Ecological Investigation and Monitoring of the North Ongerup Wetlands, Ongerup, Great Southern, WA

Report prepared for Green Skills Inc by Steve & Geraldine Janicke

November 2016

Acknowledgements

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Cover photos: G Janicke |, Salt Home and Chamberlain Lakes and field day participants.

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Disclaimer: The authors have, in good faith, made every effort to ensure the accuracy of the information presented and to acknowledge the sources, subject to the limitations of the methods used and take no responsibility for how this information is used subsequently by others, including implied notions and conclusions drawn.

CONTENTS

INTRODUCTION

The North Ongerup wetlands system is located near the southern edge of the Yilgarn Craton, a vast undulating plateau that defines much of the geology of the southern half of Western Australia. The authors visited six of these wetlands on the 9th of November 2016, on behalf of Green Skills Inc. The site visits combined a community field excursion “Exploring the life of Salt Lakes”, an event organised through Green Skills[1], and hosted by farmers Kingsley and Sandy Vaux and a science excursion for students and teachers from the Ongerup Primary School. Five wetlands were sampled to see what aquatic macroinvertebrates lived in the waters. A sixth wetland visited was dry.

Prior to extensive land clearing many wetlands in the system held fresh water, but subsequently went saline, although naturally saline lakes were likely a feature of the area. The ground water at depth in the area has been shown to be saline (Ferdowsian and Ryder, 1997), but the hydrological balance was such that fresh surface water and perched aquifers were able to persist above the saline water table. The native vegetation intercepted rainfall and acted to control groundwater recharge, maintaining the water table at depth. Since then rising saline ground water has led to many of the freshwater lakes becoming salinised. The condition of the wetlands therefore acts as a barometer of hydrogeological pressures and trends. The trend has not only had an extensive impact on the wetland ecosystems, but has also had an influence on agricultural productivity in the surrounding plains.

The casual observer may simply see a flat landscape with shallow saltpans that appear much the same, however there is a growing appreciation of the diversity of these systems and the subtle geological foundations and hydrological processes that give them their unique and intriguing character. The complex, but not all that obvious, geological foundations of the region in which the North Ongerup wetlands are situated, highlights the principle that the features of the environment are intricately connected across the landscape.

REGIONAL LANDSCAPE CONTEXT

An examination of aerial images of the North Ongerup region reveals that a complex of wetlands lie north of the town of Ongerup and these extend northward in a broad band. A wider regional view shows that the wetland system follows the characteristic pattern of a large river drainage system. This ancient river cut into the granitic basement rock of the Yilgarn Craton and was subsequently filled with sediments as the hills and valleys eroded down to the present low relief topography. The shallow valleys are referred to as paleo-channels (Figure 1). The undulating plains, low rainfall and sediment filled valleys ensure that floodwaters remain relatively local and there is little movement of surface waters northward along the ancient river system. The sediments of the paleo-channels do however provide pathways for regional movement of groundwater and this process has an important influence on the character of individual wetlands. Two important factors determining whether the water held in a wetland is fresh or saline are the elevation of the wetlands beds relative to the water table and the depth of soil over the basement rock.

[1] “Exploring the Life of Salt Lakes - Ongerup Wetland Field Day & Salt Lakes Biological Survey” and event organized through Green Skills wetland conservation activities, with funding from the State Natural Resource Management Program, made possible by the State Government’s Royalties for Regions program. It has also been supported by the Yongergnow Malleefowl Centre, Ongerup and Bush Heritage Australia.

