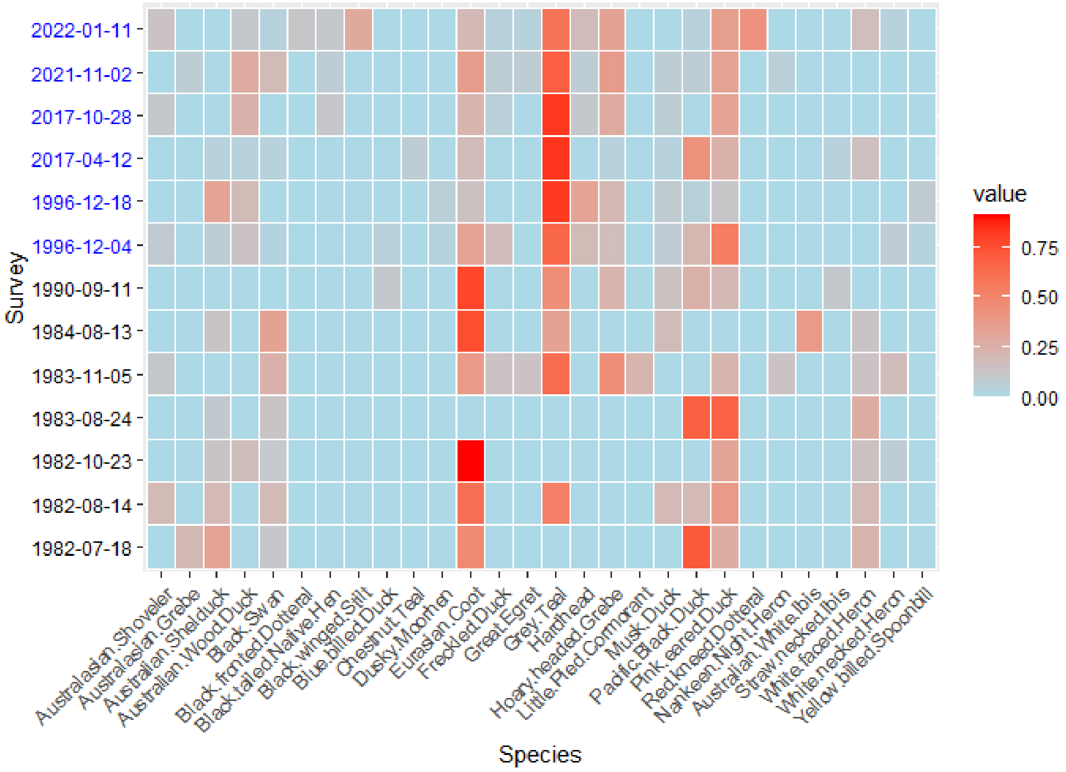

*Figure 19. Heatmap showing relative abundance of species recorded for the reference and 1996 to 2022 surveys of Walbyring Lake based on Hellinger transformed abundances.*

## Waterbird management targets

The Toolibin Lake Ecological Character Description (McMahon, 2006) suggested an interim target of 20 species to be present during a fill event. This was based on the results of the 1996 survey reported in Halse *et al.* (2000). The 2017 and 2021/22 surveys recorded 19 and 24 species respectively, over two surveys for each period, suggesting this target is being met under current conditions.

A second interim criterion of 18-25 species breeding (when water present) was based on the total number of species observed breeding over dozens of surveys conducted over five years in the 1980s and some surveys in the early 1990s (Froend *et al.*, 1997), rather than a single fill event. It is not valid as a target for any one survey.

Between 1996 and 2022 (5 surveys with the 1996 surveys combined) 13 species have been recorded breeding at Toolibin Lake, with 7 breeding at Walbyring Lake to give a combined total of 15 species (Table 8). Ten species bred at Toolibin Lake in 1996, compared to just 5 in 2017 and 7 in 2021/22. Across both lakes, 6 species were recorded breeding in 2017 and 9 in 2021/22.

These numbers are comparable to the number of species reported breeding in many other surveys, with 1 to 9 species breeding (average 4) in Toolibin Lake in the 1980s reference surveys reported by Jaensch *et al.* (1988). Ten species were breeding at Toolibin in 1974 (unpublished data), 2 species in 1988 and 4 species in 1990.

*Table 8. Evidence of breeding between 1996 and 2022.*

| | Toolibin | | | Walbyring | | |
|---|---|---|---|---|---|---|
| | 1996 | 2017 | 2021/22 | 1996 | 2017 | 2021/22 |
| Grey Teal | Y | Y | Y | | Y | |
| Pink-eared Duck | Y | Y | Y | | Y | Y |
| Australian Shelduck | Y | | | | | |
| Australasian Shoveller | Y | | | | | |
| Australian Wood Duck | | Y | | | | |
| Musk Duck | | | | | Y | |
| Eurasian Coot | Y | Y | Y | | | Y |
| Black Swan | Y | | Y | | | |
| Little Pied Cormorant | Y | | Y | | | |
| Hoary-headed Grebe | | Y | Y | | | Y |
| Nankeen Night Heron | | | Y | | | |
| Yellow-billed Spoonbill | Y | | | | | |
| White-necked Heron | Y | | | | | |
| Black-winged Stilt | Y | | | | | |
| Black-fronted Dotterel | | | | | | Y |
| Red-kneed Dotterel | | | | | | Y |

Of the indicator species (see below), broods were detected at Toolibin Lake for Pink-eared Duck (both surveys), Grey Teal (both surveys) and Eurasian Coot (Jan 2022).

The 2017 Recovery Plan had a management target:

> *To maintain the species composition of the waterbird element over the management period by maintaining appropriate waterbird habitat, and specifically: retaining the six indicator species.*

The six indicator waterbird species are Australian Shelduck, Pink-eared Duck, Grey Teal, Freckled Duck, Eurasian Coot and Black-winged Stilt, and the recovery plan aims to maintain abundances of these similar to those in earlier surveys.

Figure 20 shows abundances of the six indicator species at Toolibin Lake for three periods (reference wetlands from the 1970s and 1980s, 1996, 2017 and 2021/22). All indicator species were present at Toolibin Lake in 1996 and, except for the Black-winged Stilt, these were also present in 2017. In 2021/22, Black-winged Stilt and Freckled Duck were absent but the remaining four were present. Other than Black-winged Stilt, all indicator species were present at Walbyring Lake in both 1996 and 2017, and in 2021/22 five species were present at Walbyring, with just Australian Shelduck absent. Black-winged stilt have a relatively low frequency of occurrence at Toolibin Lake. They were recorded in December 1996 but otherwise only in three surveys during late summer 1983, all at lake depths of < 0.7m; suggesting the lake was too deep for this small wading species during the survey periods in 2017 and 2021/22. Black-winged stilt were present in the 1970s cumulative species list but not in the single 1975 survey at a depth of 0.76m. To assess the presence and abundance of this species against management goals requires waterbird surveys to be conducted at lower depths later in the hydrological cycle.

