Ecological Investigation & Fauna Survey of Lakes Nunijup and Little Nuniup, Shire of Cranbrook, WA.

Report prepared for Green Skills Inc, Denmark WA.

by Steve & Geraldine Janicke

March 2019

This project was supported by

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Cover photo: Students from Frankland River Primary School learn about water quality at Lake Nunijup. Photo Basil Schur.

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Thanks also to the Citizen Scientists who helped over the day. Special thanks to the Sylvia Leighton and the Certificate 111 Conservation and Land Management Students from Great Southern TAFE Albany for their assistance over the day. Special thanks also to the students, staff and parents of the Frankland River Primary School who came out for the afternoon and for their interest.

Contents

Introduction

Lakes Nunijup and Little Nuniup are part of the suite of wetlands within the Forests to Stirling area of the Gondwana Link Wetlands program in the Shire of Cranbrook in WA's Great Southern Region.. Lake Nunijup is the larger wetland and has in some early maps and reports been called Little Nuniup. Little Nuniup is now applied to the smaller nearby lake which has also been called Boggy lake by local farmers. In this report it is referred to as Little Nuniup Lake to distinguish it from Lake Nunijup

Lake Nunijup is a popular recreation lake, where locals and tourists go water skiing, swimming and camping. Lake Nunijup and other wetlands in the region have also been attracting attention due to their diverse ecological nature and particularly as habitat for a wide range of water bird species.

This report examines the ecology of the two connected lakes and is a reconnaissance level assessment that incorporated a Citizen Science event. The 20th February 2019 sampling event involved Citizen Scientists. It was hoped that they could be trained in how to use the phone app *iNaturalist*, an online platform for sharing observations by uploading photos with other users adding identifications. This was not successful as most of the attendees' phones could not connect to the mobile network. However, the citizen scientist attendees were very helpful in sampling and picking macroinvertebrates for later laboratory identification.

Green Skills have engaged rural schools across the Great Southern to partner in education outings for upper primary school students. The Frankland River Primary School undertook an outing to Lake Nunijup for their upper primary classes in the afternoon of 20th February 2019.

The purpose of the report

This ecological investigation was conducted on 14th December 2018 and 19th to 20th February 2019. The main question was; *What waterbirds are using the lake and what are they eating?* There had been some discrepancy between waterbirds present, their dietary preferences and the aquatic macroinvertebrates assemblage present in past sampling of saline wetlands. The question was raised whether the macroinvertebrate population was different elsewhere around the lake to where the sample was taken. Thus, a secondary question was proposed: *Are the macroinvertebrate populations uniform around the lakes?* To answer these questions, it was proposed to sample the lakes at two sites on the up-wind and down-wind sides of the lake. Lake Nunijup was sampled in December and again in February to give an idea of changes over time in the macroinvertebrate assemblage.

After the bird survey, several further questions were posed regarding the lake and its use by a variety of waterbirds, as follows;

1. Why are so many birds using the lakes currently?
2. What different food sources the individual species likely to be feeding on in the lakes?
3. Why in particular are there so many Eurasian Coots and Black Swan on both lakes?
4. Why does the smaller Little Nuniup Lake have Pink Eared Duck and Blue Billed Duck while Lake Nunijup doesn't?
5. Why does the smaller Little Nuniup Lake have far more Hoary-Headed Grebe than Lake Nunijup?
6. Are there any wetland bird species that should be present but are not? And if so, why not?
7. Is there a preference for the birds that can be related to the growth stage of aquatic plant growth?

Other habitat-based questions to be considered are:-

8. How saline is each lake?
9. Does this influence food supply?
10. What is the acidity or alkalinity of the waters (pH)?
11. Why do these two lakes support the water levels they do?
12. What is it the lake bed made of?
13. Is there a groundwater waterflow?

14. Are these lakes typical of lakes in the general area and do others hold good water levels as well from winter or recent rains?