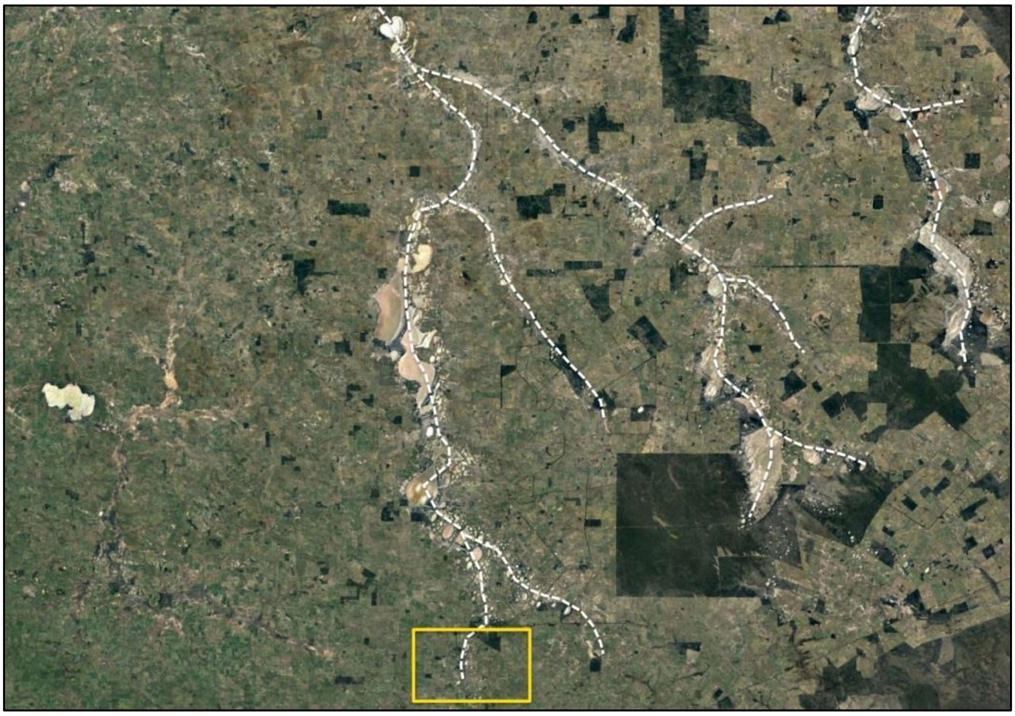

Figure 1: The salt lakes system extends northward and the visited wetlands (within the yellow box) can be seen to be in the upper reaches of the ancient paleo drainage system.

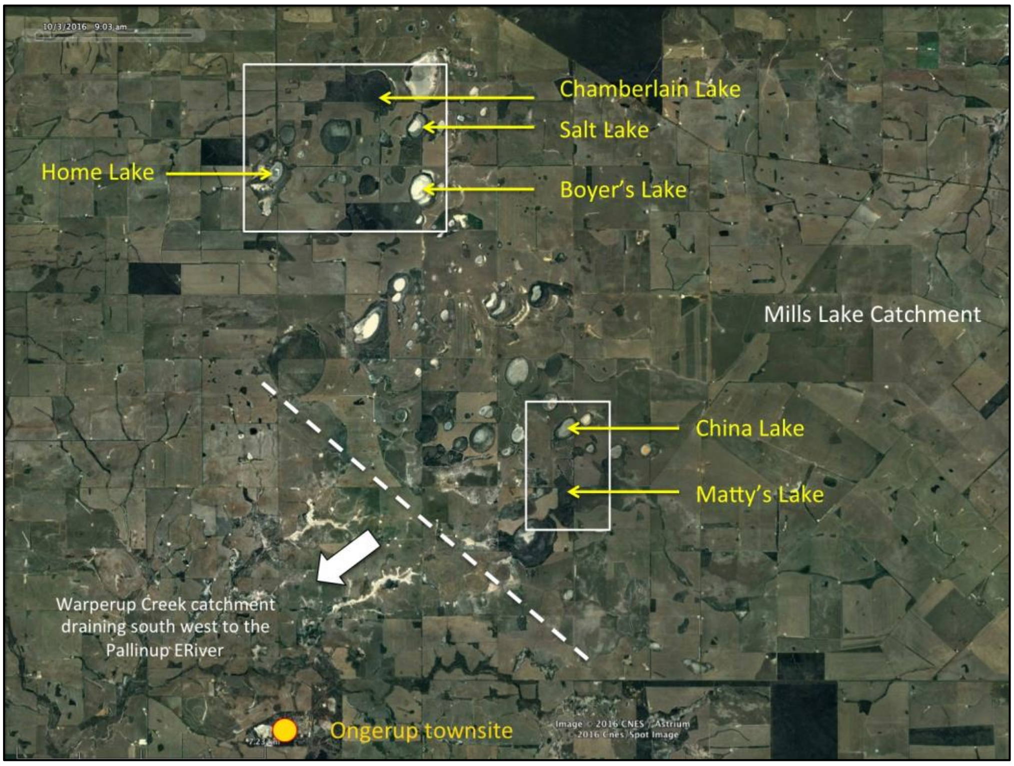

Figure 2: The relative locations of the wetlands that were visited

The North Ongerup wetlands lie in a transition zone between the South Coast rivers and the inland catchments of the Avon and Blackwood Rivers. South Coast rivers are relatively short and geologically recent compared with the ancient northern river system. The surface drainage along the southern edge of the Yilgarn plateau flows to the Southern Ocean terminating typically in a broad shallow estuary. These rivers are a result of tectonic scale tilting of the southern edge of the continent that produced what is known as the Ravensthorpe Ramp.

The dotted line in Figure 2 shows the approximate divide between the Warperup Creek, a tributary of the southward flowing Pallinup River, and the paleo-channel system.

In many areas, the granite basement rock is overlain by a layer of coarse sands, sandstones and conglomerates deposited in the older river system. This is referred to as the Werrilup formation. Marine sediments composed of fine silts and sponge spicules (Spongeolite) may be found overlying the Werrilup formation and play a part in the development of various wetlands. Other geological features of the region contributing to the ecological character of the lake and wetland systems are various fault lines and dolerite dykes.

In 1997 Ruhi Ferdowsian and Arjen Ryder from the Department of Agriculture produced a detailed report on the hydrogeology of the Mills Lake Catchment nearby. The report discussed the hydrogeology of the landscape and the processes that have formed the wetlands and have now modified them. These processes have relevance to the wetland systems discussed in this brief report.