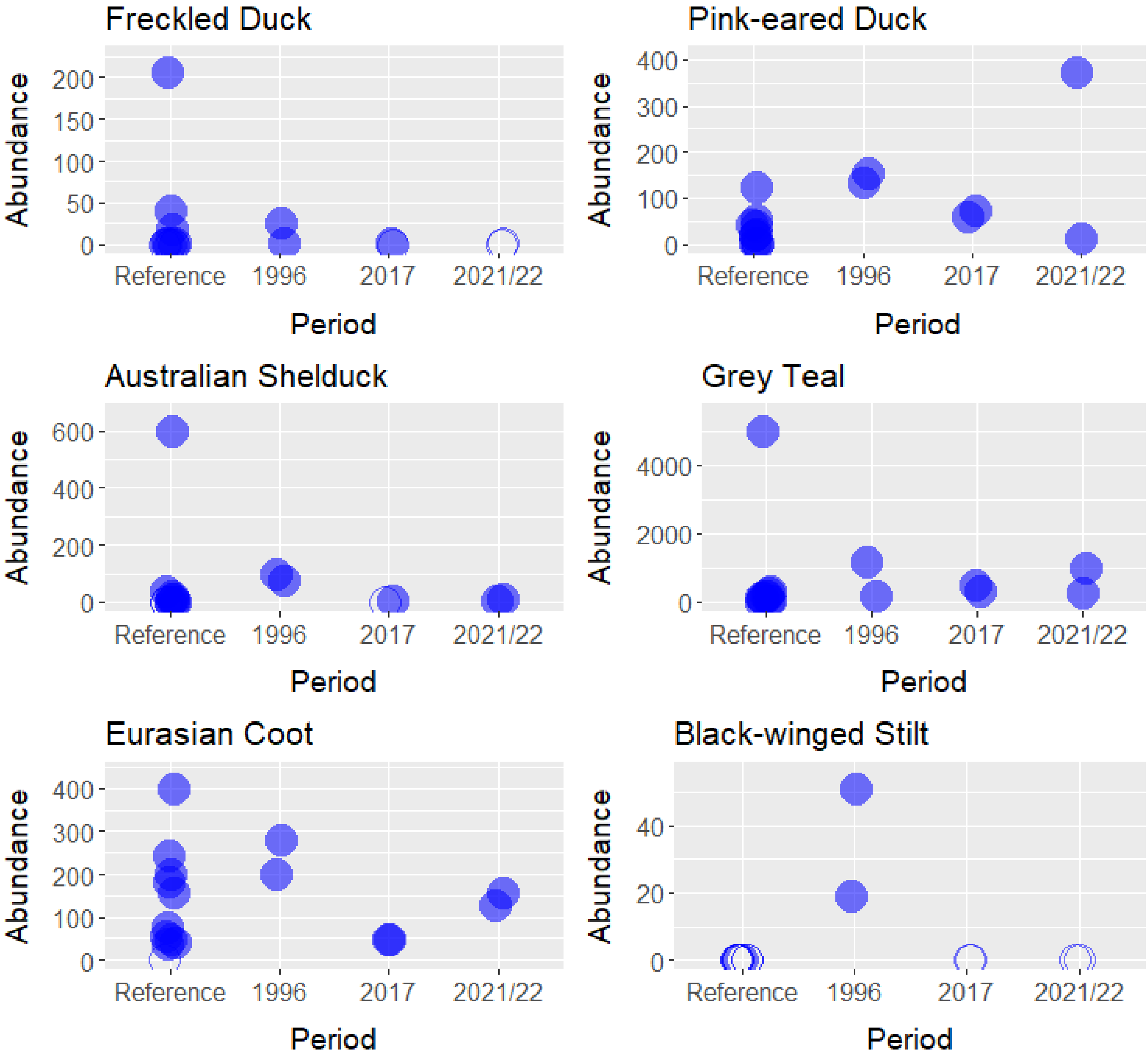

*Figure 20. Abundances of the six indicator species for Toolibin Lake by four periods. Points are 'jittered' to show multiple similar abundances within a period. Deeper colour results from overlapping points. Open circle = no birds recorded.*

Freckled Duck were not observed during the 2021/22 surveys at Toolibin Lake. Only a single individual was recorded in 2017, whereas 25 were seen in December 1996 and between 0 and 206 during the reference surveys. Two-thirds of the reference surveys recorded this species, but mostly only 1 or 2 individuals (average 33). The only count higher than the maximum count recorded during a reference survey, is 600 in December 1982, which is an exceptional count for this species.

Numbers of Australian Shelduck in 2021/22 (6 and 10) were similar to the numbers present in 2017 (0 and 7) but lower than in 1996 (74 and 97), The 2021/22 counts were lower than average for the reference surveys (57) but within the interquartile range (1.75 to 11). Excluding a single count of 600 in 1976, the average for the reference surveys is 7.5 and interquartile range 1.5 to 8), so the 2021/22 is not unusual.

Numbers of Eurasian Coot and Grey Teal in 2021/22 were well within the range of counts from previous periods. The count of 985 Grey Teal in Jan 2022 was higher than all but one reference survey and all but four of any of the previous surveys. The 2021/22 counts of Eurasian Coot (126 and 158) were higher than the average for reference surveys and between the 1996 and 2017 counts.

The count of 372 Pink-eared Ducks in Jan 2022 is higher than for any previous survey.

There is no current management target for total abundance of waterbirds. With median counts of 413 and 818 for reference surveys and 1996 to 2022 surveys respectively, a target of 500 birds per survey seems reasonable.

## Acknowledgements

Maria Lee and Shari Dougall (Wheatbelt Region, DBCA) assisted the authors with the Nov 2021 and Jan 2022 waterbird surveys respectively. Karin Strehlow sorted some of the invertebrate samples. Jessica Sciano assisted in the field for the Nov 2021 trip. Heidi Oswald and Ray McKnight provided comments and suggestions that improved the report. This work was undertaken as part of DBCA's Ramsar wetland monitoring program with support from the Wheatbelt Region.

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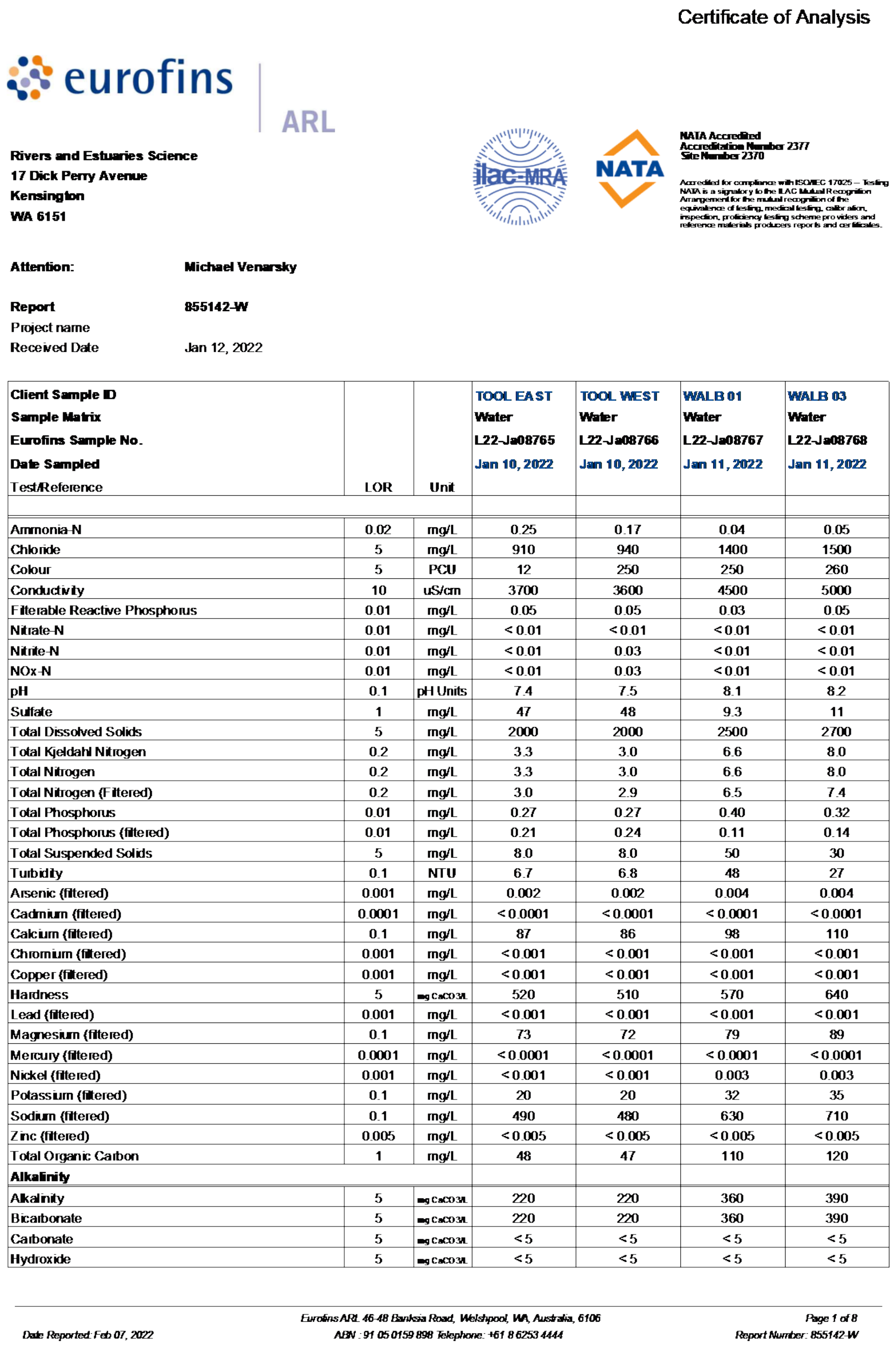
# Appendix 1. Original report on water chemistry from Eurofins



## Certificate of Analysis

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**17 Dick Perry Avenue**
**Kensington**
**WA 6151**

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**Attention:** **Michael Venarsky**