Relevant management questions are:-

15. How would both lakes benefit from planting of fringing low vegetation (sedges etc) to provide cover and food supply?
16. Is the difference in fringing plants between the lakes, at all water levels, an important factor distinguishing the character of the two lakes?
17. Could both lakes benefit from artificial islands?

Answering these questions is no small task, but the lakes themselves hold clues that may help. One of the first steps is to gain a better understanding of the surrounding landscape and how water moves into and through the area and what determines its quality.

Landscape setting

Lakes Nunijup and Little Nuniup are situated 33 Kilometres north-west of the town of Mt Barker and 18 kms south-west of the town of Cranbrook. It is in the Upper Kent River catchment and sits partly within Reserves 1759 and R29175, vested in the Cranbrook Shire for recreational purposes. Two thirds of the edge of Lake Nunijup is adjacent to farmland. Little Nuniup Lake is a smaller, elliptical wetland immediately upstream of Nunijup. Little Nuniup sits mostly within farmland although the lake itself is Unallocated Crown Land.

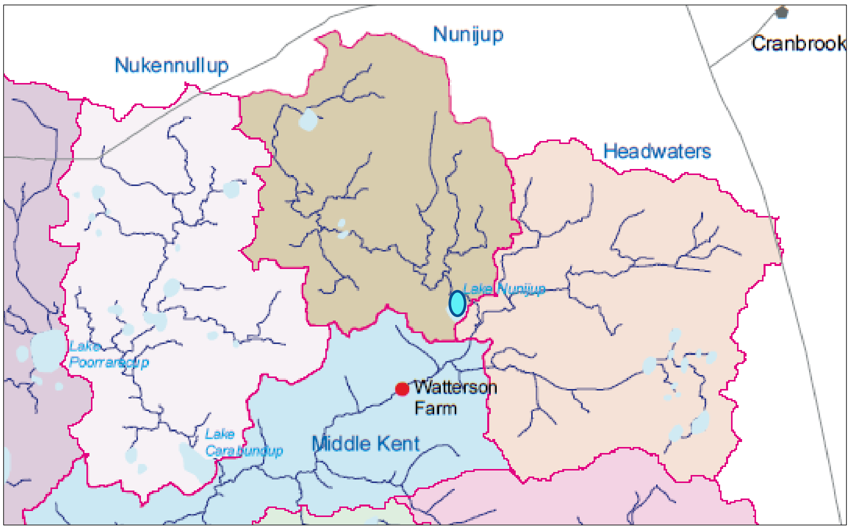

Figure 1: Lake Nunijup catchment in the upper Kent River catchment.[1]

The catchment area for Nunijup is approximately 75sq km^2, but figures vary up to 100sq km[3]. The gently undulating nature of this part of the landscape makes it difficult to work out the exact catchment boundary. Nunijup has a fringing native vegetation buffer zone that ranges from none up to 95m from the wetland edge (including the reserve area).

[1] Bari, MA & De Silva, J 2009, *Hydrology of Lakes Nunijup, Poorrarecup and Carabundup, Salinity and Land Use Impacts Series*, Report No. SLUI 26, Department of Water, Perth.
[2] Lake Nunijup Report Card, DOW 2008, South Coast Wetland Monitoring Project
[3] Bari, MA & De Silva, J 2009, *Hydrology of Lakes Nunijup, Poorrarecup and Carabundup, Salinity and Land Use Impacts Series*, Report No. SLUI 26, Department of Water, Perth

Figure 2: Location of Lakes Nunijup and Little Nuniup. The path for lake bed profile observations are marked as white lines across the lake. (Images Google Maps and Google Earth)

Figure 3: Little Nuniup Lake is surrounded mostly by a narrow band of vegetation apart from the northern edge. (Imagery, Airpix as commissioned by Green Skills Inc.)