WETLANDS ASSESSED

The selected wetlands fit within an area extending 10 Km west to east and 13 Km north to south. There are numerous other wetland basins, large and small in this area. The open water areas of the selection are of similar dimensions and on average measure approximately 600 - 900 meters long by 500 - 700 meters wide. The wetland bed typically rises relatively steeply over a short distance around the perimeter of the basin and this riparian zone is generally well vegetated. Figure 3 shows that two of the wetlands, Chamberlain and Matty's Lakes, are well vegetated throughout. Chamberlain Lake was dry at the time of the visit and the landowner mentioned that it had not held water for about 15 years.

Table 1: Location of wetlands (Approximate central point in UTM coordinates, Zone 50)

Local wetland name	Easting	Northing	Access
Salt Lake	0640920	6257915	K & S Vaux property
Boyers Lake	0639750	6258920	K & S Vaux property
Home Lake	0636806	6256675	K & S Vaux property
China Lake	0645090	6249150	O'Neil Road
Matty's Lake	0645080	6247325	O'Neil Road

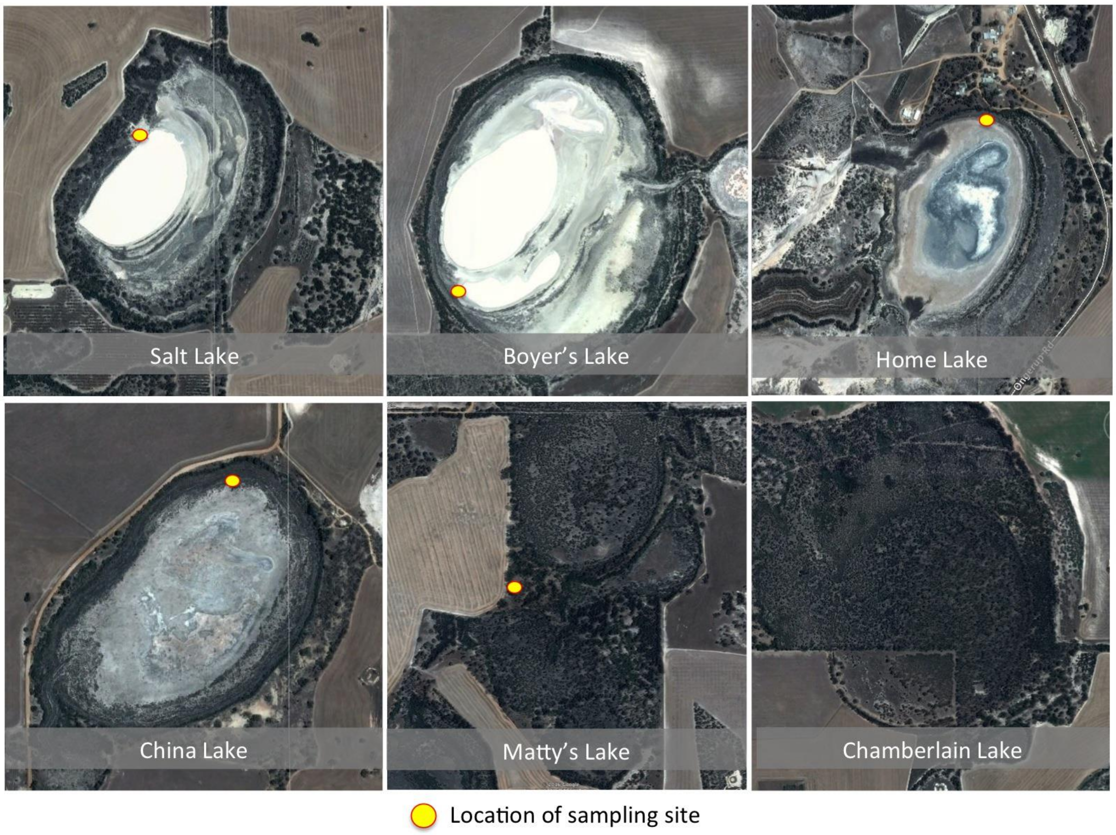

Figure 3: The wetlands visited

WATER QUALITY

Basic water quality measurements were taken to complement the macro-invertebrate survey.

Table 2: Water quality data collected 9 November 2016 (* pH Indicative only | GPS locations: WGS84 Zone 50.)

Wetland **local** name	**Site Easting**	**Site Northing**	**Salinity (Salinometer) ppt**	**Conductivity (ADMA AD32) mS/cm**	**pH (ADMA AD11)**	**Temperature (thermometer) Celsius**	**Turbidity (Tube) NTU**
Salt	0640852	6258058	> 260			17	12
Boyer's	0640765	6255855	> 260		8.1*	19	15
Home	0636917	6256930	45		8.5	18	12
China	0645165	6249439	30		10	19	< 10
Matty's	0644765	6246812		1.34	6	20	40

Salinity categories have been determined according to salinity tolerances of freshwater and saline tolerant macroinvertebrates (Pinder et al, 2005). Note: seawater is usually 35 ppt (52ms/cm).

