Biodiversity and Conservation Science

Aquatic invertebrate diversity of Lake McLarty in 2019

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Ecosystem Science Program

Aug 2020

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Australian Government | National Landcare Programme

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The recommended reference for this publication is:

Pinder AM, Cale DJ, Lewis L 2020. *Aquatic invertebrate diversity of Lake McLarty in 2019*, Department of Biodiversity, Conservation and Attractions, Perth.

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Acknowledgments

We acknowledge the Noongar people as Traditional Custodians of this land and pay our respects to all elders past and present. Field work was funded by Peel Harvey Catchment Council (PHCC). Rick James (PHCC) facilitated our involvement in the Ramsar 482 project at Lake McLarty and he and Geoff Barrett (DBCA Swan Region) helped scope the project. Some invertebrates sampled for a Western Swamp Tortoise project in 2013 (used here as comparison data) were identified by Kirsty Quinlan (DBCA) and Russell Shiel (University of Adelaide). Some data on Lake McLarty invertebrates collected by Melita Pennifold (ex DBCA) is also used. Heidi Bucktin provided other water chemistry data for the lake.

Summary

- Sampling in October 2019 was the first attempt to comprehensively document aquatic invertebrate diversity at Lake McLarty.
- At least 116 aquatic invertebrate species were collected, and it is estimated that about 141 species may have been present within the areas sampled. A total of 134 species have now been collected between 1999 and 2019.
- The invertebrate community of Lake McLarty in 2019 was exceptionally diverse compared to other wetlands sampled on the Swan Coastal Plain, although there have been no comparable studies of Swan Coastal Plain wetland invertebrates south of Mandurah. The Lake McLarty invertebrate community also appears to be compositionally distinct from other Swan Coastal Plain wetlands sampled to date.
- While the Lake McLarty invertebrate fauna contains few species that are rare or restricted, this is typical of wetlands on the Swan Coastal Plain. An exception is the water mite *Arrenurus* sp. 25 which was previously known only from a few groundwater associated wetlands north of Perth. This may be a rare Swan Coastal Plain endemic.
- Sites in shallower areas of the lake had greater species richness but the diversity of habitats across the lake would have contributed to the total species list.
- The gilgie (*Cherax quinquecarinatus*) was present in 1999 and 2016 but was not collected in 2017 and 2019. This species may be affected by acidic conditions in drying sediments as the species burrows to survive dry periods.
- Water chemistry was within the range of previous and subsequent data, with water alkaline and fresh but possibly with elevated nutrients (especially on the western side). Monitoring data suggests a drop in the upper bound of the pH range in recent years, but the lake remains alkaline when inundated.

Previous invertebrate studies

There have been three previous projects that have surveyed aquatic invertebrate diversity at Lake McLarty.

- Core samples, collected by Michael Davis in 1999/2000 (two survey dates over summer), and additional small (500 ml) samples of the water column, with laboratory processing of samples. This produced a very small list of species (Davis, 2000).
- The South West Catchments Council and DBCA included Lake McLarty in a broad program of sampling wetlands in the south-west in 2007. These were live-picked samples collected over 10 metres, similar to those collected by Melita Pennifold below, identified mostly to family level. Two sites within the lake were sampled in August and October 2007 and all were identified by Adrian Pinder at DBCA.
- Melita Pennifold (then at DBCA) sampled invertebrates at two sites in spring 2016 and spring 2017 (Pennifold, 2018). On each occasion, invertebrates were collected with a coarse mesh net (250 µm) over a distance of 20 metres within aquatic

macrophytes. Invertebrates were removed from samples alive in the field, then preserved and identified to family level in the lab. These methods were designed to rapidly assess wetland condition using invertebrates as an indicator. For this report, the 2016 and 2017 specimens have been identified to finer taxonomic resolutions (species where possible).

Aim

This project aimed to comprehensively document aquatic invertebrate biodiversity of Lake McLarty. This involved much greater sampling effort than has occurred previously, plus laboratory processing of samples and species level identifications. This project did not aim to replicate sampling undertaken in previous years which involved a rapid assessment of invertebrate communities (coarse net, small samples, field sorting and family level ids) as an indicator of wetland condition.

2019 Methods

Sampling design

Sampling effort was designed to be equivalent to standard DBCA invertebrate biodiversity survey projects. These are much larger samples than have been used when invertebrates have been sampled as indicators of wetland condition. A standard sample is normally 50 metres of sweep netting with both a fine-mesh plankton net and a coarser net 'benthic' net. These large samples encompass all macrohabitats (e.g. submerged and emergent macrophyte and leaf litter) in the one sample. Where resources allow, we have taken multiple smaller samples, each within a more uniform habitat, so we can better analyse relationships between invertebrates and habitat structure, but with the total area sampled still about 50 metres. This approach was taken for this project, in two areas of the lake – the south-east corner and the mid- western to north-western part of the lake. Sites were selected so that we sampled the major aquatic habitats present.

Figure 1 shows the locations of the 2019 invertebrate biodiversity sampling locations, plus locations at which invertebrate abundance samples were collected in spring 2019 and late summer 2020 (see Wetland Research and Management 2020), and the locations sampled by Melita Pennifold in 2016 and 2017. In this report invertebrate and water chemistry sampling sites are listed as follows. Sampling for this report was undertaken on the 21st and 22nd October 2019.

Water chemistry

Two water samples were collected for laboratory analyses, one from site SE (south-east) and one from NE (north-west). These were analysed for total and total filterable nitrogen and phosphorus (with the latter filtered through a filter paper (pore size 0.45 µm) prior to freezing), calcium, magnesium, hardness, alkalinity, turbidity, colour and total dissolved solids (gravimetric = by evaporation). Total (unfiltered) N and P includes N or P assimilated by plankton and adhered to or within to suspended particles. Total (filtered) phosphorus measures only the dissolved (molecular) components. Samples of water from the same sites were filtered through a glass microfibre filter paper and the filter paper frozen and analysed for chlorophyll fractions (a,b,c) and phaeophytin. In the field pH, conductivity, temperature and turbidity were measured at each of the six invertebrate sampling sites using calibrated hand-held TPS meters.

Table 1. Locations and site details of the invertebrate sampling locations.

		South-east (SE)		North-west (NW)		West (W)
	sample 1	**sample 2**	**sample 3**	**sample 1**	**sample 2**	**sample 1**
Location	SE corner among sparse sedges	SE corner amongst Typha	SE corner ain shallow water on edge of Melaleucas	NW corner in open water	NW corner under Melaleuca	W shore amongst Cyperus bed
Coordinates	32°42'39.1"S, 115° 43'06.0"E	32°42'40.5"S, 115° 43'12.5"E	32°42'44.1"S, 115° 43'11.8"E	32°41'45.5"S , 115° 42'36.4"E	32°41'45.0"S , 115° 42'35.2"E	32°41'45.0"S , 115° 42'35.2"E
Depth of sample (cm)	20 to 40	5 to 20	5 to 10	up to 60	5 to 40	10 to 20
Macrophytes	80% cover of mixed submerged macrophytes (Chara, Ruppia, Sporobolus with dense but sparsely distrubuted clumped sedge	Dense Typha with 50% cover of mixed submerged macrophytes, including Myriophyllum	100% cover of submerged macrophytes/herbaceous meadow. Sparse tall sedges and Melaleuca. Some filamentous algae.	80% cover submerged macrophytes in beds up to 50cm deep, mostly Ruppia and mats of Sporobolus and abundant filamentous algae	Sparse terrestrial grasses (,1% cover) plus some semiaquatic emergent plants	Moderate to dense stands of Cyperus with 100% cover of submerged Chara and Sprobolus
Sediment	Gritty clay over a layer of broken bivalve shells	Decaying Typha over gritty clay with shell grit	Dark clayey sand with dense root mat	Very fine black organic clayey sediment	Fine to coarse organic material (twigs, leaves, bark) over loose organic soil with fine roots	Fine gritty organic black clayey sediment