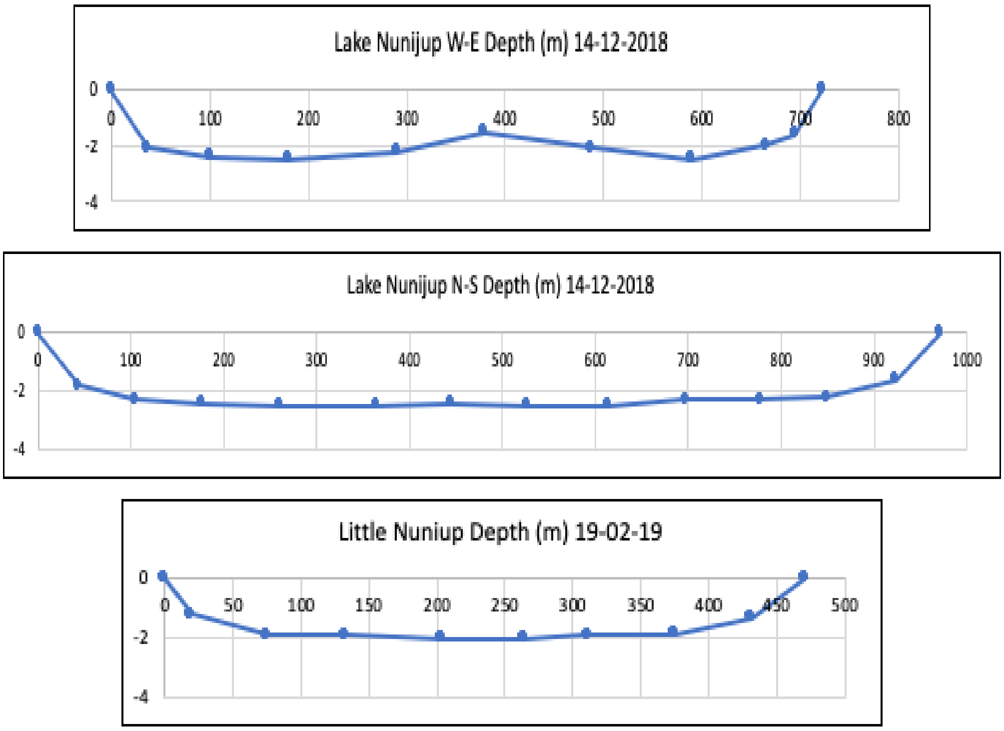

Figure 4: The general bed profile for each lake.

The surface area at moderate water levels is approximately; 75 - 80 Hectares and the corresponding depth of the lake is 2.5 – 3 meters in the centre. The bed profile is shaped like a dinner plate rather than a bowl (Figure 4). The same is true for neighbouring Little Nuniup Lake which has a surface area of around 22 Ha.

The lake bed sediments of both lakes appeared to have a thin black/brownish silt layer over a moderately firm bed however it was not extensively sampled.

Hydrology and Hydrogeology

A comprehensive understanding of the hydrologically function of the Kent River catchment including Nunijup and Little Nuniup Lakes, can be found in two reports prepared by the Department of Water. The first was published in 2006 and is titled, *Salinity Situation Statement: Kent River*[4] and the second was published in 2009 and is titled H*ydrology of Lakes Nunijup, Poorrarecup and Carabundup, Salinity and Land Use Impacts Series*[5]. In additional in 2008, a DOW report card[6] was produced providing information on the monitoring of the wetlands. These reports contain a lot of technical details and a number of the findings appear relevant to gaining a better understanding of the ecology of the two wetlands. These are summarised below.

Rainfall

The lakes receive up to 600 mm of annual average rainfall. The open water annual evaporation is approximately 1500 mm. Evaporation therefore greatly exceeds rainfall and is an important factor determining what conditions prevail in the lakes.