**Report** **855142-W**
Project name
Received Date Jan 12, 2022

| **Client Sample ID**<br>**Sample Matrix**<br>**Eurofins Sample No.**<br>**Date Sampled**<br>Test/Reference | LOR | Unit | **TOOL EAST**<br>**Water**<br>**L22-Ja08765**<br>**Jan 10, 2022** | **TOOL WEST**<br>**Water**<br>**L22-Ja08766**<br>**Jan 10, 2022** | **WALB 01**<br>**Water**<br>**L22-Ja08767**<br>**Jan 11, 2022** | **WALB 03**<br>**Water**<br>**L22-Ja08768**<br>**Jan 11, 2022** |
|---|---|---|---|---|---|---|
| Ammonia-N | 0.02 | mg/L | 0.25 | 0.17 | 0.04 | 0.05 |
| Chloride | 5 | mg/L | 910 | 940 | 1400 | 1500 |
| Colour | 5 | PCU | 12 | 250 | 250 | 260 |
| Conductivity | 10 | uS/cm | 3700 | 3600 | 4500 | 5000 |
| Filterable Reactive Phosphorus | 0.01 | mg/L | 0.05 | 0.05 | 0.03 | 0.05 |
| Nitrate-N | 0.01 | mg/L | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| Nitrite-N | 0.01 | mg/L | < 0.01 | 0.03 | < 0.01 | < 0.01 |
| NOx-N | 0.01 | mg/L | < 0.01 | 0.03 | < 0.01 | < 0.01 |
| pH | 0.1 | pH Units | 7.4 | 7.5 | 8.1 | 8.2 |
| Sulfate | 1 | mg/L | 47 | 48 | 9.3 | 11 |
| Total Dissolved Solids | 5 | mg/L | 2000 | 2000 | 2500 | 2700 |
| Total Kjeldahl Nitrogen | 0.2 | mg/L | 3.3 | 3.0 | 6.6 | 8.0 |
| Total Nitrogen | 0.2 | mg/L | 3.3 | 3.0 | 6.6 | 8.0 |
| Total Nitrogen (Filtered) | 0.2 | mg/L | 3.0 | 2.9 | 6.5 | 7.4 |
| Total Phosphorus | 0.01 | mg/L | 0.27 | 0.27 | 0.40 | 0.32 |
| Total Phosphorus (filtered) | 0.01 | mg/L | 0.21 | 0.24 | 0.11 | 0.14 |
| Total Suspended Solids | 5 | mg/L | 8.0 | 8.0 | 50 | 30 |
| Turbidity | 0.1 | NTU | 6.7 | 6.8 | 48 | 27 |
| Arsenic (filtered) | 0.001 | mg/L | 0.002 | 0.002 | 0.004 | 0.004 |
| Cadmium (filtered) | 0.0001 | mg/L | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |
| Calcium (filtered) | 0.1 | mg/L | 87 | 86 | 98 | 110 |
| Chromium (filtered) | 0.001 | mg/L | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Copper (filtered) | 0.001 | mg/L | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Hardness | 5 | mg CaCO3/L | 520 | 510 | 570 | 640 |
| Lead (filtered) | 0.001 | mg/L | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Magnesium (filtered) | 0.1 | mg/L | 73 | 72 | 79 | 89 |
| Mercury (filtered) | 0.0001 | mg/L | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |
| Nickel (filtered) | 0.001 | mg/L | < 0.001 | < 0.001 | 0.003 | 0.003 |
| Potassium (filtered) | 0.1 | mg/L | 20 | 20 | 32 | 35 |
| Sodium (filtered) | 0.1 | mg/L | 490 | 480 | 630 | 710 |
| Zinc (filtered) | 0.005 | mg/L | < 0.005 | < 0.005 | < 0.005 | < 0.005 |
| Total Organic Carbon | 1 | mg/L | 48 | 47 | 110 | 120 |
| **Alkalinity** | | | | | | |
| Alkalinity | 5 | mg CaCO3/L | 220 | 220 | 360 | 390 |
| Bicarbonate | 5 | mg CaCO3/L | 220 | 220 | 360 | 390 |
| Carbonate | 5 | mg CaCO3/L | < 5 | < 5 | < 5 | < 5 |
| Hydroxide | 5 | mg CaCO3/L | < 5 | < 5 | < 5 | < 5 |

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*Date Reported: Feb 07, 2022* *ABN : 91 05 0159 898 Telephone: +61 8 6253 4444* *Report Number: 855142-W*

**Sample History**

Where samples are submitted/analysed over several days, the last date of extraction is reported.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

| Description | Testing Site | Extracted | Holding Time |
|---|---|---|---|
| Ammonia-N | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL303 - Ammonia in Water by Discrete Analyser | | | |
| Chloride | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL305 - Chloride in Water by Discrete Analyser | | | |
| Colour | Welshpool | Jan 13, 2022 | 2 Days |
| - Method: ARL310 - Colour in Water | | | |
| Conductivity | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL019 - Conductivity and Salinity in Water | | | |
| Filterable Reactive Phosphorus | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL309 - Filterable Reactive Phosphorus in Water by Discrete Analyser | | | |
| Nitrate-N | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL313/319 - NOx in Water by Discrete Analyser | | | |
| Nitrite-N | Welshpool | Jan 13, 2022 | 2 Days |
| - Method: ARL311 - Nitrite in Water by Discrete Analyser | | | |
| pH | Welshpool | Jan 13, 2022 | 1 Day |
| - Method: ARL014 - pH in Water | | | |
| Sulfate | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL301 - Sulfate in Water by Discrete Analyser | | | |
| Total Dissolved Solids | Welshpool | Jan 13, 2022 | 7 Days |
| - Method: ARL No. 017 - Total Dissolved Solids | | | |
| Total Nitrogen (Filtered) | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL No. 330 - Persulfate Method for Simultaneous Determination of TN & TP | | | |
| Total Phosphorus | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL308 - Total Phosphorus in Water by Discrete Analyser | | | |
| Total Phosphorus (filtered) | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: SOP #6 Analysis of Volatile Organic Compounds in Passivated Canisters EPA Method TO-15 | | | |
| Total Suspended Solids | Welshpool | Jan 13, 2022 | 7 Days |
| - Method: ARL No. 016 - Total Suspended Solids | | | |
| Turbidity | Welshpool | Jan 13, 2022 | 1 Day |
| - Method: ARL No. 045 - Turbidity | | | |
| Calcium (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL029 - Metals in Water by AAS | | | |
| Hardness | Welshpool | Jan 13, 2022 | 180 Day |
| - Method: ARL029 - Metals in Water by AAS | | | |
| Magnesium (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL029 - Metals in Water by AAS | | | |
| Potassium (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL029 - Metals in Water by AAS | | | |
| Sodium (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL029 - Metals in Water by AAS | | | |
| Alkalinity | Welshpool | Jan 13, 2022 | 14 Days |
| - Method: ARL037 - Alkalinity in Water | | | |
| NOx-N | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL313/319 - NOx in Water by Discrete Analyser | | | |
| Total Kjeldahl Nitrogen | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL No. 330 - Persulfate Method for Simultaneous Determination of TN & TP | | | |
| Total Nitrogen | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL No. 330 - Persulfate Method for Simultaneous Determination of TN & TP | | | |
| Arsenic (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL402/403 - Metals in Water by ICPOES/ICPMS | | | |
| Cadmium (filtered) | Welshpool | Jan 13, 2022 | 180 Days |

*Date Reported: Feb 07, 2022*

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*Page 2 of 8*
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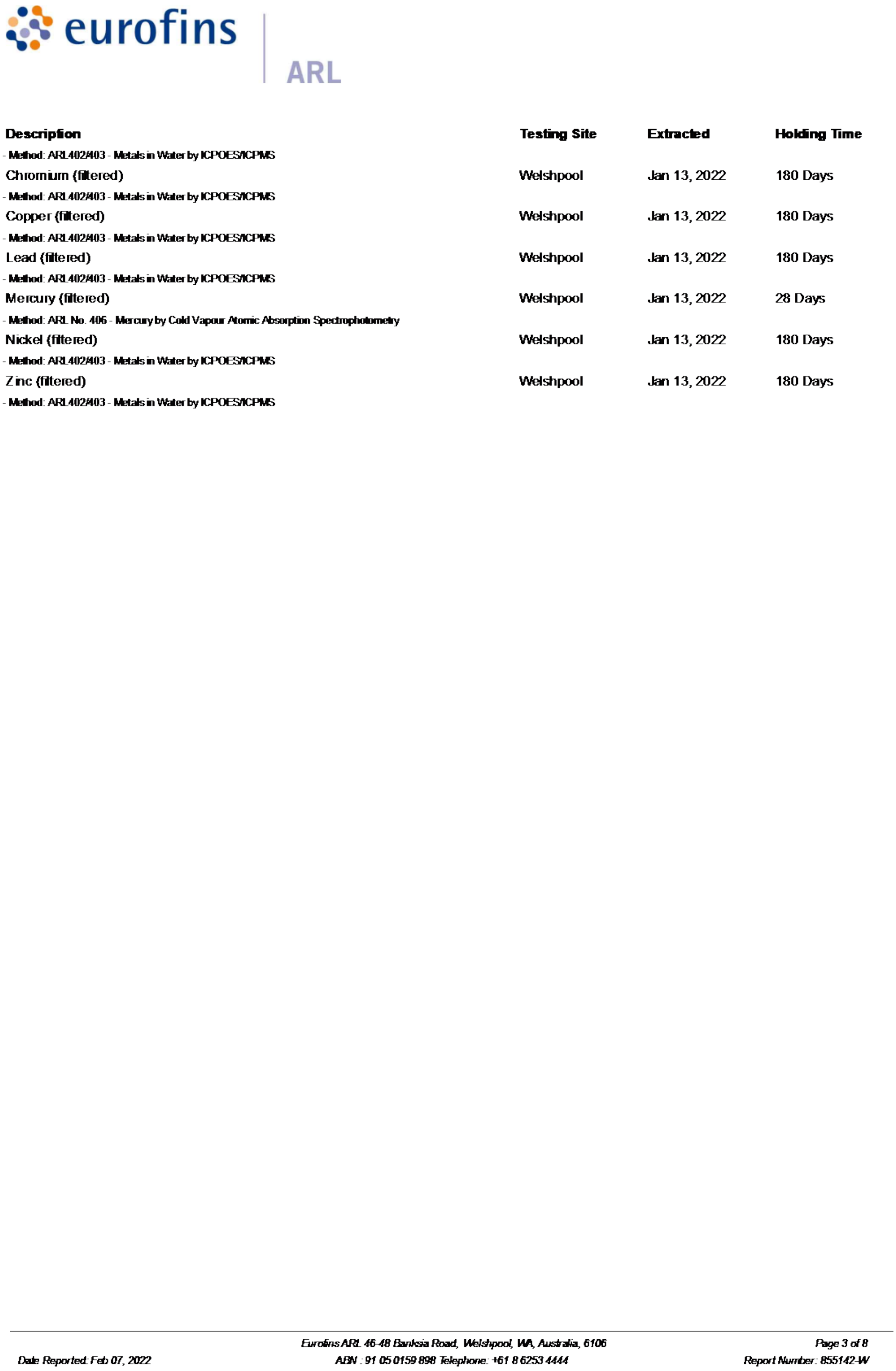
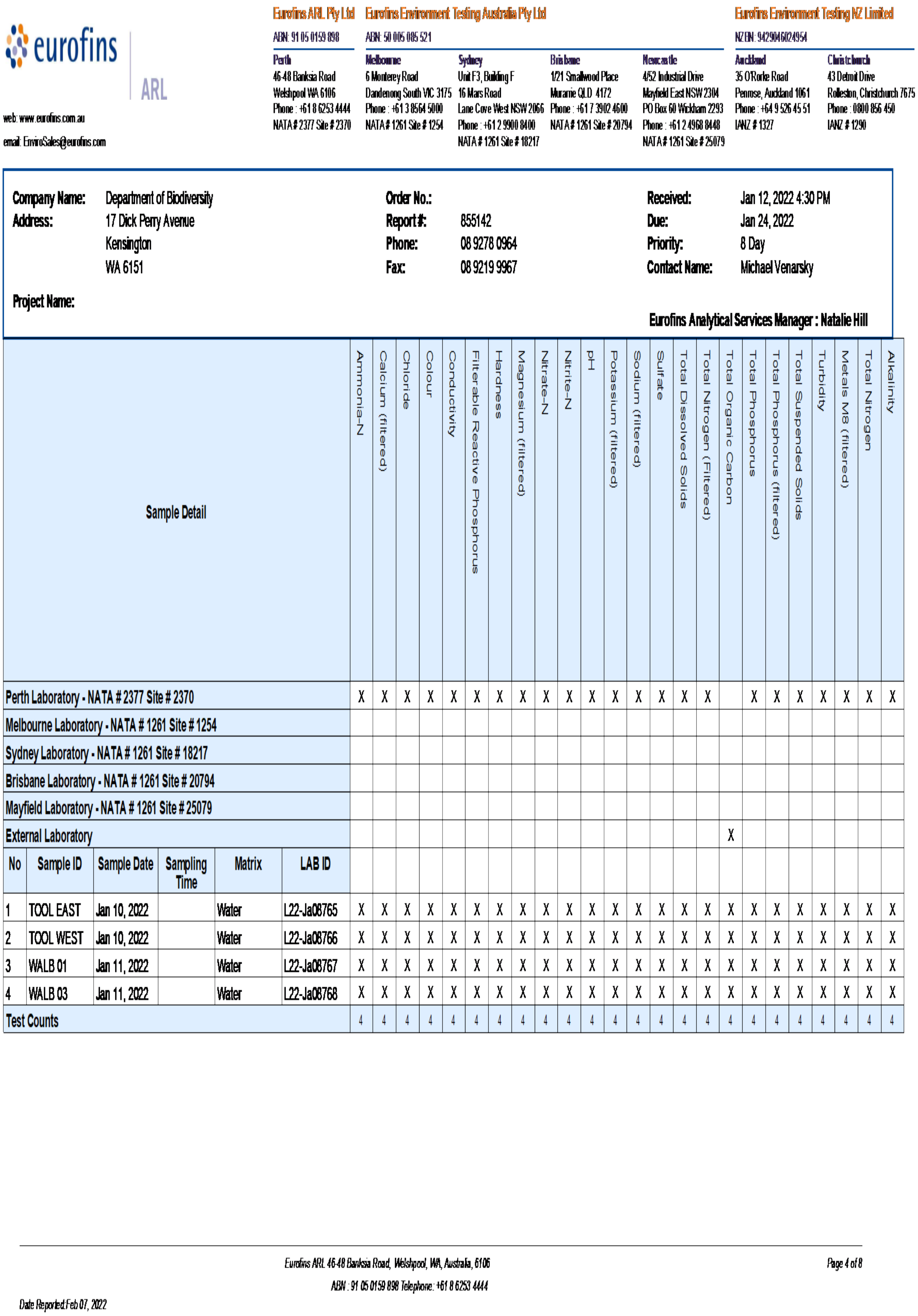