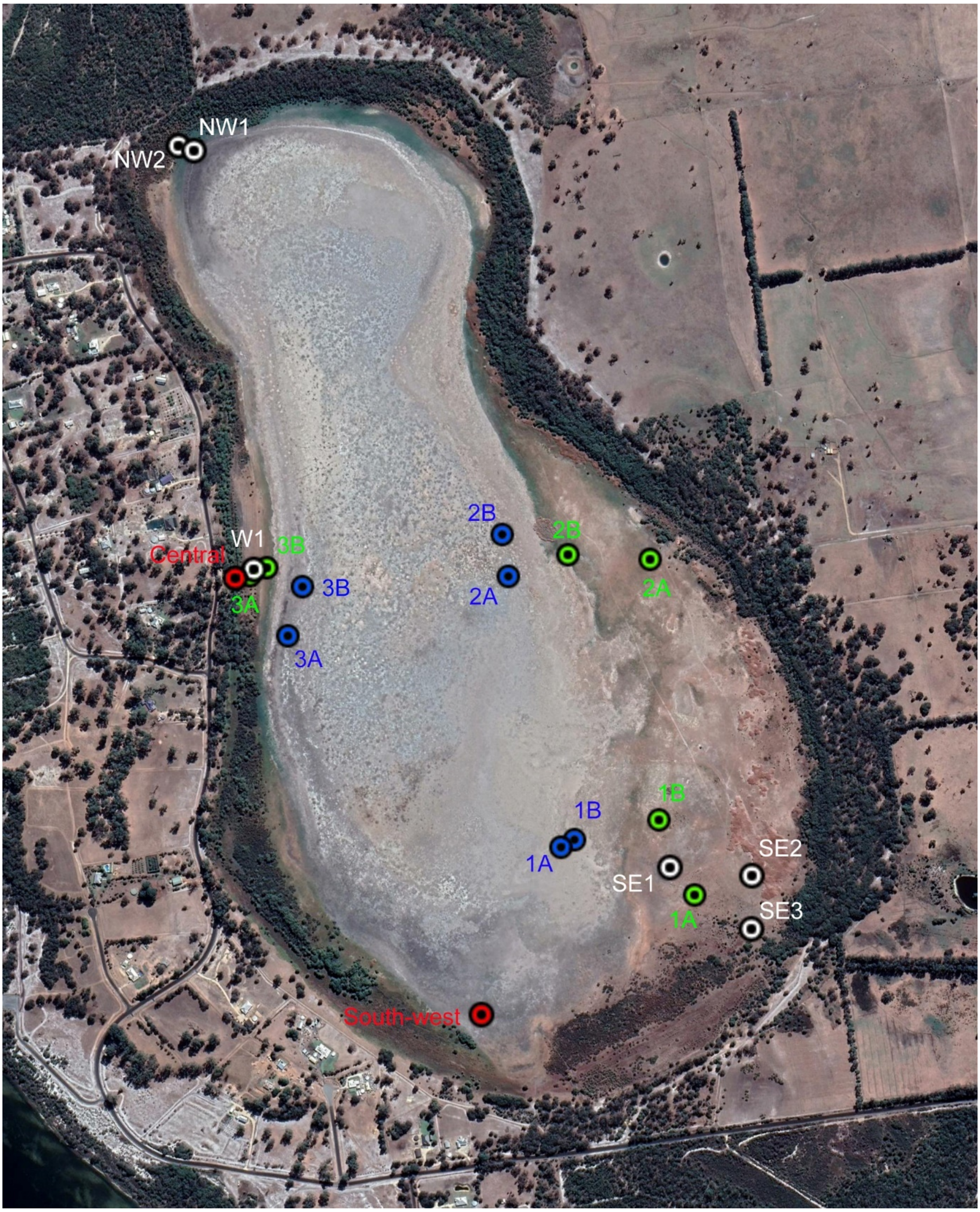

Figure 1. Locations of 2019 invertebrate biodiversity sampling in 2019 (in white), locations of sampling undertaken in 2016 and 2017 by Melita Pennifold (in red), and locations of invertebrate abundance samples collected in Nov 2019 (in blue) and Jan 2020 (in green).

Invertebrates

At each of six locations around the lake (Table 1, Figure 1, Figure 2), we collected two samples; one 'benthic' sample with a coarse mesh (250 µm) net and one ''plankton' sample with a fine mesh (50 µm) net. Each sample was collected in a relatively uniform habitat over a distance of 17 metres. Each benthic sample was collected by stirring up sediment and aquatic plants with the net or by foot and sweeping through the stirred-up material. The plankton sample was collected by sweeping through undisturbed water column, albeit partly through aquatic plants when present. Plankton samples were preserved in 100% ethanol. Benthic samples were elutriated to remove coarse sediment, then much of the macrophyte material was removed by washing plant material in a bucket of lake water and the water passed back through the net. The benthic sample was preserved in 100% ethanol and both samples returned to the lab for processing.

In the lab, benthic samples were washed through a series of sieves (2 mm, 0.5 mm and 0.25 mm mesh sizes). All material from the two larger sieve sizes were sifted and representative invertebrates removed. One quarter of the finest sieve fraction was sifted. The plankton sample was washed through a series of sieves (2 mm, 0.09 mm and 0.05 mm). All material from the two larger sieve sizes were sifted and representative invertebrates removed. The 0.05 mm sieve fraction has been retained in case there are resources later to have the rotifers and protozoans identified. Invertebrates were identified to the lowest taxonomic level possible (mostly species).

This project was designed to survey aquatic invertebrate diversity at Lake McLarty rather than use invertebrates as a rapid indicator of condition, so it is to be expected that recorded diversity will be higher than obtained during previous work.

Data analysis

Cluster analyses were performed using the hclust function within the stats package of base R-3.6.1 (R Development Core Team, 2019) run within RStudio version 1.2.5019 (RStudio, 2019). Linkage for this was group averaging. The Chao estimator within the specpool function of vegan for R (Oksanen *et al.*, 2019) was used to estimate number of missed species.