- <3 ppt, freshwater
- 3 to 12 ppt, sub-saline or brackish
- 12 to 35 ppt, saline
- >35 ppt, hyper-saline.

Two of the lakes were hyper-saline (brine) at the time of the site visit. The salinity was measured using an optical Salinometer as the brine was well above the measuring capacity of the conductivity meter. Both lakes gave readings greater than 260 ppt, which was off the Salinometer scale and suggested a salinity around 7 - 8 time that of seawater. The pH meter was used briefly at Boyer's Lake and immediately rinsed with rain water. It was thought that the salt levels could potentially damage the sensitive probe. The reading suggests the waters of Boyers Lake were alkaline, but the accuracy in such extreme situations is unknown. The basic measurements of salinity, pH, temperature and turbidity revealed a wide range of water quality conditions across the wetlands at the time of sampling and this highlights the diversity of environmental conditions that characterize the wetland system.

Salt Lake and Boyer's Lake have the distinctive pink coloration characteristic of the presence of the green micro algae *Dunaliella salina*. The release of beta carotene accounts for the pink tinge the micro-algae imparts to the brine. The salt-loving *Halobacteria cutirubrum* is also a candidate as it too is adapted to highly saline conditions and produces a reddish dye.

WETLAND SALINITY AND HYDROGRAPHY

Ferdowsian and Ryder (1997) identified a number of factors that characterise the interaction between the surface wetlands and the groundwater system of the nearby Mills Lake catchment. Both regional and local influences were investigated. These factors are likely to be relevant to the ecological character of the wetlands of the North Ongerup region. They are;

- the depth of the regional saline water table below the surface,
- the direction of the regional groundwater movement,
- the inflow of surface water during and after storm events,
- the movement of sub-surface fresh water above the water table.
- the position of the wetland in the undulating landscape (landform pattern),
- the relative altitude of the bed of the wetland with respect to surrounding landscape,
- the local depth of the regolith (soil profile, basement rock highs and lows).
- the salt content of the regolith,
- the existence of paleo channels in which coarse sediments conduct groundwater.
- regional tectonic features such as uplifting, tilting, distortion of the earth's crust and dolerite dykes.

Detailed studies are required to determine which of these factors may be influencing a particular wetland and to what extent each plays a part in its ecological development. The pre-clearing condition of the wetlands can only be surmised by anecdotal evidence. The diversity of basic water quality measurements made during the site visits suggest that different hydrological processes are at work. Ferdowsian and Ryder observed that, "many low-lying parts of the study area (Mills Lake) have become salt affected recently" thus identifying the depth from surface to water table as a critical hydrogeological parameter.

The following graphs <u>tentatively</u> explore the role of bed altitude within the suite of local wetlands. The data is not rigorous, but validates the importance of the physical location of a wetland with respect to landform, both horizontally and vertically. It suggests that a meter or two of altitude may make a substantial difference to the ecological characteristics of the wetland and this is consistent with the low relief of the undulating plain on which the wetlands sit.

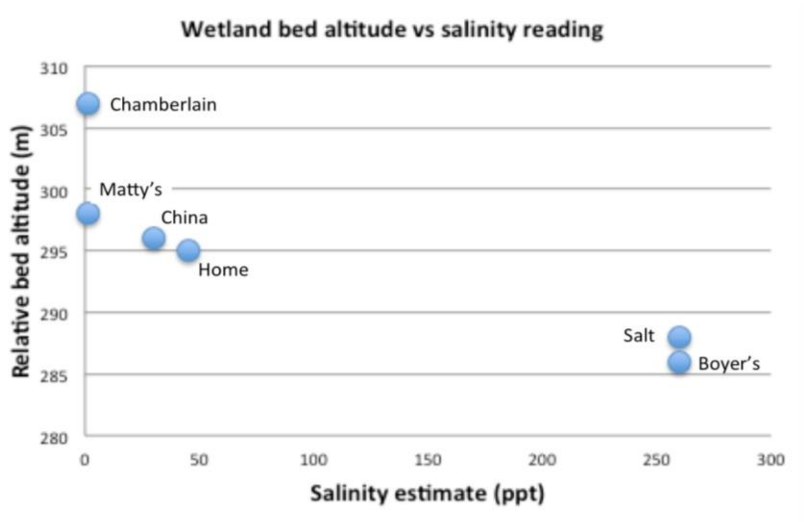

Figure 4: Wetland salinity versus bed altitude for the sites visited

Figure 4 shows a plot of approximate salinity values against approximate bed altitude (relative readings taken from Google Earth) and Figure 5 compares 3 simple categories of vegetation cover with bed altitude for 19 wetlands in the immediate area, including those visited. The salinity value for Chamberlain Lake, which was dry at the time of the site visit, was inferred from comments about its freshness in the past and the lack of signs of salinization since it was last flooded.

The differentiation of vegetative condition with altitude appears quite consistent.