eurofins | ARL

| Description | Testing Site | Extracted | Holding Time |
|---|---|---|---|
| - Method: ARL402/403 - Metals in Water by ICPOES/ICPMS | | | |
| Chromium (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL402/403 - Metals in Water by ICPOES/ICPMS | | | |
| Copper (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL402/403 - Metals in Water by ICPOES/ICPMS | | | |
| Lead (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL402/403 - Metals in Water by ICPOES/ICPMS | | | |
| Mercury (filtered) | Welshpool | Jan 13, 2022 | 28 Days |
| - Method: ARL No. 406 - Mercury by Cold Vapour Atomic Absorption Spectrophotometry | | | |
| Nickel (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL402/403 - Metals in Water by ICPOES/ICPMS | | | |
| Zinc (filtered) | Welshpool | Jan 13, 2022 | 180 Days |
| - Method: ARL402/403 - Metals in Water by ICPOES/ICPMS | | | |



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**Company Name:** Department of Biodiversity
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Kensington
WA 6151

**Project Name:**

**Order No.:**
**Report #:** 855142
**Phone:** 08 9278 0964
**Fax:** 08 9219 9967

**Received:** Jan 12, 2022 4:30 PM
**Due:** Jan 24, 2022
**Priority:** 8 Day
**Contact Name:** Michael Venarsky

**Eurofins Analytical Services Manager : Natalie Hill**

| Sample Detail | | | | | | Ammonia-N | Calcium (filtered) | Chloride | Colour | Conductivity | Filterable Reactive Phosphorus | Hardness | Magnesium (filtered) | Nitrate-N | Nitrite-N | pH | Potassium (filtered) | Sodium (filtered) | Sulfate | Total Dissolved Solids | Total Nitrogen (Filtered) | Total Organic Carbon | Total Phosphorus | Total Phosphorus (filtered) | Total Suspended Solids | Turbidity | Metals M8 (filtered) | Total Nitrogen | Alkalinity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Perth Laboratory - NATA # 2377 Site # 2370 | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X |
| Melbourne Laboratory - NATA # 1261 Site # 1254 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sydney Laboratory - NATA # 1261 Site # 18217 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Brisbane Laboratory - NATA # 1261 Site # 20794 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mayfield Laboratory - NATA # 1261 Site # 25079 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| External Laboratory | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | |
| No | Sample ID | Sample Date | Sampling Time | Matrix | LAB ID | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | TOOL EAST | Jan 10, 2022 | | Water | L22-Ja08765 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 2 | TOOL WEST | Jan 10, 2022 | | Water | L22-Ja08766 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 3 | WALB 01 | Jan 11, 2022 | | Water | L22-Ja08767 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 4 | WALB 03 | Jan 11, 2022 | | Water | L22-Ja08768 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Test Counts | | | | | | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

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*Date Reported:Feb 07, 2022*

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## Internal Quality Control Review and Glossary

### General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples follows guidelines delineated in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended May 2013 and are included in this QC report where applicable. Additional QC data may be available on request.
2. All soil/sediment/solid results are reported on a dry basis, unless otherwise stated.
3. All biota/food results are reported on a wet weight basis on the edible portion, unless otherwise stated.
4. Actual LORs are matrix dependant. Quoted LORs may be raised where sample extracts are diluted due to interferences.
5. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds.
6. SVOC analysis on waters are performed on homogenised, unfiltered samples, unless noted otherwise.
7. Samples were analysed on an 'as received' basis.
8. Information identified on this report with blue colour, indicates data provided by customer that may have an impact on the results.
9. This report replaces any interim results previously issued.

### Holding Times

Please refer to 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours prior to sample receipt deadlines as stated on the SRA.

If the Laboratory did not receive the information in the required timeframe, and regardless of any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the date of sampling, therefore compliance to these may be outside the laboratory's control.

For VOCs containing vinyl chloride, styrene and 2-chloroethyl vinyl ether the holding time is 7 days however for all other VOCs such as BTEX or C6-10 TRH then the holding time is 14 days.

### Units

**mg/kg:** milligrams per kilogram
**ppm:** parts per million
**org/100 mL:** Organisms per 100 millilitres
**mg/L:** milligrams per litre
**ppb:** parts per billion
**NTU:** Nephelometric Turbidity Units
**μg/L:** micrograms per litre
**%:** Percentage
**MPN/100 mL:** Most Probable Number of organisms per 100 millilitres

### Terms

| | |
|---|---|
| **APHA** | American Public Health Association |
| **COC** | Chain of Custody |
| **CP** | Client Parent - QC was performed on samples pertaining to this report |
| **CRM** | Certified Reference Material (ISO17034) - reported as percent recovery. |
| **Dry** | Where a moisture has been determined on a solid sample the result is expressed on a dry basis. |
| **Duplicate** | A second piece of analysis from the same sample and reported in the same units as the result to show comparison. |
| **LOR** | Limit of Reporting. |
| **LCS** | Laboratory Control Sample - reported as percent recovery. |
| **Method Blank** | In the case of solid samples these are performed on laboratory certified clean sands and in the case of water samples these are performed on de-ionised water. |
| **NCP** | Non-Client Parent - QC performed on samples not pertaining to this report, QC is representative of the sequence or batch that client samples were analysed within. |
| **RPD** | Relative Percent Difference between two Duplicate pieces of analysis. |
| **SPIKE** | Addition of the analyte to the sample and reported as percentage recovery. |
| **SRA** | Sample Receipt Advice |
| **Surr - Surrogate** | The addition of a like compound to the analyte target and reported as percentage recovery. |
| **TBTO** | Tributyltin oxide (*bis*-tributyltin oxide) - individual tributyltin compounds cannot be identified separately in the environment however free tributyltin was measured and its values were converted stoichiometrically into tributyltin oxide for comparison with regulatory limits. |
| **TCLP** | Toxicity Characteristic Leaching Procedure |
| **TEQ** | Toxic Equivalency Quotient or Total Equivalence |
| **QSM** | US Department of Defense Quality Systems Manual Version 5.4 |
| **US EPA** | United States Environmental Protection Agency |
| **WA DWER** | Sum of PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFBS, PFHxS, PFOS, 6:2 FTSA, 8:2 FTSA |

### QC - Acceptance Criteria

The acceptance criteria should be used as a guide only and may be different when site specific Sampling Analysis and Quality Plan (SAQP) have been implemented

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is 30% however the following acceptance guidelines are equally applicable:

Results <10 times the LOR: No Limit

Results between 10-20 times the LOR: RPD must lie between 0-50%

Results >20 times the LOR : RPD must lie between 0-30%

NOTE: pH duplicates are reported as a range not as RPD

Surrogate Recoveries: Recoveries must lie between 20-130% for Speciated Phenols & 50-150% for PFAS

PFAS field samples that contain surrogate recoveries in excess of the QC limit designated in QSM 5.4 where no positive PFAS results have been reported have been reviewed and no data was affected.