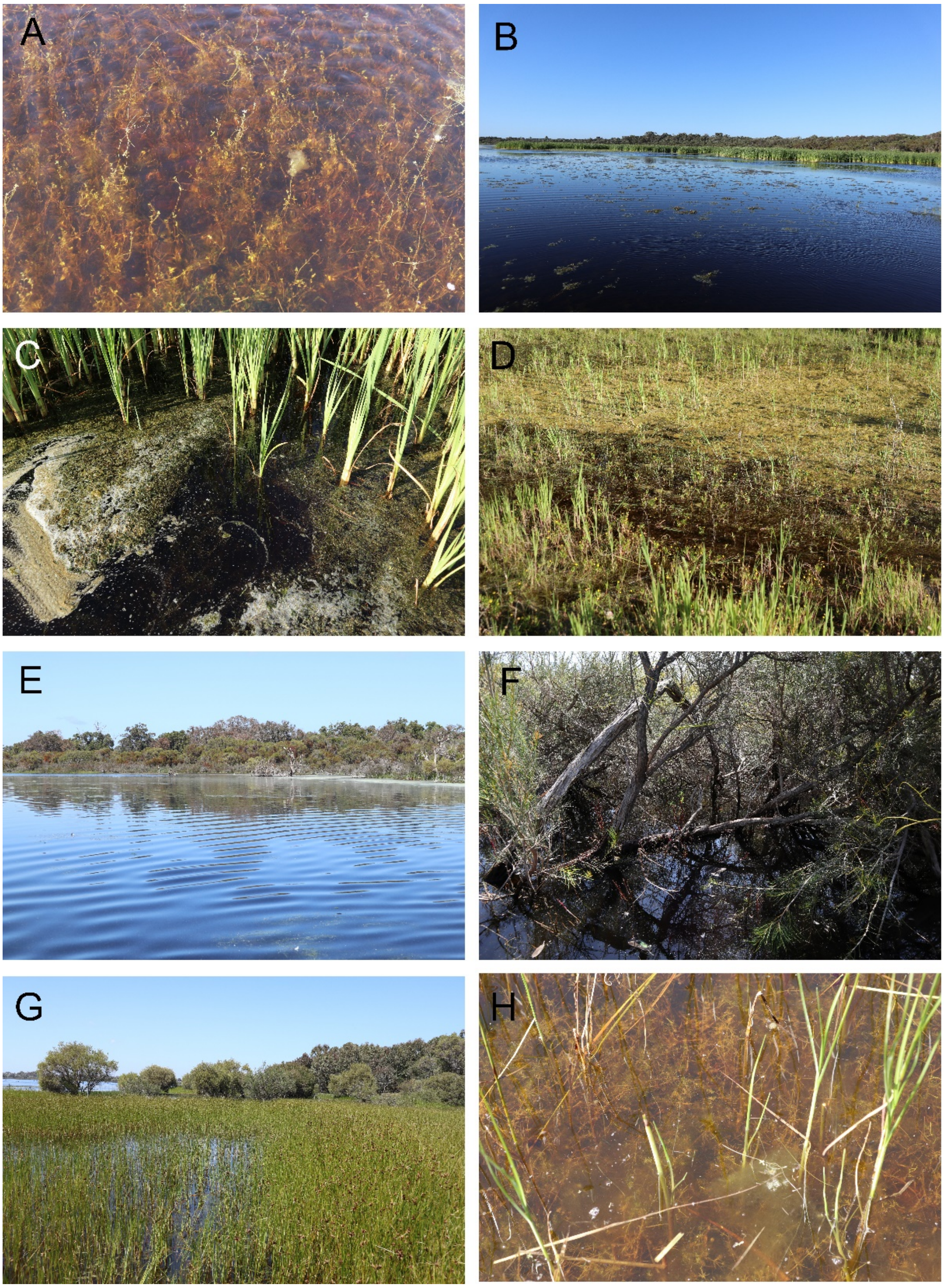

Figure 2. Invertebrate sampling locations within Lake McLarty (Oct 2019). A, dense submerged macrophytes at the south-east site; B, view of the south-east corner of the lake; C, submerged macrophytes within sparse Typha at the south-east site; D, Shallow submerged macrophyte and herb meadow at the south-east site; E, View towards shore at the north-west site; F, Melaleuca habitat sampled at the north-west site; G, sedgeland sampled on the western shore; H, submerged macrophyte amongst sedges on the western shore.

Results and discussion

Water chemistry

Water quality data is provided in Table 2 and in Appendix 1.

Table 2. Field and laboratory measured water chemistry.

	South-east (SE)			North-west (NW)		West (W)
	sample 1	sample 2	sample 3	sample 1	sample 2	sample 1
Field measurements						
Turbidity (NTU)	2.4	2.5	1.5	2.3	6.8	2.8
Electrical conductivity (mS/cm)	3.47	3.35	3.99	3.56	3.68	3.55
Total dissolved solids (g/L) field	1.8	1.72	2.08	1.85	1.9	1.83
pH	9.32	7.75	8.11	8.38	7.86	8.38
Temp ©	29.1	26.7	31.6	22.4	20	24.1
Laboratory analyses						
Total dissolved solids (g/L)		1.9		2		
Turbidity (NTU)		2.5		2.4		
Colour (TCU)		100		130		
Chlorophyll a (mg/L)		0.001		0.006		
Chlorophyll a (mg/L)		<0.001		0.001		
Chlorophyll a (mg/L)		<0.001		<0.001		
Phaeophytin (mg/L)		0.002		0.002		
Total soluble nitrogen (mg/L)		1.5		2.8		
Total nitrogen (mg/L)		1.6		3.3		
Total soluble phosphorus (mg/L)		0.021		0.077		
Total phosphorus (mg/L)		0.031		0.099		
Calcium (mg/L)		69.5		76.4		
Magnesium (mg/L)		79.2		84		
Hardness (mg/L)		500		540		
Alkalinity (mg/L calcium carbonate equivalent)		120		90		

Lake McLarty was reasonably fresh when sampled, though not as fresh as recorded for many other Swan Coastal Plan wetlands, with total dissolved solids (gravimetric) of 1.9 to 2.0 g/L. This matches salinity calculated by the conductivity meter (1.7 to 2.08 g/L). The Ramsar limit of acceptable change for salinity is < 1 ppt in sedges and <0.5 ppt under *Melaleuca* (Hale & Butcher, 2007). This was probably too low a limit even in 2007, with spring salinity in previous years frequently above 2 g/L and very rarely <1 g/L even at relatively high depths (>1 metre) (Lane, Clarke & Winchcombe, 2017). Salinity in Oct 2019 was well within the range of other measurements (1993 to 2020) for equivalent depths (~0.8 m) (Figure 3).

pH was alkaline at all sites (7.75 to 9.32, with the latter in the deeper more open site in the south-east corner). These lie within the range of previous measurements of pH at Lake McLarty (mostly in the range 7 to 10). Figure 4 to Figure 6 show pH recorded in the southern, central and northern parts of the lake, with the October 2019 measurements indicated.

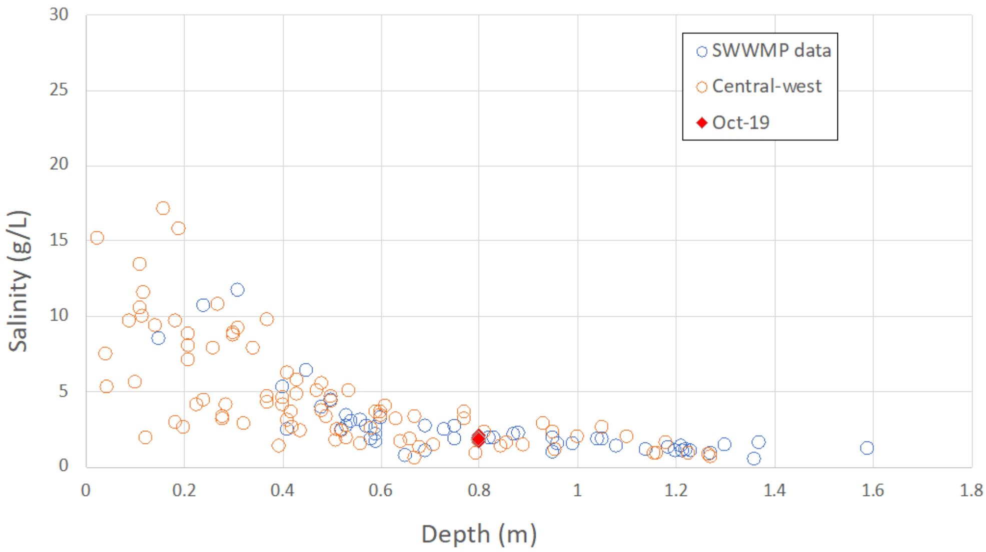

Figure 3. Salinity (derived from conductivity in meter) measured at the south-west SWWMP site, the central-west site and all measurements for this project, along the lake's maximum depth range.

The south-west part of the wetland has the longest pH data record (September and November records from 1993 to 2018) (Lane *et al.*, 2017). At this site (Figure 4) pH has varied between about 7.5 and 10.5 over 25 years with no trend apparent. The October 2019 measurements in the south-east corner of the lake are within this range.

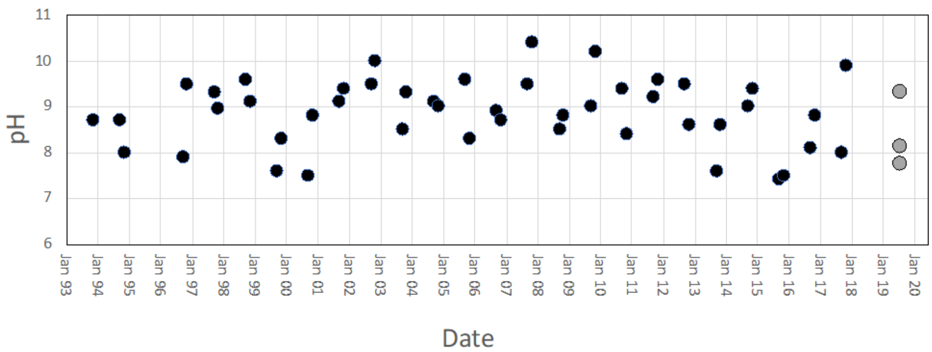

Figure 4. pH recorded in the south-western part of Lake McLarty during the South-west Wetland Monitoring Program (1993 to 2018) (black circles) and three measurements from the south-east of the lake in October 2019 (grey circles).

There is also a 12 year dataset for pH measured in the centre-west of Lake McLarty. Figure 5 separates measurements made in the morning versus the afternoon because photosynthesis can increase pH during the day and respiration decrease pH during the night. In this dataset almost all of the pH values of 10 or greater were measured in the afternoon. However, other than what might be a slight effect of time of day, there is no trend in pH between 2008 and

2016, with pH varying mostly between 8 and 10. From 2017 pH dropped in range to between about 7.5 and 9.5, with a few records below 7.5 (in late winter/early spring 2018).