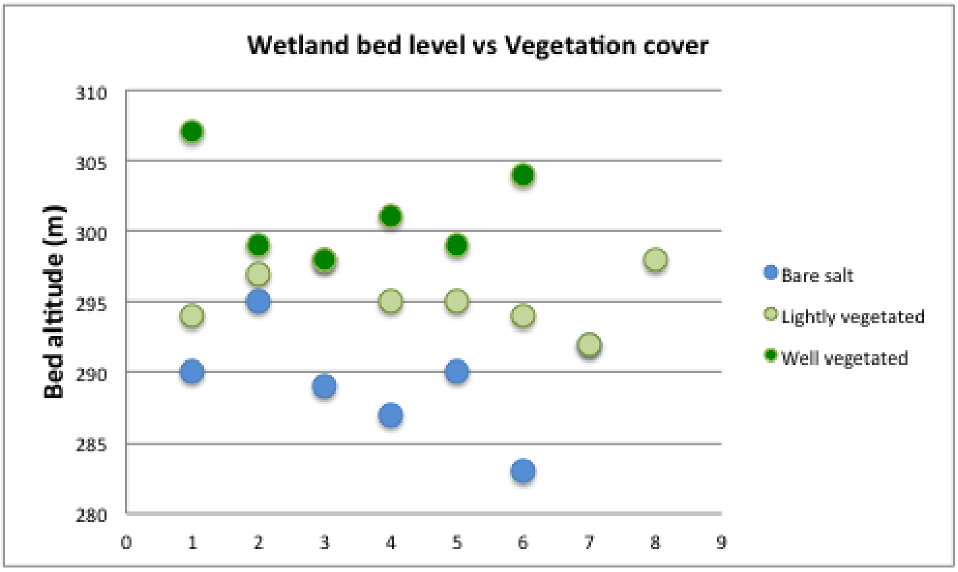

Figure 5: Compares a basic vegetation cover category obtained using aerial photo coloration, with bed altitude (Google Earth) for 23 medium to large wetlands in the area visited.

Episodic storm events may flood some wetlands in a short period of time and thus 'reset' the aquatic environment. The after effects of this flooding can be observed in the distinctive concentric vegetation bands of the riparian zone. Evaporation steadily increases the salt concentration over subsequent years. Historically this was part of a natural cycle and not a problem provided no extra salt found its way into the wetland. Once the salt input increased, chiefly through increasing groundwater discharge, there was no mechanism for removing the buildup and the well-vegetated wetlands began to adopt the characteristics of naturally saline wetlands lower in the landscape.

The presence of dead yates in the middle of some wetlands, China Lake for example, suggests a time when the waters were fresh and surface water was relatively short lived. The distribution and size of dead standing trees gives a clue to the original state of the wetland.

Figure 6: Stands of Yates on the fringe of Chamberlain Lake. The bed is dry for most years and the waters are fresh when present.

Kingsley indicated that the Yates seen to the left in Figure 6 grew from the time of the massive regional floods of 1955. This wetland has been mostly dry over the years.

The two brine lakes, Salt (Figure 7) and Boyer's do not have dead standing trees or remnant stumps in the central basin and along with the extreme salt content this suggests they were naturally saline prior to clearing. The content of the macro-invertebrate samples suggest that while appearing similar to the Salt Lake, Boyer's may have a more variable brackish-saline cycle despite experiencing the same weather patterns.

Figure 7: Salt Lake, the pink tinge is likely due to the presence of the micro-algae *Dunaliella salina*.

The most significant modifying influence in the landscape during the twentieth century was the replacement of native vegetation by crops and pastures. The increased salinization of the soils and surface waters in the area is now well accepted as a consequence of land clearing. The preservation of natural values in each wetland will depend on whether local landscape factors are more significant than the long-term regional groundwater trends. If local influences are the key there is the possibility of managing the local vegetation, including crops and pastures, to help in the conservation of the wetlands. It is uncertain whether some wetlands that originally held fresh water can be returned to the likeness of their former condition after having become salinized. However, it should also be appreciated that some lakes have possibly been naturally saline to hyper-saline given the nature of the landscape. Nevertheless, conservation efforts will need to accommodate a permanent shift in the average condition of the wetlands.

The fluctuating water levels due to the seasonal and annual cycle of rainfall obscure long-term trends, but consistent monitoring will eventually reveal the trend and this will of course determine the final environmental outcomes.

SAMPLING FOR MACROINVERTEBRATES

Five wetlands (Figure 3) were sampled on the 9th November 2016 for macroinvertebrate composition, Chamberlain Lake was dry. Aquatic macroinvertebrates were sampled using a 250-µm mesh net to sweep around as many habitats as possible adjacent to a 30-metre section of wetland foreshore. All samples were passed through appropriate sized sieves and placed in white trays and live picked with the help of participants in the "Exploring the Life of Salt Lakes" event. All picked animals were placed into sample containers with 70% ethanol, and returned to the laboratory where all specimens were identified to the lowest taxonomic level possible.

Figure 8: Participants in the "Exploring the Life of Salt Lakes" event learning about life in the Home Lake while helping to pick out the invertebrates.