.

### QC Data General Comments

1. Where a result is reported as a less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch, but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown is not data from your samples.
3. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling. Therefore, laboratory analysis is unlikely to be completed within holding time. Analysis will begin as soon as possible after sample receipt.
4. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of recovery the term "INT" appears against that analyte.
5. For Matrix Spikes and LCS results a dash "-" in the report means that the specific analyte was not added to the QC sample.
6. Duplicate RPDs are calculated from raw analytical data thus it is possible to have two sets of data.

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**Quality Control Results**

| Test | Units | Result 1 | | | Acceptance Limits | Pass Limits | Qualifying Code |
|---|---|---|---|---|---|---|---|
| **Method Blank** | | | | | | | |
| Ammonia-N | mg/L | < 0.02 | | | 0.02 | Pass | |
| Chloride | mg/L | < 5 | | | 5 | Pass | |
| Colour | PCU | < 5 | | | 5 | Pass | |
| Conductivity | uS/cm | < 10 | | | 10 | Pass | |
| Filterable Reactive Phosphorus | mg/L | < 0.01 | | | 0.01 | Pass | |
| Nitrate-N | mg/L | < 0.01 | | | 0.01 | Pass | |
| Nitrite-N | mg/L | < 0.01 | | | 0.01 | Pass | |
| NOx-N | mg/L | < 0.01 | | | 0.01 | Pass | |
| Sulfate | mg/L | < 1 | | | 1 | Pass | |
| Total Dissolved Solids | mg/L | < 5 | | | 5 | Pass | |
| Total Nitrogen | mg/L | < 0.2 | | | 0.2 | Pass | |
| Total Nitrogen (Filtered) | mg/L | < 0.2 | | | 0.2 | Pass | |
| Total Phosphorus | mg/L | < 0.01 | | | 0.01 | Pass | |
| Total Phosphorus (filtered) | mg/L | < 0.01 | | | 0.01 | Pass | |
| Total Suspended Solids | mg/L | < 5 | | | 5 | Pass | |
| Turbidity | NTU | < 0.1 | | | 0.1 | Pass | |
| Arsenic (filtered) | mg/L | < 0.001 | | | 0.001 | Pass | |
| Cadmium (filtered) | mg/L | < 0.0001 | | | 0.0001 | Pass | |
| Calcium (filtered) | mg/L | < 0.1 | | | 0.1 | Pass | |
| Chromium (filtered) | mg/L | < 0.001 | | | 0.001 | Pass | |
| Copper (filtered) | mg/L | < 0.001 | | | 0.001 | Pass | |
| Lead (filtered) | mg/L | < 0.001 | | | 0.001 | Pass | |
| Magnesium (filtered) | mg/L | < 0.1 | | | 0.1 | Pass | |
| Nickel (filtered) | mg/L | < 0.001 | | | 0.001 | Pass | |
| Potassium (filtered) | mg/L | < 0.1 | | | 0.1 | Pass | |
| Zinc (filtered) | mg/L | < 0.005 | | | 0.005 | Pass | |
| **Method Blank** | | | | | | | |
| **Alkalinity** | | | | | | | |
| Alkalinity | mg CaCO3/L | < 5 | | | 5 | Pass | |
| Bicarbonate | mg CaCO3/L | < 5 | | | 5 | Pass | |
| Carbonate | mg CaCO3/L | < 5 | | | 5 | Pass | |
| Hydroxide | mg CaCO3/L | < 5 | | | 5 | Pass | |
| **LCS - % Recovery** | | | | | | | |
| Conductivity | % | 87 | | | 80-120 | Pass | |
| Cadmium (filtered) | % | 88 | | | 80-120 | Pass | |
| Calcium (filtered) | % | 112 | | | 80-120 | Pass | |
| Lead (filtered) | % | 86 | | | 80-120 | Pass | |
| Magnesium (filtered) | % | 110 | | | 80-120 | Pass | |
| Potassium (filtered) | % | 99 | | | 80-120 | Pass | |
| Zinc (filtered) | % | 108 | | | 80-120 | Pass | |
| **CRM - % Recovery** | | | | | | | |
| Colour | % | 113 | | | 80-120 | Pass | |
| NOx-N | % | 105 | | | 80-120 | Pass | |
| Arsenic (filtered) | % | 83 | | | 80-120 | Pass | |
| Cadmium (filtered) | % | 84 | | | 80-120 | Pass | |
| Calcium (filtered) | % | 102 | | | 90-110 | Pass | |
| Chromium (filtered) | % | 89 | | | 80-120 | Pass | |
| Copper (filtered) | % | 84 | | | 80-120 | Pass | |
| Lead (filtered) | % | 87 | | | 80-120 | Pass | |
| Magnesium (filtered) | % | 101 | | | 90-110 | Pass | |
| Nickel (filtered) | % | 90 | | | 80-120 | Pass | |

| Test | | | Units | Result 1 | | | Acceptance Limits | Pass Limits | Qualifying Code |
|---|---|---|---|---|---|---|---|---|---|
| Potassium (filtered) | | | % | 104 | | | 90-110 | Pass | |
| Sodium (filtered) | | | % | 103 | | | 90-110 | Pass | |
| Zinc (filtered) | | | % | 104 | | | 80-120 | Pass | |
| **Test** | **Lab Sample ID** | **QA Source** | **Units** | **Result 1** | | | **Acceptance Limits** | **Pass Limits** | **Qualifying Code** |
| **Spike - % Recovery** | | | | | | | | | |
| | | | | Result 1 | | | | | |
| Ammonia-N | L22-Ja09617 | NCP | % | 105 | | | 80-120 | Pass | |
| Chloride | L22-Ja03474 | NCP | % | 85 | | | 70-130 | Pass | |
| Colour | L22-Ja08765 | CP | % | 83 | | | 80-120 | Pass | |
| Filterable Reactive Phosphorus | L22-Ja09720 | NCP | % | 109 | | | 80-120 | Pass | |
| Sulfate | L22-Ja09020 | NCP | % | 88 | | | 70-130 | Pass | |
| Total Nitrogen | L22-Ja09005 | NCP | % | 97 | | | 70-130 | Pass | |
| **Spike - % Recovery** | | | | | | | | | |
| | | | | Result 1 | | | | | |
| Nitrite-N | L22-Ja03474 | NCP | % | 110 | | | 80-120 | Pass | |
| NOx-N | L22-Ja03474 | NCP | % | 89 | | | 80-120 | Pass | |
| **Spike - % Recovery** | | | | | | | | | |
| | | | | Result 1 | | | | | |
| Total Phosphorus | L22-Ja08768 | CP | % | 95 | | | 80-120 | Pass | |
| Total Phosphorus (filtered) | L22-Ja08768 | CP | % | 93 | | | 80-120 | Pass | |
| **Test** | **Lab Sample ID** | **QA Source** | **Units** | **Result 1** | | | **Acceptance Limits** | **Pass Limits** | **Qualifying Code** |
| **Duplicate** | | | | | | | | | |
| | | | | Result 1 | Result 2 | RPD | | | |
| Ammonia-N | L22-Ja09618 | NCP | mg/L | < 0.02 | < 0.02 | <1 | 30% | Pass | |
| Chloride | L22-Ja03473 | NCP | mg/L | 170 | 180 | 8.0 | 30% | Pass | |
| Colour | L22-Ja08667 | NCP | PCU | < 5 | < 5 | <1 | 30% | Pass | |
| Conductivity | L22-Ja08765 | CP | uS/cm | 3700 | 3700 | <1 | 30% | Pass | |
| Filterable Reactive Phosphorus | L22-Ja09721 | NCP | mg/L | < 0.01 | < 0.01 | <1 | 30% | Pass | |
| Nitrate-N | L22-Ja17438 | NCP | mg/L | 16 | 16 | 2.0 | 30% | Pass | |
| Nitrite-N | L22-Ja17438 | NCP | mg/L | < 0.01 | < 0.01 | <1 | 30% | Pass | |
| NOx-N | L22-Ja17438 | NCP | mg/L | 16 | 16 | 2.0 | 30% | Pass | |
| pH | L22-Ja08765 | CP | pH Units | 7.4 | 7.4 | 1.0 | 30% | Pass | |
| Sulfate | L22-Ja09019 | NCP | mg/L | 130 | 130 | 5.0 | 30% | Pass | |
| Total Nitrogen | L22-Ja09001 | NCP | mg/L | 0.5 | 0.5 | 2.0 | 30% | Pass | |
| Total Phosphorus | L22-Ja09002 | NCP | mg/L | 0.40 | 0.39 | 2.0 | 30% | Pass | |
| Total Suspended Solids | L21-De05525 | NCP | mg/L | < 5 | < 5 | <1 | 30% | Pass | |
| Turbidity | L22-Ja36718 | NCP | NTU | < 0.1 | < 0.1 | <1 | 30% | Pass | |
| Mercury (filtered) | L22-Ja08306 | NCP | mg/L | < 0.0001 | < 0.0001 | <1 | 30% | Pass | |
| **Duplicate** | | | | | | | | | |
| **Alkalinity** | | | | Result 1 | Result 2 | RPD | | | |
| Alkalinity | L22-Ja08765 | CP | mg CaCO3/L | 220 | 220 | <1 | 30% | Pass | |
| Bicarbonate | L22-Ja08765 | CP | mg CaCO3/L | 220 | 220 | <1 | 30% | Pass | |
| Carbonate | L22-Ja08765 | CP | mg CaCO3/L | < 5 | < 5 | <1 | 30% | Pass | |
| Hydroxide | L22-Ja08765 | CP | mg CaCO3/L | < 5 | < 5 | <1 | 30% | Pass | |
| **Duplicate** | | | | | | | | | |
| | | | | Result 1 | Result 2 | RPD | | | |
| Total Dissolved Solids | L22-Ja08768 | CP | mg/L | 2700 | 2600 | 4.0 | 30% | Pass | |