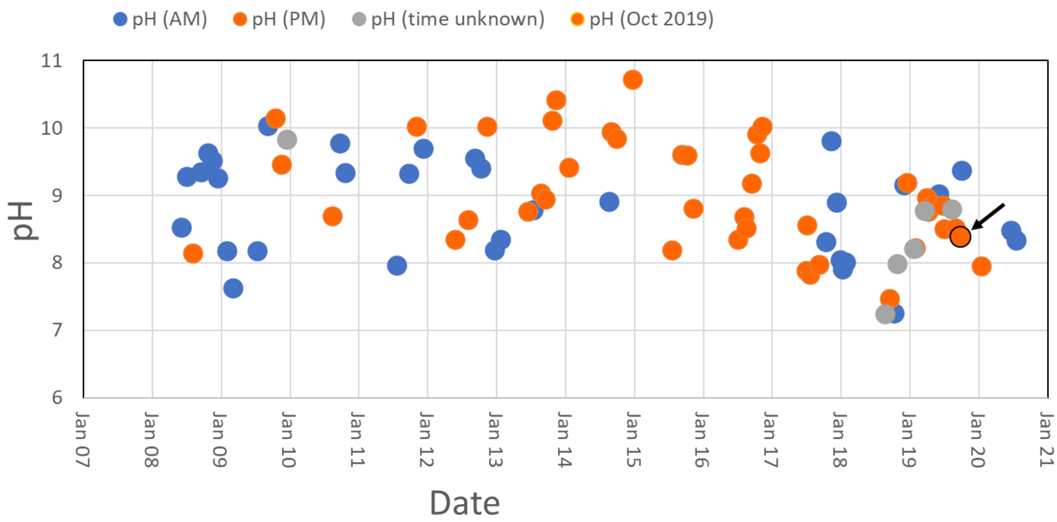

Figure 5. pH recorded from sites sampled on the central west of Lake McLarty, coloured by whether the measurements were made in the morning (blue circles) or afternoon (orange circles) or at an unknown time (grey circles). The Oct 2019 measurement is marked by an arrow.

A third dataset is available for some dates between 2017 and 2020 for the north-west of the lake, including two measurements on 22 Oct 2019 (Figure 6). This dataset shows no trend in pH.

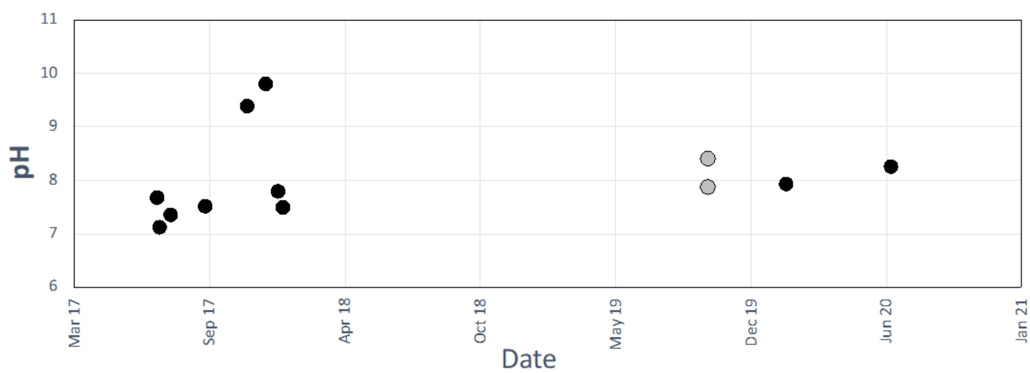

Figure 6. pH recorded from the north-west of the lake, with Oct 2019 measurements indicated by grey circles.

The limit of acceptable change for pH in the Ecological Character Description (Hale & Butcher, 2007) is >7, so is still met at Lake McLarty.

Turbidity was low across the lake (< 7 NTU, mostly <3) and well within the range of previous measurements (up to 200 NTU). Turbidity measured in the lab and in the field was about the same. The low turbidity would at least partly reflect the almost complete coverage of submerged macrophytes preventing sediment suspension, but also indicates that phytoplankton were not abundant. Water colour was also low (<150 TCU) compared to some Swan Coastal Plain (SCP) wetlands which have been recorded with TCU values up to 1000 (Davis *et al.*, 1993; Storey *et al.*, 1993).

Total (unfiltered) phosphorus (TP) was 0.031 mg/L at the south-east site and 0.099 mg/L at the north-west site in October 2019. Total filterable (=soluble) phosphorus (TFP) was 0.01 mg/L at the south-east site and 0.077 at the north-west site in October 2019. These values for TP and TFP are within the ranges recorded by Lane et al. (2017) (TP and TFP) and other sampling at Lake McLarty (TP only), albeit on the high side for site B (Table 3). The north-west values are above the ANZECC and ARMCANZ (2000) trigger values of 0.06 mg/L (TP) and 0.03 mg/L (TFP) and close to (for TP) or above (TFP) the median values for 40 Swan Coastal Plain wetlands sampled by Davis et al. (1993) (see Table 3).

Table 3. Values of nutrients and chlorophyll in lake McLarty in October 2019 in comparison with other data from Lake McLarty, water quality guidelines and other wetlands on the Swan Coastal Plain.

	South-east	North-west	SWWMP (south-west)	McLarty Lake (Centre)	ANZECC/ARMCANZ 2000 guidelines	Davis et al. (1993)
Total phosphorus (mg/L)	0.031	0.099	0.01-0.45 (median 0.06)	0.012 – 0.2 (median 0.07)	< 0.06	0.006 to 0.910 (median 0.1)
Total soluble phosphorus (mg/L)	0.021	0.077	0.01 – 0.18 (median 0.03)	-	<0.03	0.0038 to 0.888 (median 0.36)
Total nitrogen (mg/L)	1.6	3.3	1.8 - 7.3 (median 2.4)	1.9 to 14 (median 2.85)	<1.5	0.126 to 30 (median 2.118)
Total soluble nitrogen (mg/L)	1.5	2.8	1.1 – 6.5 (median 2.0)	-	-	-
Chlorophyll-a (mg/L)	0.004	0.0095	-	0.0025 – 0.106 (median 0.011)	0.030	0 – 0.29 (median 0.0078)

Total (unfiltered) nitrogen (TN) was 1.6 mg/L at the south-east site and 3.3 mg/L at the north-west site (north-west) in October 2019. Total (filtered) nitrogen (TN) was 1.5 mg/L in the south-east and 2.8 mg/L in the north-west in October 2019. These values for TN are within the ranges recorded by Lane et al. (2017). The site B value for TN is significantly above the ANZECC and ARMCANZ (2000) trigger value of 1.5 mg/L and above the median value for 40 Swan Coastal Plain wetlands sampled by Davis et al. (1993) (see Table 3).

Total chlorophyll (including phaeophytin) was 0.004 mg/L in the south-east and 0.0095 in the north-west. These are values are within the ranges recorded for McLarty in the past (Table 3) and below the ANZECC and ARMCANZ (2000) trigger value of 0.03 mg/L. The value for the north-west site was only just above the median value for Swan Coastal Plain wetlands in Davis et al. (1993).

Nitrogen and phosphorus concentrations in Lake McLarty are indicative of mild enrichment, most likely from the agricultural catchment. However, in October 2019 primary production in was clearly dominated by dense growth of submerged macrophytes rather than phytoplankton and water clarity was high.

Invertebrates

Lake McLarty diversity

At least 116 species of aquatic invertebrates were collected in the 2019 samples. That some groups (such as flatworms and nematodes) could not be resolved to species suggests total richness is slightly higher in these samples. The Chao equation in the 'specpool' function of Oksanen (2019) was used to estimate how many species are likely to have been missed within the areas sampled in 2019. This analysis estimated that 25 ± 12 species are likely to have been missed, which would bring the total richness from the areas sampled to between 128 and 153.

As is typical for Swan Coastal Plain wetlands (Horwitz *et al.*, 2009), most species collected in 2019 are very widespread in at least southern Western Australia. Exceptions are:

- *Paramphisopus palustris* is restricted to groundwater-fed wetlands and springs, mostly on the Swan Coastal Plains, but also some sites in the Darling Range, including Darkin Swamp (Pinder et al. 2004) and Little Darkan Swamp (Cale, 2020) where it can burrow to avoid desiccation in summer if the wetland dries. Gouws and Stewart (2007) provide evidence of genetic structuring within this 'species' that corresponds to geographic locations, noting a southern variety *(P. palustris fairbridgei)* from sites around Pinjarra. It is possible that the Lake McLarty population belongs to this more restricted southern form.
- *Arrenurus* sp. 25 is an undescribed water mite otherwise known only from springs in the Jurien hinterland and from groundwater fed wetlands in the Hutt Catchment.
- The beetle *Berosus majusculus* is widely distributed across southern Australia but not commonly collected in the south-west. DBCA has only three other records from

the SCP and it was not recorded by Davis et al. (1993). One of the other records is from Lake McLarty sampled in 2007.