MACROINVERTEBRATE COMPOSITION

The brine in Salt Lake contained no invertebrate life while the brine in Boyers Lake contained the remnants of 9 taxa. A total of 34 macroinvertebrate taxa were collected from other the four lakes (Table 3) with the freshwater lake being the most species rich. The most species diverse group of invertebrates in the lakes were Crustaceans with 9 species of seed shrimps (Ostracoda) and four species of water fleas (Cladocera) collected from the four lakes. See Appendix 1 for the list of macroinvertebrates collected.

Species commonly occurring in freshwater but tolerant of some salinity are referred to as halotolerant, while halophiles are those considered to show a strong preference for saline environments. Crustaceans, such as brine shrimp, seed shrimp (Ostracoda) and copepods, are the most common invertebrate communities of naturally saline wetlands. The south-west of Western Australia is a global hotspot for inland crustacean diversity with diversity of salt loving endemic ostracods a 'result of long history of aridity on the continent' (DeDecker 1983b)

Table 3: Species richness within macroinvertebrate orders for four lakes. Salinity in ppt is given for each lake.

Class	Order	Salt Lake (>260 ppt)	Boyers Lake (>260 ppt)	Home Lake (45 ppt)	China Lake (30 ppt)	Matty's Lake (<3 ppt)
Arthropoda	Acarina					1
Crustacea	Amphipoda			1	1	1
Crustacea	Anostraca		1			
Crustacea	Cladocera			2	1	3
Crustacea	Copepoda		1		1	1
Crustacea	Ostracoda		2	4	2	6
Insecta	Coleoptera			2		3
Insecta	Collembola		1			
Insecta	Diptera		1	2	2	2
Insecta	Hemiptera				1	5
Insecta	Odonata				1	1
Mollusca	Gastropoda		1			
Total species richness		**0**	**7**	**11**	**9**	**23**

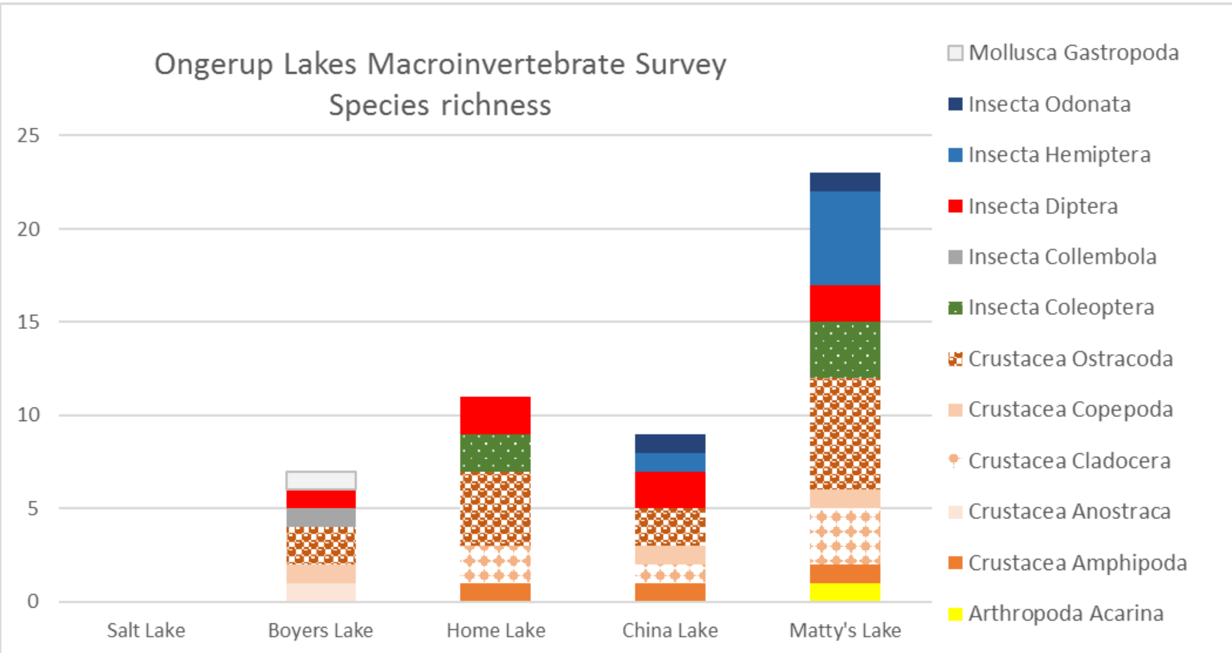

Figure 9: Species richness of the four lakes sampled. Note that Crustaceans (orange colours) dominate all the wetlands except for the fresh water Matty's lake

Salt Lake

Although this lake was sampled, there were nothing collected in the nets. The brine had deposited white crystals of salt on the lake bed and around the edge. The pink colouration of the water could be due to the green micro algae *Dunaliella salina* which releases beta carotene into the brine. The salt-loving *Halobacteria cutirubrum* is also a candidate as it too is adapted to highly saline conditions and produces a reddish dye.