**Comments**

TOC analysis by: MPL, NATA accreditation no. 2901, report reference 275268

**Sample Integrity**

| | |
|---|---|
| Custody Seals Intact (if used) | N/A |
| Attempt to Chill was evident | Yes |
| Sample correctly preserved | Yes |
| Appropriate sample containers have been used | Yes |
| Sample containers for volatile analysis received with minimal headspace | Yes |
| Samples received within HoldingTime | Yes |
| Some samples have been subcontracted | Yes |

**Authorised by:**

| | |
|---|---|
| Natalie Hill | Analytical Services Manager |
| Douglas Todd | Senior Analyst-Metal (WA) |
| Sam Becker | Senior Analyst-Inorganic (WA) |

**Kim Rodgers**
**Business Unit Manager**

Final Report – this report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request

# Appendix 2. Invertebrate data for samples collected between 1996 and 2022

| | | TE-D96 | TS-D96 | TW-D96 | TE-A17 | TS-A17 | TW-A17 | TS-O17 | TW-O17 | TE-O17 | TE-N21 | TS-N21 | TW-N21 | TE-J22 | TS-J22 | TW-J22 | W1-D96 | W2-D96 | W3-D96 | W1-A17 | W2-A17 | W3-A17 | W1-O17 | W2-O17 | W3-O17 | W1-N21 | W2-N21 | W3-N21 | W1-J22 | W2-J22 | W3-J22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sponges | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cnidarians | *Hydra sp.* | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | 1 |
| Flatworms | *Turbellaria* | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| | *Microturbellaria* | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | | | 1 | 1 | | | | | | |
| Nematodes | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | |
| Gastropoda | *Ferrissia petterdi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Isidorella cf. bradshawi* | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | 1 | 1 | 1 | |
| | *Isidorella* sp. | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | |
| | *Bayardella* sp. | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| | Planorbidae | | | | | | | | | | | | 1 | | | | | | | | | | | 1 | | | 1 | | | | 1 |
| | *Hydrococcus* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Hirudinea | Glossiphoniidae | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| Oligochaeta | Naididae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Dero digitata* | | | | | | | 1 | 1 | 1 | | | | | | | | | | 1 | | 1 | 1 | 1 | 1 | | | | | | |
| | *Dero nivea* | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | |
| | *Chaetogaster diastrophus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Bratislavia WA1* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Tubifex tubifex* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Ainudrilus nharna* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Ainudrilus sp.* | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| | *Opisthopora* | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| Water mites | *Hydrachna nr. approximata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Limnochares australica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Eylais* sp. | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| | *Hydrodroma* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| | *Limnesia dentifera* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Koenikea nr australica* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Acercella falcipes* | | | | | | | 1 | 1 | 1 | 1 | | | 1 | | 1 | | | | | | | 1 | 1 | | | | | | | |
| | *Piona cumberlandensis* | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| | *Arrenurus (Arrenurus) balladoniensis* | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | Pezidae | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Oribatida | | | | | | 1 | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | |
| | Mesostigmata | | | | 1 | | 1 | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | |
| | Trombidioidea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cladocerans | *Alona rigidicaudis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Alona n. sp.?* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Celsinotum cf. hypsilophum* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Dunhevedia crassa* | 1 | 1 | 1 | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| | *Kurzia latissima* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | |
| | *Leberis cf. diaphanus vermiculata* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Leberis diaphanus* | | | | | | | | | | 1 | 1 | | 1 | | | | | | | | | | | | | 1 | | | 1 | |
| | *Leydigia australis* | | | | | | | | | | | | | | | | 1 | 1 | | | | | | 1 | | | | | | | |
| | *Leydigia nr laevis* | | | | | | | | | | | | 1 | 1 | | 1 | | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 |
| | *Pleuroxus foveatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Pleuroxus inermis* | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| | *Pleuroxus cf. inermis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Armatalona macrocopa* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Flavalona setigera* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Ceriodaphnia sp.* | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| | *Ceriodaphnia cf. dubia* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Ceriodaphnia n. sp. c* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | TE-D96 | TS-D96 | TW-D96 | TE-A17 | TS-A17 | TW-A17 | TS-O17 | TW-O17 | TE-O17 | TE-N21 | TS-N21 | TW-N21 | TE-J22 | TS-J22 | TW-J22 | W1-D96 | W2-D96 | W3-D96 | W1-A17 | W2-A17 | W3-A17 | W1-O17 | W2-O17 | W3-O17 | W1-N21 | W2-N21 | W3-N21 | W1-J22 | W2-J22 | W3-J22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flavalona setigera | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ceriodaphnia sp. | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| | Ceriodaphnia cf. dubia | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ceriodaphnia n. sp. c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Daphnia carinata s.l. | | | | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | 1 | 1 | 1 | | 1 | 1 |
| | Daphnia cephalata | | | | | | | 1 | 1 | 1 | | | | | | | | | 1 | | | | 1 | 1 | 1 | | | | | | |
| | Daphnia cf. cephalata | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Daphnia queenslandensis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Daphnia sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Simocephalus vetulus | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| | Simocephalus elizabethae | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | |
| | Simocephalus gibbosus | | | | | | | 1 | | 1 | | | | 1 | 1 | 1 | | | | | | | | | | | | | 1 | 1 | 1 |
| | Simocephalus victoriensis | | | | | | | | | | | | | | 1 | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Simocephalus sp. | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| | Macrothrix breviseta | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 1 |
| | Macrothrix cf. flagellata | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Macrothrix cf. indistincta | | 1 | 1 | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| | Macrothrix cf. capensis | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Moina australiensis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Moina sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | |
| | Moina cf. micrura | | | | 1 | 1 | 1 | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | |
| Ostracoda | Limnocythere mowbrayensis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Ilyocypris australiensis | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| | Alboa worooa | 1 | 1 | 1 | | | | 1 | | | 1 | 1 | | 1 | 1 | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 | 1 | | 1 |
| | Bennelongia barangaroo lineage | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Bennelongia frumenta | | | | | | | | | | 1 | | | 1 | 1 | 1 | | 1 | | | | | | | | | 1 | 1 | 1 | 1 | 1 |
| | Bennelongia gwelupensis | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| | Bennelongia sp. | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | | | | | |
| | Candonocypris novaezelandiae | 1 | 1 | | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 |
| | Cypretta baylyi | | | | | | | | | | | | | | | | 1 | 1 | | | | | 1 | 1 | 1 | | | | | | |
| | Cypretta sp. 527 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Cypretta sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | Cyprinotus cingalensis | 1 | 1 | 1 | | | | | | | 1 | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| | Diacypris spinosa | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Diacypris sp. | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| | Heterocypris sp. | | | | | | | | | 1 | | | | | | | | | | | | | | | 1 | 1 | | | | | |
| | Mytilocypris ambiguosa | 1 | 1 | 1 | | | | | | | | 1 | 1 | | | | 1 | 1 | 1 | | | | | | | 1 | | | | | |
| | Mytilocypris mytiloides | 1 | 1 | 1 | | | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | |
| | Mytilocypris sp. | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| | Ilyodromus amplicolis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Cypricercus salinus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Cypricercus sp. 442 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Platycypris baueri | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sarscypridopsis aculeata | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Copepoda | Boeckella triarticulata s.l. | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Boeckella sp. | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| | Calamoecia ampulla | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| | Calamoecia sp. | | | | | | | | | 1 | | | | | | | | | | | | | | | 1 | | | | | | |
| | Calamoecia sp. 342 | | | | | | | 1 | 1 | | 1 | 1 | | 1 | 1 | 1 | | | | | | | | 1 | | 1 | 1 | 1 | 1 | | 1 |
| | Microcyclops sp. 368 | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | |

| | | TE-D96 | TS-D96 | TW-D96 | TE-A17 | TS-A17 | TW-A17 | TS-O17 | TW-O17 | TE-O17 | TE-N21 | TS-N21 | TW-N21 | TE-J22 | TS-J22 | TW-J22 | W1-D96 | W2-D96 | W3-D96 | W1-A17 | W2-A17 | W3-A17 | W1-O17 | W2-O17 | W3-O17 | W1-N21 | W2-N21 | W3-N21 | W1-J22 | W2-J22 | W3-J22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Australocyclops australis* | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | *Mesocyclops australiensis* | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Mesocyclops brooksi* | | | 1 | | | | | 1 | 1 | | | | | | | 1 | | 1 | | | 1 | | 1 | | | | | | | |
| | *Eucyclops australiensis* | | | | | | | 1 | 1 | | | | | | | | | | | | | | | | 1 | | | | | | |
| | *Paracyclops ?chiltoni* | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| | *Apocyclops dengizicus* | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Pescecyclops sp. 442* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Pescecyclops sp. 434* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Mesochra baylyi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Mesochra nr flava* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Canthocamptidae* sp. 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Australocamptus* sp. 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Nitokra* sp. 5 (*nr reducta*) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Amphipoda** | *Austrochiltonia subtenuis* | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 | | | | | | | 1 | | | 1 | 1 | 1 |
| Decapoda | *Cherax preissii* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Beetles | *Haliplus fuscatus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Haliplus* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Hydrovatus* sp. | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| | *Hyphydrus elegans* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Hyphydrus* sp. | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | 1 | | |
| | *Gibbidessus pictipes* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Limbodessus shuckhardi* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Limbodessus inornatus* | 1 | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | |
| | *Allodessus bistrigatus* | | | | | | | | | | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | | | | | | 1 | | 1 | | | |
| | *Bidessini* sp. | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | 1 | | | | |
| | *Antiporus gilberti* | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | |
| | *Antiporus* sp. | | | | | | | | 1 | 1 | 1 | 1 | | | | | | | | | | | 1 | 1 | | 1 | 1 | | | | |
| | *Sternopriscus multimaculatus* | | | | | | | | | | | | 1 | | | | 1 | 1 | 1 | | | | | | | | 1 | | | | |
| | *Sternopriscus* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 |
| | *Necterosoma penicillatus* | | | 1 | | | | | | | | 1 | 1 | | | | | | | | | | | | | | 1 | | | 1 | |
| | *Necterosoma* sp. | | | | | | | | | | 1 | | | | | | | | | | | | | | | 1 | | | | | |
| | *Megaporus howittii* | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | 1 |
| | *Megaporus solidus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Megaporus* sp. | | | | | | | 1 | | | | | | | 1 | | | | | | | | | | | | | 1 | 1 | 1 | |
| | *Rhantus suturalis* | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| | *Rhantus* sp. | | | | 1 | 1 | | 1 | | 1 | 1 | 1 | | | | | | | | 1 | | | 1 | 1 | 1 | | 1 | 1 | | | |
| | *Lancetes lanceolatus* | 1 | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| | *Hyderodes crassus* | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| | *Hyderodes* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| | *Eretes australis* | | | | 1 | | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| | *Onychohydrus scutellaris* | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | |
| | *Onychohydrus* sp. | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| | *Berosus australiae* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Berosus discolor* | 1 | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| | *Berosus macumbensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Berosus munitipennis* | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Berosus nutans* | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Berosus* sp. | 1 | 1 | 1 | | | | 1 | 1 | | 1 | | | | | | 1 | 1 | 1 | 1 | | 1 | | 1 | | | 1 | | | | |
| | *Enochrus elongatulus* | | | | 1 | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | |
| | *Enochrus eyrensis* | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |

| | | TE-D96 | TS-D96 | TW-D96 | TE-A17 | TS-A17 | TW-A17 | TS-O17 | TW-O17 | TE-O17 | TE-N21 | TS-N21 | TW-N21 | TE-J 22 | TS-J 22 | TW-J 22 | W1-D96 | W2-D96 | W3-D96 | W1-A17 | W2-A17 | W3-A17 | W1-O17 | W2-O17 | W3-O17 | W1-N21 | W2-N21 | W3-N21 | W1-J 22 | W2-J 22 | W3-J 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Enochrus maculiceps* | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| | *Enochrus* sp. | | | | | 1 | | 1 | | 1 | | | | 1 | | | | | | | | | | | | | | | | | |
| | *Paracymus* sp. | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Hydrophilidae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Hydraena luridipennis* | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Staphylinidae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Scirtidae | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Diptera | Tipulidae | 1 | 1 | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| | *Anopheles annulipes* s.l. | 1 | 1 | 1 | | | | 1 | | | | | | | | | | | | | | 1 | | | | | | | | | |
| | *Anopheles* sp. | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Anopheles* (*Cellia*) sp. 2 | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Aedes camptorhynchus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Culex* (*Culex*) *australicus* | | | | 1 | 1 | 1 | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | |
| | *Culex* (*Culex*) *annulirostris* | | | | 1 | 1 | | | | | | | | | | | | | | | | 1 | | | | | | | | | |
| | *Culex* sp. | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| | *Bezzia* sp. | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | *Culicoides* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Monohelea* sp. | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| | *Nilobezzia* sp. | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | 1 | 1 | 1 |
| | *Atrichopogon* sp. | | | | | | | | | | 1 | | | | | 1 | | | | | 1 | 1 | | | | | | | | | |
| | *Forcipomyia* sp. | 1 | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| | Ceratopogonidae | 1 | | 1 | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | |
| | Psychodidae | | | | | | | | | 1 | | | | | | | | | | | | | | | | | 1 | | | | |
| | *Tabanidae* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Stratiomyidae | 1 | 1 | 1 | | 1 | | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | |
| | Dolichopodidae | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| | Syrphidae | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| | Ephydridae | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | 1 | | | | | | 1 | | 1 | | | | 1 | 1 | 1 | | | |
| | Muscidae sp. | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Procladius paludicola* | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | *Procladius villosimanus* | | | | | | | | 1 | 1 | | | | 1 | | 1 | | | | | | | | | | | 1 | 1 | 1 | 1 | 1 |
| | *Ablabesmyia notabilis* | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| | *Paramerina levidensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Paralimnophyes pullulus* | | | | | | | | 1 | | | | | | | | | | | | | | | 1 | | | | | | | |
| | *Cricotopus albitarsus* | | | | | | | | | | 1 | | | 1 | | | | 1 | | | | | | | | | | | | | |
| | *Compterosmittia* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Limnophyes vestitus* | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | 1 | | | | |
| | *Tanytarsus* nr *bispinosus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Tanytarsus fuscithorax/semibarbitarsus* | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | 1 | | | | 1 | 1 | |
| | *Chironomus occidentalis* | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | 1 | | | | | | | 1 | 1 | 1 | | | | 1 | | | | 1 | |
| | *Chironomus tepperi* | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | *Chironomus* aff. *alternans* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | *Dicrotendipes conjunctus* | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | | 1 | | | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 |
| | *Dicrotendipes jobetus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Dicrotendipes pseudoconjunctus* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Dicrotendipes* sp. A | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Dicrotendipes* 'CA1' | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Kiefferulus intertinctus* | 1 | 1 | | | | | 1 | | 1 | | | | | | | 1 | 1 | | | | | | | | | | | | | |
| | *Kiefferulus martini* | | | | 1 | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | |

| | | TE-D96 | TS-D96 | TW-D96 | TE-A17 | TS-A17 | TW-A17 | TS-O17 | TW-O17 | TE-O17 | TE-N21 | TS-N21 | TW-N21 | TE-J 22 | TS-J 22 | TW-J 22 | W1-D96 | W2-D96 | W3-D96 | W1-A17 | W2-A17 | W3-A17 | W1-O17 | W2-O17 | W3-O17 | W1-N21 | W2-N21 | W3-N21 | W1-J 22 | W2-J 22 | W3-J 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Polypedilum nubifer*** | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | 1 | | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 |
| | ***Polypedilum watsoni*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Cryptochironomus griseidorsum*** | | 1 | | | | | | 1 | | | | | | | | 1 | 1 | 1 | | | | | 1 | | | | | | 1 | |
| | ***Cladopelma curtivalva*** | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Parachironomus* sp.** | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | 1 | | | | |
| | ***Parachironomus* sp. 1 (VSCL35)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Hemiptera** | ***Mesovelia* sp.** | | 1 | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| | ***Microvelia (Pacificovelia) oceanica*** | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Microvelia* sp.** | | | | | 1 | 1 | | | | | | | | | | 1 | | | | | 1 | | | | | | | | | |
| | **Veliidae** | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Diaprepocoris* sp.** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Sigara truncatipala*** | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 |
| | ***Sigara mullaka*** | | 1 | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | |
| | ***Sigara* sp.** | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | 1 | |
| | ***Agraptocorixa eurynome*** | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | | 1 | 1 |
| | ***Agraptocorixa parvipunctata*** | 1 | | | | | | 1 | 1 | 1 | | | | | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | | 1 | 1 | 1 |
| | ***Agraptocorixa hirtifrons*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| | ***Agraptocorixa* sp.** | | | | 1 | 1 | | | | | 1 | 1 | 1 | | | | | | | 1 | | 1 | | | | 1 | 1 | 1 | | | |
| | ***Micronecta robusta*** | 1 | | 1 | | 1 | | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | 1 | | | 1 | 1 | 1 | 1 |
| | ***Micronecta gracilis*** | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Micronecta* sp.** | | | | | | | | | | | | 1 | | | | | | | | | | 1 | | | 1 | 1 | | | | |
| | ***Anisops thienemanni*** | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 |
| | ***Anisops hyperion*** | | | | | | | | 1 | | | | | | | | | | | | | 1 | | | | | | | | | |
| | ***Anisops gratus*** | | | | 1 | 1 | 1 | | | 1 | | | | | 1 | | 1 | 1 | 1 | | | | | | | | | | 1 | 1 | |
| | ***Anisops hackeri*** | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| | ***Anisops stali*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Anisops* sp.** | | | | | | | | | | | 1 | | | | | | | | 1 | 1 | | | | | | 1 | | | | |
| | **Notonectidae** | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| **Lepidoptera** | **Pyralidae** | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **Pyralidae nr. sp. 39/40** | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Drangflies/damselflies** | ***Austroagrion cyane*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| | ***Xanthagrion erythroneurum*** | 1 | 1 | 1 | | | | 1 | | 1 | | | | 1 | | 1 | | 1 | 1 | | | | | | | | | | 1 | 1 | 1 |
| | **Coenagrionidae** | | 1 | | 1 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | |
| | ***Austrolestes analis*** | | | | | | | 1 | 1 | 1 | | 1 | 1 | | | | | | | | | | | 1 | | 1 | 1 | 1 | | | |
| | ***Austrolestes annulosus*** | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | 1 | | | 1 | | 1 | 1 | 1 | 1 |
| | ***Austrolestes aridus*** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Austrolestes io*** | | | | | | | 1 | 1 | | 1 | | 1 | | | | | | | | | | | 1 | | 1 | 1 | | | | |
| | ***Anax papuensis*** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| | **Aeshnidae** | | | | | | | | | | | 1 | | | 1 | | | | | | | | | | | | | | | | |
| | ***Diplacodes bipunctata*** | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Orthetrum caledonicum*** | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | ***Hemicordulia tau*** | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 |
| | ***Hemicordulia* sp.** | | | | | 1 | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| | **Hemicorduliidae** | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| **Caddisflies** | ***Ecnomus* sp.** | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| | ***Notalina spira*** | 1 | 1 | 1 | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| | ***Oecetis* sp.** | | | | | | | | 1 | | | | 1 | | | | 1 | 1 | | | | | | | | | | | 1 | 1 | |
| | ***Triplectides australis*** | 1 | 1 | | | | | 1 | 1 | 1 | | | 1 | | 1 | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 |
| | **Leptoceridae** | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |

# Appendix 3. Waterbird data 1996 to 2022 for Toolibin Lake

| | Toolibin | | | | | Walbyring | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dec 1996 | Apr 2017 | Oct 2017 | Nov 2021 | Jan 2022 | Dec 1996 | Apr 2017 | Oct 2017 | Nov 2021 | Jan 2022 |
| Grey Teal | 1162 | 508 | 309 | 259 | 985 | 367 | 408 | 275 | 166 | 213 |
| Chestnut Teal | | | | | | | 3 | | | |
| Pink-eared Duck | 134 | 72 | 60 | 12 | 372 | 8 | 35 | 44 | 40 | 79 |
| Hardhead | 60 | | 7 | 12 | 6 | 58 | | 4 | 2 | 20 |
| Australian Shelduck | 97 | 7 | | 6 | 10 | 57 | 1 | | | |
| Pacific Black Duck | 3 | 64 | 4 | 2 | 4 | 1 | 107 | | 2 | 1 |
| Blue-billed Duck | | | | 3 | | | | | | |
| Musk Duck | | 2 | 5 | 7 | 6 | 4 | 1 | 2 | 2 | |
| Freckled Duck | 25 | | 1 | | | | | 1 | 2 | 1 |
| Australasian Shoveler | 56 | 12 | 2 | | 18 | | | 4 | | 12 |
| Australian Wood Duck | | 18 | 5 | 6 | 10 | 20 | 1 | 24 | 27 | 6 |
| Black Swan | 2 | 10 | 5 | 6 | 11 | | 1 | | 12 | 1 |
| Eurasian Coot | 281 | 48 | 49 | 126 | 158 | 12 | 19 | 20 | 46 | 23 |
| Dusky Moorhen | | | | | | 2 | | | | |
| Black-tailed Native-Hen | | | 8 | | 2 | | | 5 | 2 | 6 |
| Australasian Grebe | | 12 | | | | | | | 2 | |
| Hoary-headed Grebe | 1 | 21 | 78 | 33 | 832 | 22 | 1 | 32 | 61 | 68 |
| Little Pied Cormorant | 1 | | | 3 | 19 | | | | | |
| Swamp Harrier | | | 1 | | | | | | | |
| Australian White Ibis | | | | | 1 | | | | | |
| White-necked Heron | 1 | | 2 | | | | | | | 1 |
| Great Egret | 1 | | | | 1 | | | | 2 | 1 |
| Nankeen Night Heron | | | | 3 | 1 | | | | 1 | |
| White-faced Heron | 2 | 12 | 13 | | 36 | | 14 | | | 17 |
| Straw-necked Ibis | | 3 | 1 | | | | 1 | | | |
| Yellow-billed Spoonbill | 2 | | | | | 4 | | | | |
| Black-fronted Dotteral | | | 1 | | | | | | | 8 |
| Black-winged Stilt | 19 | | | | | | | | | 51 |
| Red-kneed Dotteral | 11 | | | | | | | | | 111 |

# Appendix 4. Recommended protocols for aquatic fauna monitoring at Toolibin and Walbyring Lakes

**Water chemistry.** During the waterbird and invertebrate surveys, the following water quality parameters should be measured as a minimum.

- Conductivity
- In-situ pH
- Water temperature
- Dissolved oxygen (% and mg/L) at the top and bottom of the water column.

Water samples should be collected for laboratory analyses as follows:

- Unfiltered water for analysis of total nitrogen and phosphorus.
- Chlorophyll by filtering 1000ml of water through a glass fibre filter paper, to be immediately frozen.
- A sample of water filtered through a 0.45 μm filter paper for analysis of total dissolved nitrogen and phosphorus and filterable reactive phosphorus (orthophosphorus).

Other water quality measures could include those in Tables 2 and 3 of this report.

**Water depth** should be measured from gauges in the lake, noting differences in measurements between gauges, as above.

**Waterbirds.** Waterbird surveys have been undertaken at Toolibin Lake and Walbyring Lake using a consistent protocol since 1996. Surveys should attempt to count all individuals of all species present, though some inaccuracies are inevitable in such a large lake where stands of trees hinder single counts of large areas. Notes should be kept on nesting, presence of eggs and juvenile stages. Where possible a motorboat should be used to traverse the entire wetland, with two observers. This will take half a day when the lake is full. Where depths do not allow use of a motorboat, a combination of walking and/or paddling will provide a similar result but the survey will take much longer. Recent surveys have departed from adjacent to the pumping station on the west of the lake.

Surveys should be undertaken at different stages of the fill event, preferably about 3 months after filling and again after another 3-4 months. An additional survey could be undertaken when the lake is shallow (e.g. <0.5 metres) to allow the values of the wetlands for shorebirds to be assessed.

**Invertebrates.** Surveys of invertebrates have largely followed standard protocols used in many monitoring and survey projects by DBCA and its predecessor organisations (e.g. Halse *et al.*, 2000; Cale *et al.*, 2004; Pinder *et al.*, 2004). Since 1996 three locations within Toolibin Lake and three within Walbyring Lake have been sampled for aquatic invertebrates. Sampling locations should be sites W, S and E in Toolibin Lake and sites 1B, 2 and 3 in Walbyring Lake (see Figure 1). Sampling is qualitative, so suitable for determining species richness and composition but not abundance.

Two samples were collected at each sampling site.

- A sample of planktonic invertebrates is collected using a standard D-framed net with a 53 µm mesh to gently sweep the water column and submerged plants through 50 metres of water, generally as 50 x 1 metre sweeps over a distance of about 200 metres. This disjunct 50m sampling path includes all recognisable microhabitats but should not collect stirred up sediments or collect large amounts of plant material or organic debris. The aim is to keep this sample ‘clean’ to enable picking of very small planktonic animals.
- A sample incorporating the benthos is collected using a standard D-framed net with a 250 µm mesh, vigorous sweeping surfaces and through submerged plant communities and kicking up benthic substrates to collect larger and faster species and to ensure collection of sediment dwelling species. The aim is to maximise collection of invertebrates without collecting excessive sediment or debris. To achieve this, wait a second or two between stirring up the sediment and sweeping through the water so heavier sediment and debris fall back to the substrate prior to sweeping. If the net gets too full to manipulate empty into a bucket with some lake water and continue sweeping.

  There are some methods of cleaning and reducing the size of the sample prior to preservation, which also helps to make preservation more effective. If there is sand or gravel in the sample then you’ll need to remove this by elutriation. Place the sample in a bucket and fill to about 80% with water from the same wetland. Stir up the sample with your hand, wait a few seconds for sediment to settle and pour the sample back through the same net (leaving the sediment in the bucket). Repeat 3-4 times until only clean sediment is left behind and then discard the sediment.

  If there is a lot of leaf litter and sticks then this will also need to be partly removed. Place sample back into a bucket and fill with wetland water. Fill a second bucket with wetland water. Take a few leaves/sticks at a time out of the sample, drop them into the second bucket, swirl them around, then remove them, make sure no bugs are stuck to them and discard (generally this is enough to ensure all bugs are removed from the litter). Repeat until the sample is small enough to fill 1 to 3 (preferably 1 or 2) 2L sample containers to about 1/3rd full each – any more than this in one container reduces effectiveness of preservation.
- Both samples should be preserved in the field in 100% ethanol and processed in the laboratory.
- Laboratory processing involves 1) sieving samples with a graded series of sieves to assist in the detection of all species under a binocular microscope at 10-40x magnification and 2) the removal of sufficient representative specimens of each taxon to ensure identification of all species. Specimens from the plankton and benthic samples are combined to yield a single sample of community structure for each site. The efficacy of this sampling protocol has been described elsewhere (Halse et al., 2002; Pinder et al., 2010).