Eighteen of the 70 species recorded at Lake McLarty previously (1999/2000, 2007, 2016 and 2017) were absent in 2019. This is most likely just normal inter-annual variability in composition and imperfect sampling. All but three of the absent species are insects which would mostly colonise from other wetlands each year, so some variability would be expected. Exceptions are an ostracod (*Eucypris virens*), the gligie (*Cherax quinquecarinatus*) and unidentified leeches. The gilgie, recorded in 1999 and 2016, is probably resident, surviving dry periods in burrows. That it was not recorded in 2017 and in 2019 is of concern, though it may still be present in low numbers. It is likely to be sensitive to low pH which may be a problem for it surviving dry periods where acidification is an issue. Leeches, collected only in 1999, may have been brought in by waterbirds, enter via surface flows (they are common in drains in the area) or survive in moist refuges in the sediment. If the latter, it may also have been affected by low pH as the lake dried in recent years.

We have not attempted to compare richness between the various sampling events due to differences in sampling methodology. The 2019 sampling was deliberately designed to more completely document the aquatic invertebrate values of the lake rather than contribute to ongoing monitoring.

In 2019, zooplankton diversity was greatest in the *Typha* sample (site SE2: 51 species) and lowest in the deeper macrophyte samples (SE1: 23 species and NW1: 18 species) (Figure 7). The macrophytes in the latter areas were very dense and possibly precluded some swimming species. The higher diversity within the *Typha* sample was across most taxonomic groups but most notable amongst fly larvae, especially chironomids (non-biting midges). Chironomids are primarily sediment dwelling species, but earlier instar larvae can be planktonic and may have been present but prevented from occurring in the water column where macrophytes were very dense. Greatest diversity in the 'benthic' samples (which includes larger planktonic animals) was in the shallow area in the south-east with dense macrophytes and semi-aquatic herbs (site SE3: 64 species) and lowest under the *Melaleuca* (site NW2: 36 species) and in the deeper macrophyte area (site SE1: 37 species). High richness in benthic sample SE3 was particularly notable amongst the diptera, beetles, cladocerans and damselflies/dragonflies.

Figure 8 shows combined richness of the paired plankton and benthic samples at each of the six sampling locations. Highest richness is in the shallower edge sites (SE2, SE3 and W1) with depth ≤ 20 cm. These sites had notably more beetles and fly larvae. This may be an effect of greater light penetration to the wetland bed (the bed under the dense macrophyte beds would be quite dark) and benthic algal growth, though this was not quantified.

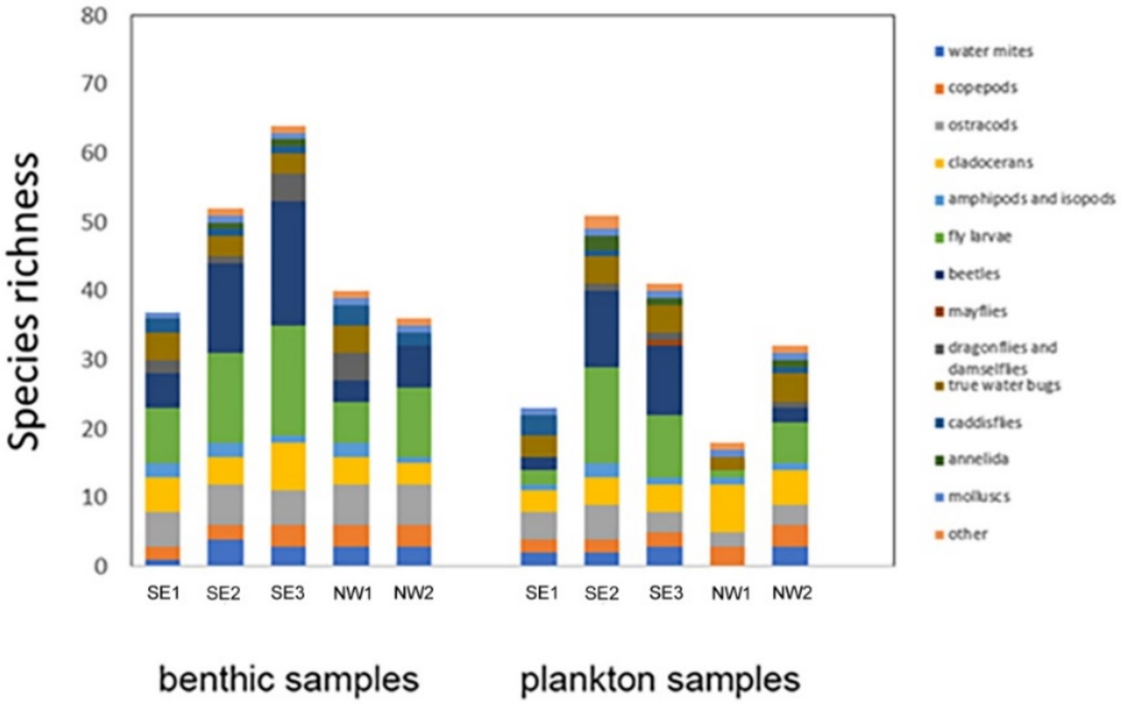

Figure 7. Species richness and composition by major taxonomic groups of benthic and plankton samples collected from Lake McLarty in October 2019.

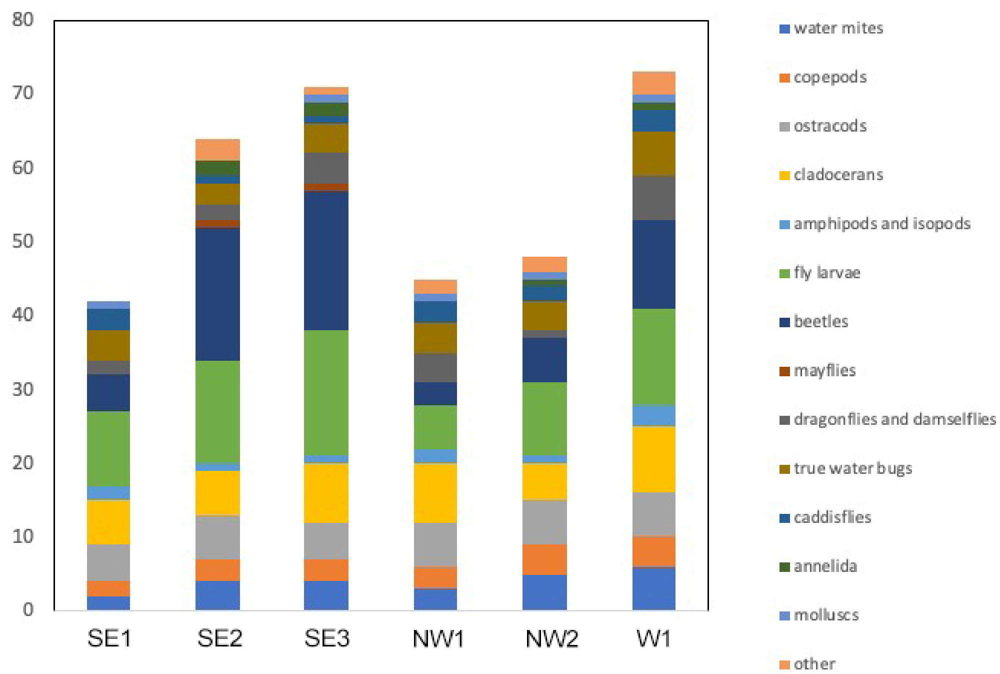

Figure 8. Richness of invertebrates within combined plankton and benthic samples at each site.