Figure 10: Salt Lake, the pink tinge is likely due to the presence of the micro-algae Dunaliella salina.

Figure 11: Steve gathering water quality information while participants of the "Exploring the Life of Salt Lakes" event watch.

Boyers Lake

Although the salinity of Boyers Lake was also off the scale of the Salinometer. There were fewer salt crystals on the lake bed and around the edge suggesting it was less salty in more recent times. No live animals were collected, only the remnants (exoskeletons) of seven macroinvertebrates and all these were halophiles.

There were exoskeletal remains of the brine shrimp *Artemia parthenogenetica* which is not a native to the area. They were first observed in lakes on Rottnest Island where their dispersal inland has been by a variety of migrating shorebirds. (McMaster, K. et al. 2007). They have also been introduced as fish food and to control algae in salt production ponds. Their desiccation resistant eggs or cysts float and can sometimes can been seen as a 'cake' of material along the shoreline. These eggs can also collect on bird feet and feathers and be transported to the next wetland. *Artemia parthenogenetica* tolerate up to 215 ppt (Australian Biodiversity - Salt Sensitivity Database) which is much saltier than our endemic Parartemia can tolerate. Kingsley Vaux made the comment that he had observed many birds on the lake some weeks earlier. It would seem that they had found food there which may have been the brine shrimp.

The seed shrimp *Platycypris baueri* and the snail, *Coxiella* sp. were other halophiles found in Boyers Lake. *Platycypris baueri* has been recorded in brine to 288ppt (Australian Biodiversity - Salt Sensitivity Database) but flourishes in lower levels of salinity. Similarly, *Coxiella* snails can live in brine to 124 ppt. They are endemic to saline wetlands of Australia and survive during dry periods by burrowing under debris or mud and blocking the opening of the shell with their operculum. It is unknown how many species there are as the genus needs revision with analysis of DNA.

Figure 12: Boyer's Lake, salty as the Salt Lake, but with less of a pinkish tinge

Figure 13: The bands of different riparian vegetation illustrate the cycle of inundation and drying in these systems.

Home and China Lakes

Home and China Lakes were similar with dead tree trunks in the water and inundated Samphires around the edge and both had a salinity around that of sea water. The dead trees indicate that these lakes may have been fresher and inundated less often.

They had 11 and 9 taxa respectively dominated by seed shrimps (Ostracoda) and water fleas (Cladocera). There were dense swards of the macroalgae *Lamprothanmium papulosum* and Swan grass *Ruppia megacarpa* that supported the abundance of both salt tolerant and salt loving Crustacean fauna. Most of the taxa collected were common to secondarily salinised wetlands in the Wheatbelt (Pinder *et al* 2002 and Pinder *et al* 2004). The Amphipod *Austrochiltonia subtenuis* was also present and unlike the seed shrimps and water fleas, do not produce drought-resistant eggs. The can survive short dry periods by taking refuge in damp areas such as in mud under debris. Hence they are more common in permanent waters.

Figure 14: Geraldine Janicke coordinates the macro-invertebrate sampling at Home Lake adjacent to Kingsley and Sandy Vaux's place.

Figure 15: China Lake, a victim of rising saline groundwater and water-logging.

Figure 16: Several Black Swan nests were observed at China Lake

Figure 17: The foreshore of China Lake here suggests a shift in the type of riparian vegetation as a result of increasing salinity of the wetland waters.

Matty's Lake

Matty's Lake was fresh with the highest number of taxa collected. Unlike Home and China Lakes, there was a low abundance of individuals per species collected and this is typical of healthy freshwater wetlands. There were 11 species of Insects and 11 species of Crustaceans and one species of water mite. Most of the macroinvertebrates were freshwater species however there were several halotolerant species that were also recorded in the saline lakes including the Amphipod *Austrochiltonia subtenuis,* the water flea *Daphniopsis pusilla,* and the large seed shrimp *Mytilocypris tasmanica chapmani complex.*

There were a high number of water bugs (Hemiptera) including juvenile back swimmers (so called since they swim on their back). Back swimmers (Anisops sp.) have haemoglobin within cells of their abdomen which store oxygen. This enables them to store less gas and maintain a neutral buoyancy requiring less effort to remain submerged in the water column (Andersen and Weir, 2004). They are predators and will feed on invertebrates that move through the water column such as seed shrimp, water fleas and copepods as well as mosquito larvae. There were three species of water boatman which unlike the back swimmers need to carry a larger amount of air on their body under their wings and hence have to be strong swimmers. They are generally found close to the bottom clinging to debris and have a varied diet of algae, detritus and animal prey. Water bugs do not have desiccation resistant eggs but are able to fly from drying wetlands to new locations including farm dams.

Figure 18: Students from the Ongerup Primary School learning about aquatic life in Matty's Lake and helping to pick the invertebrates.

Figure 19: Matty's lake, fresh and deeply tannin coloured.