Comparisons with other wetlands

The largest comparable dataset with species level identifications is Davis et al. (1993) who collected 237 species from 40 wetlands on the Swan Coastal Plain sampled over three seasons (January 1989, November 1989 and November 1990). The wetlands ranged from Loch McNess in the north to Lake Cooloongup in the south, so all were well north of Lake McLarty. About 36 of the Lake McLarty species were not recorded by Davis *et al*. (1993) but this is partly due to improved taxonomic resolution and taxonomic knowledge about WA aquatic invertebrates. Davis et al. (1993) took 10 metre long sweep net samples with a 250 μm mesh net (the net was "moved from the surface to the bed ten times over a distance of 10 metres"). Results in Davis et al. (1993) are for three such samples per wetland, so 30 metres of sampling per date. This is almost the same effort as two of the 2019 benthic samples (2 x 17 metres = 34 metres) with the same type of net. Combinations of two benthic samples from Lake McLarty in 2019 give richness values of 54 to 81 species (average 65). This is at the upper limit of richness sampled by Davis et al. (1993): 12 to 62 species for spring 1989 and 1990 respectively (average 33). The 2019 McLarty data has greater taxonomic resolution for some groups (annelids and cyclopoid and harpacticoid copepods) than the Swan Coastal Plain dataset. When the taxonomic resolution is matched between the two datasets, the 2019 sampling at McLarty had 53 to 79 species (average 64). Some of the reasons we collected more species may be the slightly greater sample size (34 versus 30 metres) and potentially different sampling technique. The Davis et al. method involved sweeping the net from the surface to the bed ten times over a distance of 10 metres. There is no mention of stirring up the sediment during this process, as in the 2019 sampling. If this difference had a significant effect, then sediment dwelling species (especially chironomids) should have been disproportionately richer in the McLarty samples. The 2019 McLarty samples had 8 to 12 species of chironomids (per combination of two benthic samples) with an average of 10.2. By contrast the Swan Coastal Plain wetlands had 1 to 11 chironomids with an average of 6. This does suggest that the 2019 sampling of McLarty sampled sediment dwelling species more effectively. Nonetheless, it is clear that the McLarty samples are comparatively rich compared to other wetlands on the Swan Coastal Plain.

In a cluster analysis (Figure 9) including three combinations of 2 x 17 metre Lake McLarty samples plus all of the spring (1989 and 1990) invertebrate presence/absence data from Davis et al. (1993), the more acidic and saline of the Davis et al. sites separated from remaining sites (to the left of the cluster tree), as they did when classified using a different clustering technique by Davis et al. (1993). McLarty then formed a group (underlined in red) separate to all of the remaining Davis et al. (1993) sites. This suggests that, in 2019, McLarty had an invertebrate community quite different to those further north on the Swan Coastal Plain sampled in 1989-1990.

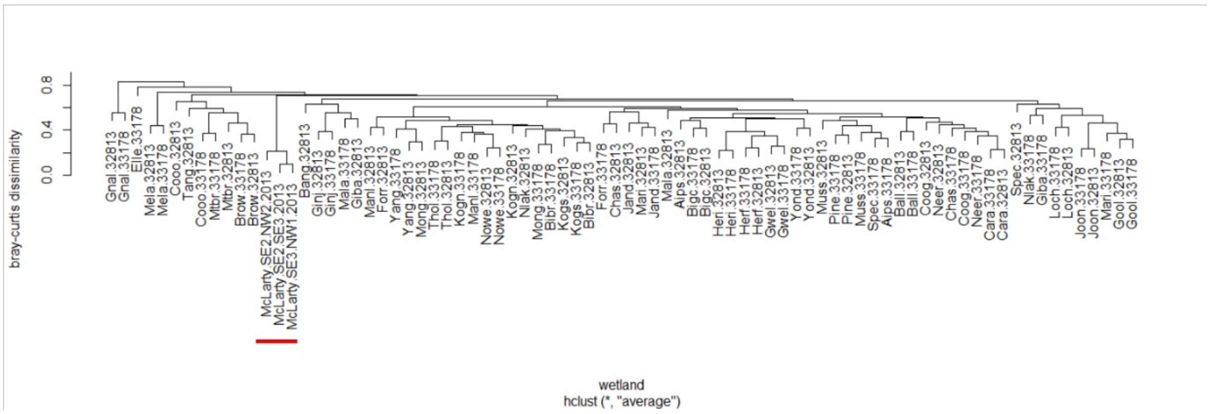

Figure 9. Hierarchical cluster analysis of invertebrate data from spring 1989 and 1990 from Davis et al. (1993) and three combinations of two benthic samples from Lake McLarty sampled in 2019.

Another (unpublished) dataset was compiled from samples collected from six other wetlands used (or potentially suitable for) the Western Swamp Tortoise (DBCA, unpublished data) in 2013, herein referred to as WST sites. These sites were in Moore River Nature Reserve, Ellen Brook Nature Reserve, Mogumber Nature Reserve, Twin Swamps Nature Reserve, one of the Perth Airport wetlands and Brixton Street Nature Reserve. All of these wetlands are shallow vegetated claypans (*Melaleuca* or sedges across much of the bed) so quite different to Lake McLarty. They also tend to have more diverse invertebrate faunas than less temporary and more open wetlands on the Swan Coastal Plain. That project took one 50 metre plankton sample (53 µm mesh net) and one 50 metre benthic sample (250 µm), so about equivalent to the south-east McLarty sampling (all samples from site A) or the combined west and north-west McLarty sampling (all samples from sites B and C combined), each of which involved 3 x 17 metres = 51 metres of benthic and plankton sampling. Harpacticoid copepods and ostracods have not yet been identified for the WST sites so these were excluded when comparing diversity and composition with Lake McLarty. Also, water mites have only been identified to family in the WST samples so the McLarty water mite data was similarly reduced to family level.

Using this restricted range of species, the two sets of combined McLarty samples had 82 and 76 species respectively. This is higher than the number of species recorded from the six WST sites sampled in 2013 (36 to 68 species, average 58). These figures will be revised once the full suite of species identifications is available from the WST sites. Lake McLarty invertebrate fauna is thus comparatively diverse, even when compared to these comparatively rich claypans.

In a cluster analysis of invertebrate communities from Lake McLarty and the WST sites (Figure 10) McLarty formed a group with Twin Swamps separate to the other five wetlands, highlighting differences between the communities of Lake McLarty and these other wetlands.

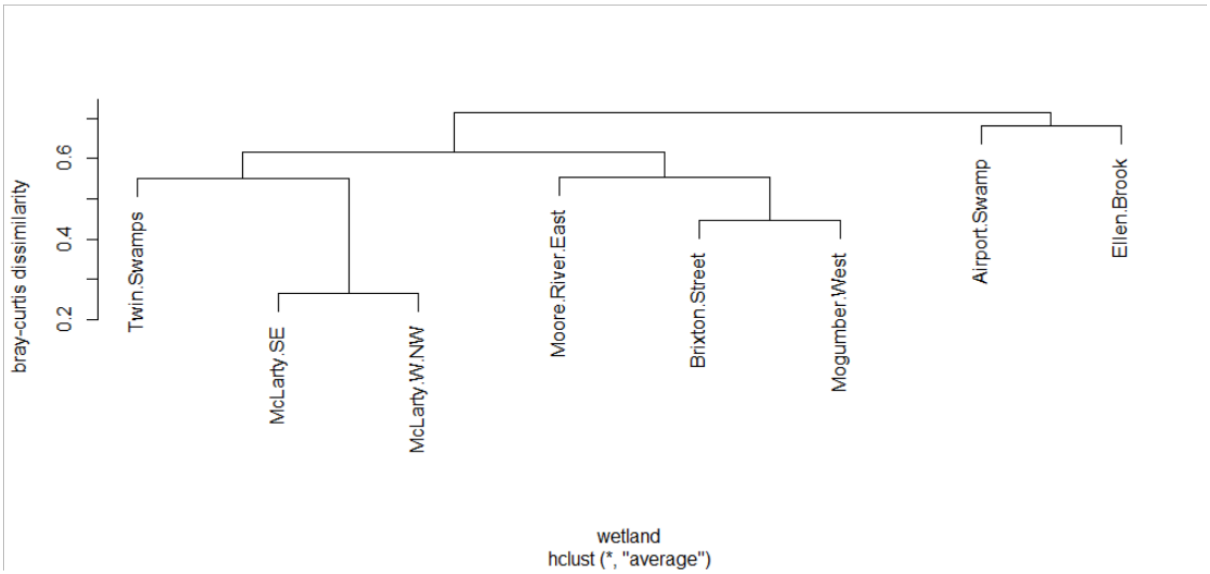

Figure 10. Hierarchical cluster analysis (average grouping) of invertebrate communities from two combinations of Lake McLarty (2019) samples and equivalent data from six Swan Coastal Plain vegetated claypans sampled for a Western Swamp Tortoise project in 2013.

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P.O. Box 51
Waneroo WA 6065

Attention: David Cale

Report on: 4 samples received on 25/10/2019

LAB ID	Material	Client ID and Description
19S1783 / 001	water	Little Darkin site A
19S1783 / 002	water	Little Darkin site B
19S1783 / 003	water	Lake McLarty site A
19S1783 / 004	water	Lake McLarty site B

LAB ID			001	002	003	004
Client ID			Little Darkin site A	Little Darkin site B	Lake McLarty site A	Lake McLarty site B
Sampled			07/10/2019	07/10/2019	21/10/2019	22/10/2019
Analyte	**Method**	**Unit**				
Alkalinity as CaCO3	iALK2WATI	mg/L	19		120	90
Calcium	nMET1WCICP	mg/L	1.0		69.5	76.4
Chlorophyll a	iCHLA1WACO	mg/L	0.006	0.001	0.001	0.006
Chlorophyll b	iCHLA1WACO	mg/L	0.002	<0.001	<0.001	0.001
Chlorophyll c	iCHLA1WACO	mg/L	<0.001	<0.001	<0.001	<0.001
Chlorophyll Volume	iCHLA1WACO	mL	500	1000	350	1000
Colour, TCU	iCOL1WACO	TCU	270		100	130
Hardness, total	iHTOT3WACA	mg/L	6		500	540
Magnesium	nMET1WCICP	mg/L	0.8		79.2	84.0
Phaeophytin a	iCHLA1WACO	mg/L	0.003	<0.001	0.002	0.002
Total dissolved solids(grav)	iSOL1WDGR	mg/L	78		1900	2000
Nitrogen, total	iNPT1SFAA	mg/L	1.5	1.4	1.6	3.3
Phosphorus, total	iNPT1SFAA	mg/L	0.030	0.016	0.031	0.099
Phosphorus, total soluble	iNPT1SFAA	mg/L	0.016	0.011	0.021	0.077
Nitrogen, total soluble	iNPT1SFAA	mg/L	1.3	1.4	1.5	2.8
Turbidity	iTURB1WCZZ	NTU	16		2.5	2.4

Method	Method Description
iALK2WATI	Alkalinity, Bicarbonate, Carbonate, Hydroxide and Total Carbon Dioxide by acid titration. pH and Conductivity in water (compensated to 25C) by meter.
iCHLA1WACO	Chlorophyll A, B, C and phaeophytin by colourimetry.
iCOL1WACO	Colour by spectrometry.
iHTOT3WACA	Total Hardness as mg/L CaCO3 by calculation from calcium and magnesium.
iNPT1SFAA	Low Level Nutrients by Segmented Flow Auto Analyser
iSOL1WDGR	Total dissolved solids (TDS) by gravimetry, dried at 178 - 182 C.
iTURB1WCZZ	Turbidity of water by Nephelometer.
nMET1WCICP	Total dissolved metals by ICPAES.

Appendix 2. All aquatic invertebrate presence/absence data for samples collected between 1999 and 2019

			1999/2000	Aug 2007		Oct 2007		2016		2017		2019										
Higher group	**Family**	**Identification**		**site 1**	**site 3**	**site 1**	**site 3**	**site C**	**site D**	**site C**	**site D**	**A1 benthic**	**A1 plankton**	**A2 benthic**	**A2 plankton**	**A3 benthic**	**A3 plankton**	**B1 benthic**	**B1 plankton**	**B2 benthic**	**B2 plankton**	**C1 benthic + plankton**
Cnidaria	Hydridae	*Hydra* sp.																				1
Turbellaria	-	Microturbellaria													1				1		1	1
Nematoda	-	Nematoda												1	1	1	1	1		1		1
Mollusca (snails)																						
	Planorbidae	*Glyptophysa* cf. *gibbosa*						1	1			1	1	1	1	1	1	1	1	1	1	1
Annelida (polychaetes, oligochaetes and leeches)																						
	Aeolosomatidae	*Aeolosoma* sp.															1				1	
	Naididae	*Chaetogaster diastrophus*													1							
	Pristinidae	*Pristina longiseta*												1	1	1						
	Pristinidae	*Pristina sima*																				1
	-	Naididae		1																		
	-	Unidentified leech	1																			
Acarina (water mites)																						
	Limnocharidae	*Limnochares australica*		1				1	1	1	1		1					1				
	Hydrachnidae	*Hydrachnidae* sp.	1					1														
	Eylaidae	*Eylais* sp.		1				1	1		1			1		1	1					1
	Limnesiidae	*Limnesia dentifera*									1	1	1	1	1	1	1	1		1	1	1
	Limnesiidae	*Limnesia* sp.		1				1	1													
	Pionidae	*Acercella falcipes*												1	1			1		1		1
	Pionidae	*Piona cumberlandensis*																		1		
	Pionidae	*Piona murleyi*												1							1	1
	Arrenuridae	*Arrenurus* (*Truncaturus*) sp. 25															1					1
	Pezidae	Pezidae														1						
	-	Acariformes																				
	-	Oribatida sp.																			1	1
Cladocera (water fleas)																						
	Sididae	*Latonopsis brehmi*																				1
	Chydoridae	*Alona rigidicaudis*																	1			1
	Chydoridae	*Alona* cf. *setigera*															1		1			
	Chydoridae	*Alona* sp.							1		1		1		1						1	
	Chydoridae	*Dunhevedia crassa*							1	1	1					1	1	1	1	1	1	1
	Chydoridae	*Ephemeroporus barroisi* s.l.																	1			1
	Chydoridae	*Leberis diaphanus*										1		1	1	1	1					1
	Chydoridae	*Leydigia laevis*								1		1				1		1				1
	Chydoridae	*Leydigia* sp.								1	1											
	Chydoridae	*Pleuroxus* cf. *inermis*						1	1		1	1	1	1	1	1		1	1	1	1	1
	Chydoridae	*Pleuroxus* sp.								1												
	Chydoridae	Chydoridae					1															
	Daphniidae	*Ceriodaphnia* sp.							1		1			1		1			1			1
	Daphniidae	*Daphnia carinata*									1										1	
	Daphniidae	Daphniidae		1	1		1															
	Daphniidae	*Simocephalus elizabethae*						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Macrotrichidae	*Macrothrix breviseta*										1										
	Macrotrichidae	*Macrothrix* cf. *rosea*									1											
	Macrotrichidae	*Macrothrix* sp.						1		1												
	Macrotrichidae	Macrotrichidae					1															
	Neotrichidae	*Neothrix armata*														1						
Ostracoda (seed shrimps)																						
	Cyprididae	*Alboa worooa*						1						1	1			1		1		1
	Cyprididae	*Eucypris virens*	1							1												
	Cyprididae	*Bennelongia* sp.						1	1	1	1	1	1	1	1	1	1	1		1		1
	Cyprididae	*Candonocypris novaezelandiae*						1		1		1		1	1	1		1	1	1	1	1
	Cyprididae	*Cypretta* sp.							1		1	1	1	1	1	1	1	1		1	1	1
	Cyprididae	Cyprididae		1	1		1															
	Cyprididae	*Mytilocypris ambiguosa*						1	1	1	1	1	1	1		1		1		1		1
	Cypridopsidae	*Sarscypridopsis aculeata*						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Copepods																						
	Centropagidae	*Calamoecia tasmanica subattenuata*										1	1	1		1	1	1	1	1	1	1
	-	Calanoida		1			1															
	Cyclopidae	*Microcyclops varicans*														1						
	Cyclopidae	*Mesocyclops brooksi*						1	1	1	1	1	1	1	1	1	1	1	1	1		1
	-	Cyclopoida		1	1		1															
	Canthocamptidae	*Cletocamptus dietersi*																1	1	1	1	1
	Phyllognathopodidae	*Phyllognathopus nr viguieri*													1						1	1
Amphipods	Ceinidae	*Austrochiltonia subtenuis*	1					1	1	1	1	1	1	1	1			1	1	1	1	1
Isopods	Amphisopidae	*Paramphisopus palustris*	1		1				1		1	1		1	1	1	1	1				1
	Oniscidae	Oniscidae																				1
Crayfish	Parastacidae	*Cherax quinquicarinatus*	1						1													
Coleoptera (beetles)																						
	Haliplidae	*Haliplus* sp.														1						
	Dytiscidae	*Hyphydrus elegans*																				1
	Dytiscidae	*Uvarus pictipes*																				1
	Dytiscidae	*Limbodessus shuckhardi*												1		1	1					1
	Dytiscidae	*Limbodessus inornatus*						1								1	1					
	Dytiscidae	*Limbodessus* sp.													1							
	Dytiscidae	*Allodessus bistrigatus*																				1
	Dytiscidae	*Antiporus occidentalis*															1					
	Dytiscidae	*Antiporus* sp.				1				1												
	Dytiscidae	*Sternopriscus* sp.										1		1		1		1				
	Dytiscidae	*Megaporus howittii*												1		1	1					
	Dytiscidae	*Megaporus solidus*												1		1	1					1
	Dytiscidae	*Megaporus* sp.				1	1	1	1		1	1	1		1			1		1		
	Dytiscidae	*Platynectes* sp.								1												
	Dytiscidae	*Rhantus suturalis*												1	1	1						
	Dytiscidae	*Rhantus* sp.					1			1												
	Dytiscidae	*Lancetes lanceolatus*												1		1						1