Chamberlain Lake

Chamberlain Lake was dry however the soil in the bed of the lake will contain desiccation resistant eggs, cysts and seeds from a variety of Crustaceans, macroalgae and Swan grass. It is important to maintain sufficient area of the lake bed as undisturbed as possible to protect these dormant foundations of aquatic life ready for the next inundation event. Dormant eggs have been known to remain viable for decades. It is recommended that at least a portion of the Lake be kept stock free.

Figure 20: Chamberlain Lake, dry for 15 years yet a water line can be observed on the tree trunks from the last inundation.

APPENDIX 1 – MACROINVERTEBRATES

Macro-invertebrate species composition in five wetlands in the North Ongerup area, sampled on the 9th of November 2016.

North Ongerup Lakes		Salinity	>260 ppt	45 ppt	30 ppt	< 3ppt
Class	**Order**	**Family/subfamily Genus/species**	**Boyers Lake**	**Home Lake**	**China Lake**	**Matty's Lake**
	Algae	Charales *Lamprothanmium papulosum*	remnants	3	2	
	Angiosperm	Ruppiacaea *Ruppia megacarpa*	remnants	3	3	
Arthropoda	Acarina	Acarina Unknown Acarina sp.				2
Crustacea	Amphipoda	Ceinidae *Austrochiltonia subtenuis*		2	2	2
Crustacea	Anostraca	Artemiidae *Artemia parthenogenetica* remnants	1			
Crustacea	Cladocera	*Daphniidae Daphnia carinata*?? eggs		1		
Crustacea	Cladocera	Daphniidae *Daphnia cephelata*				1
Crustacea	Cladocera	Daphniidae *Daphniopsis pusilla*		2	3	1
Crustacea	Cladocera	Daphniidae *Simocephalus victoriensis* affin				3
Crustacea	Copepoda	Cyclopoid Copepoda sp.	1		2	2
Crustacea	Ostracoda	Chydoridae Chydorid sp.				3
Crustacea	Ostracoda	Cyprididae *Australocypris benneti*		1		
Crustacea	Ostracoda	Cyprididae *Cypretta sp.*				2
Crustacea	Ostracoda	Cyprididae *Cyprinotus cingalensis*				1
Crustacea	Ostracoda	Cyprididae *Mytilocypris tasmanica chapmani* complex		2	4	2
Crustacea	Ostracoda	Cyprididae *Platycypris baueri*	1	2		2
Crustacea	Ostracoda	Cyprididae *Reticypris* sp		5	2	
Crustacea	Ostracoda	Cyprididae *Sarcipridopsis* sp.				3
Crustacea	Ostracoda	Cyprididae Unknown species	1			
Insecta	Coleoptera	Curculionidae *Curculionid* sp.		1		
Insecta	Coleoptera	Dytiscidae *Necterosoma* sp. Larvae		2		
Insecta	Coleoptera	Dytiscidae *Platynectes* sp. Larvae				1
Insecta	Coleoptera	Dytiscidae *Sternopriscus multimaculatus*				1
Insecta	Coleoptera	Hydrophilidae *Enochrus elongatus*				1
Insecta	Collembola	Hypogastruridae Hypogastrurid sp.	1			
Insecta	Diptera	Chironomidae/Chironominae *Chironomus alternans*				3
Insecta	Diptera	Chironomidae/Chironominae *Tanytarsus barbitarsus*	1			

North Ongerup Lakes		Salinity	>260 ppt	45 ppt	30 ppt	< 3ppt
Class	**Order**	**Family/subfamily Genus/species**	**Boyers Lake**	**Home Lake**	**China Lake**	**Matty's Lake**
Insecta	Diptera	Chironomidae/Tanypodinae *Procladius paludicola*		1	1	
Insecta	Diptera	Stratiomyidae Stratiomyid sp.		1	1	1
Insecta	Hemiptera	Corixidae *Agraptacorixa eurynome*				2
Insecta	Hemiptera	Corixidae *Agraptacorixa parvipunctata*				2
Insecta	Hemiptera	Corixidae *Micronecta robusta*				2
Insecta	Hemiptera	Notonectidae Juvenile Notonectid			1	3
Insecta	Hemiptera	Veliidae *Microvelia* sp.				1
Insecta	Odonata	Lestidae *Austrolestes annulosis*			1	1
Mollusca	Gastropoda	Pomatiopsidae *Coxiella* sp	1			
Total Species richness			**7**	**11**	**9**	**23**

APPENDIX 2 - WATER QUALITY INSTRUMENTATION AND DATA ACCURACY

- Electrical conductivity ADWA AD32 (0 - 20 mS/cm)
- Optical Salinometer Kfuji (0 - 260 ppt)
- pH ADWA AD11 and pH (0 - 14) strips
- Turbidity Turbidity tube (NTU)
- Temperature Thermometer

Table 4: Instrument calibration and control checks

Parameter	Date	Standard mS/cm	Meter reading mS/cm	Discrepancy
EC (AD32)	7/11/2016	12.88 mS/cm	12.99	< 1%
pH (AD11)	7/11/2016	7	6.9	< 2%
pH (AD11)	7/11/2016	4.01	4.0	< 1%

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