			1999/2000	Aug 2007		Oct 2007		2016		2017		2019										
				site 1	site 3	site 1	site 3	site C	site D	site C	site D	A1 benthic	A1 plankton	A2 benthic	A2 plankton	A3 benthic	A3 plankton	B1 benthic	B1 plankton	B2 benthic	B2 plankton	C1 benthic + plankton
	Dytiscidae	*Onychohydrus scutellaris*										1				1						1
	Dytiscidae	*Onychohydrus* sp.						1	1	1	1											
	Dytiscidae	*Cybister* sp.													1							
	Dytiscidae	*Exocelina ater*				1										1						
	Dytiscidae	Dytiscidae			1																	
	Hydrophilidae	*Berosus australiae*						1	1	1	1	1		1		1	1			1		1
	Hydrophilidae	*Berosus approximans*							1	1	1			1	1	1				1		
	Hydrophilidae	*Berosus discolor*						1		1	1											
	Hydrophilidae	*Berosus majusculus*					1	1	1	1	1											
	Hydrophilidae	*Berosus* sp.	1										1					1			1	
	Hydrophilidae	*Enochrus elongatulus*													1							
	Hydrophilidae	*Enochrus eyrensis*							1					1	1	1	1					
	Hydrophilidae	*Enochrus* sp.						1														
	Hydrophilidae	*Helochares tenuistriatus*												1								
	Hydrophilidae	*Limnoxenus zelandicus*										1		1	1	1	1			1		1
	Hydrophilidae	*Paracymus pygmaeus*												1	1	1	1			1		1
	Hydrophilidae	*Hydrophilus* sp.												1	1	1	1					1
	Hydraenidae	*Ochthebius* spp.													1	1				1	1	1
	Hydrochidae	*Hydrochus australis*														1						
	-	Hydrophilidae		1	1																	
Diptera (fly larvae)																						
	Culicidae	*Anopheles annulipes*								1	1	1		1	1	1	1			1	1	1
	Culicidae	*Anopheles* sp.						1														
	Culicidae	*Culex* sp.												1		1	1					
	Culicidae	*Cocquillettia linearis*	1																			
		Culicidae		1																		
	Ceratopogonidae	*Bezzia* sp.														1						
	Ceratopogonidae	*Monohelea* sp.																1				
	Ceratopogonidae	*Nilobezzia* sp.																		1		
	Ceratopogonidae	*Forcipomyia* sp.																				1
	Ceratopogonidae	Ceratopogonidae	1	1											1							
	Scatopsidae	Scatopsidae																				1
	Stratiomyidae	Stratiomyidae						1		1		1		1	1	1	1			1	1	1
	Sciomyzidae	Sciomyzidae														1	1					
		Tipulidae		1																		
	Ephydridae	Ephydridae sp.		1	1				1	1	1			1	1	1						
	Muscidae	Muscidae sp. D															1					1
	Chironomidae	*Procladius paludicola*																1				
	Chironomidae	*Procladius villosimanus*				1						1		1	1	1		1		1		
	Chironomidae	*Procladius (DEC* sp. P1)									1											
	Chironomidae	*Procladius* (normal claws)						1														
	Chironomidae	*Paramerina levidensis*										1		1	1	1	1			1	1	1
	Chironomidae	*Corynoneura sp. (V4* 9)					1	1			1			1	1	1	1					1
	Chironomidae	*Paramerina levidensis*									1											
	Chironomidae	*Paralimnophyes pullulus* (V42)									1				1					1	1	1
	Chironomidae	*Cricotopus 'brevicornis'*											1	1	1	1	1					1
	Chironomidae	*Tanytarsus barbitarsis*												1	1	1				1		
	Chironomidae	*Tanytarsus fuscithorax/semibarbitarsus*				1	1	1			1	1		1	1	1		1				1
	Chironomidae	*Chironomus aff. alternans* (V24)								1				1	1	1				1	1	1
	Chironomidae	*Chironomus occidentalis*	1																			
	Chironomidae	*Chironomus tepperi*				1																
	Chironomidae	*Dicrotendipes conjunctus*								1	1		1	1	1	1		1	1	1	1	1
	Chironomidae	*Dicrotendipes pseudoconjunctus*				1	1	1	1			1										
	Chironomidae	*Polypedilum nubifer*				1	1	1		1	1	1		1	1	1	1	1		1		1
	Chironomidae	*Paraborniella tonnoiri*														1						
	Chironomidae	*Cryptochironomus griseidorsum*				1	1															
	Chironomidae	*Parachironomus (VSCL35)*										1										
	Chironomidae	Chironomidae		1	1																	
Ephemeroptera (mayflies)																						
	Ceinidae	Ceinidae		1		1	1															
	Baetidae	Baetidae															1					
Hemiptera (true bugs)																						
	Hydrometridae	*Hydrometra strigosa*													1							1
	Veliidae	*Microvelia (Pacificovelia) oceanica*													1	1	1					1
	Veliidae	*Microvelia* sp.						1						1							1	
	Veliidae	Veliidae										1										
	Corixidae	*Sigara truncatipala*																1				1
	Corixidae	*Sigara mullaka*									1											
	Corixidae	*Sigara* sp.																				
	Corixidae	*Agraptocorixa eurynome*								1		1	1								1	
	Corixidae	*Agraptocorixa* sp.																1				1
	Corixidae	*Micronecta robusta*	1								1	1	1	1	1	1	1	1	1		1	1
	Corixidae	*Corixidae* sp.					1	1														
	Notonectidae	*Anisops thienemanni*						1		1		1	1	1	1	1	1					1
	Notonectidae	*Anisops hyperion*															1					
	Notonectidae	*Anisops gratus*																1				
	Notonectidae	*Anisops* sp.					1		1		1								1		1	
	Notonectidae	Notonectidae			1																	
Odonata (dragonflies and damselflies)																						
	Coenagrionidae	*Austroagrion cyane*																1				1
	Coenagrionidae	*Ischnura aurora aurora*														1						1
	Coenagrionidae	Coenagrionidae																			1	
	Coenagrionidae	*Xanthagrion erythroneurum*	1																			
	Lestidae	*Austrolestes analis*						1	1	1	1			1		1		1				1
	Lestidae	*Austrolestes annulosus*				1	1	1	1		1							1				
	Lestidae	*Austrolestes io*													1	1		1				1
	Lestidae	*Austrolestes sp.*										1										
	Aeshnidae	*Anax papuensis*						1	1	1	1	1				1						1
	Aeshnidae	Aeshnidae					1															
	Libellulidae	*Diplacodes bipunctata\trivialis*	1																			1

		1999/2000	Aug 2007		Oct 2007		2016		2017		2019										
			site 1	site 3	site 1	site 3	site C	site D	site C	site D	A1 benthic	A1 plankton	A2 benthic	A2 plankton	A3 benthic	A3 plankton	B1 benthic	B1 plankton	B2 benthic	B2 plankton	C1 benthic + plankton
Libellulidae	*Lathrocordulia metallica*								1												
-	Zygoptera															1					
Trichoptera (caddisflies)																					
Hydroptilidae	*Acritoptila* sp.									1							1				1
Leptoceridae	*Notalina spira*	1										1									1
Leptoceridae	*Oecetis* sp.	1								1	1	1					1		1		
Leptoceridae	*Triplectides australis*	1					1	1	1		1	1	1	1	1		1		1	1	1
Leptoceridae	Leptoceridae									1											