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[4] De Silva, J, Bari, MA, Dixon, RNM, Coppolina, ML, Boniecka, LH & Ward, BH (2006), *Salinity Situation Statement: Kent River*, Department of Water, Water Resource Technical Series No. WRT 33, 129p.
[5] Bari, MA & De Silva, J 2009, *Hydrology of Lakes Nunijup, Poorrarecup and Carabundup, Salinity and Land Use Impacts Series*, Report No. SLUI 26, Department of Water, Perth
[6] Lake Nunijup Report Card, DOW 2008, South Coast Wetland Monitoring Project

Elevation

Elevation above sea level within the catchment ranges from 230 m near the lake to 400 m AHD near Geekabee Hill. Lake Nunijup is bounded by a 5 m-high lunette (sand and silt dune) on the southern side and its outflow point is on the north eastern side.

Water Quality and salinity

- According to local farmers, in 1963 the lake water was fresh (< 500 mg/L) and used as drinking water and for irrigation. By 1976, water had deteriorated to stock quality
- This indicates that fresher surface waters were once the main input for the lakes with the naturally saline groundwater having less impact. Large scale clearing of the natural vegetation altered the hydrological balance of the landscape and this has led to salt stored deeper in the soil being brought to the surface where it is expressed in valley floors and wetlands. Salt can also be expressed on valley sides and ridges due to complex and subtle geological structures.
- This lake had been an important source of the area's stock quality water, especially during droughts.
- Shire of Cranbrook records show that lake water quality fluctuated between 3.4ppt and 4.5ppt from 1974 to 1975.
- The salinity of Nunijup has been increasing steadily since 1988. Its salinity ranged from about 10ppt[7]. in 1988 to about 11ppt in 2001 but was recorded at 61ppt in 1984. Note: Seawater salinity is around 35ppt.
- Groundwater salinity decreases significantly in the downgradient side of Lake Nunijup compared to background groundwater salinity values, possibly because the less saline lake water is recharging groundwater.
- The Salinity Situation Statement — Kent River, Water Resource Technical Series WRT 33 posed the question; Has groundwater in the catchment reached steady-state equilibrium since the clearing controls were established in 1978? They speculated that: A large part of the catchment may have reached steady state or be very close to steady state as groundwater levels in nearly 70% of bores are either declining or steady. The 'Flats' landform that covers about one third of the upper catchment has relatively stable groundwater levels compared with the 'Hill slopes' landform where the trends are still upward.

The Department of Water reports did not address the condition of Little Nuniup Lake however it would be subject to the same hydrological constraints.

Water flow and Groundwater

- Groundwater is also an important factor for determining wetland character.
- It is worth noting that groundwater catchments do not necessarily match the surface water catchment since groundwater may flow along quite different subsurface pathways. For example, Lake Nunijup lies on the Tenterden fault line and this extends outside the surface catchment and can influence groundwater movement. These structures can influence water conditions but are more difficult to understand. Ancient river channels called paleo-channels, now filled with sediments, also provide easy pathways for ground water to flow substantial distances.
- Anecdotal evidence is that Lake Nunijup overflowed briefly in 1982, following a 180-mm rainfall event, but rarely dries out.
- The local farmer (Chris Parsons) commented that Lake Nunijup has dried up three times in his life time.
- Based on catchment and lake water balance, the annual inflow (1973–2001) to Lake Nunijup was 0.72 GL, of which about 70% evaporated and 26% seeped through the lakebed. Lake Nunijup has a capacity of 2.32 GL (one GL is equivalent to 1sq km of water at a depth of 1m.) at the overflow depth of 3.9 m. About 88% of the salt seeped through the lakebed and the rest is being stored in the lake.

[7] ppt – parts per thousand

- Groundwater is generally less than 3 m below ground level. Groundwater flow near the lake showed considerable seasonal variation during December 2001 to March 2002.
- Monitoring of the lake water and groundwater indicates that Lake Nunijup fluctuates all the way from recharge and flow-through to discharge regimes.
- Groundwater flow in December suggested that groundwater flows through the underlying sediments of the lake system in response to winter rainfall recharge to the groundwater system from May to September. However, when lake levels drop due to evaporation from the lake surface from January to March, groundwater may start discharging into the lake.
- Freshwater input can potentially reduce salt levels by transporting salt through the lake beds.

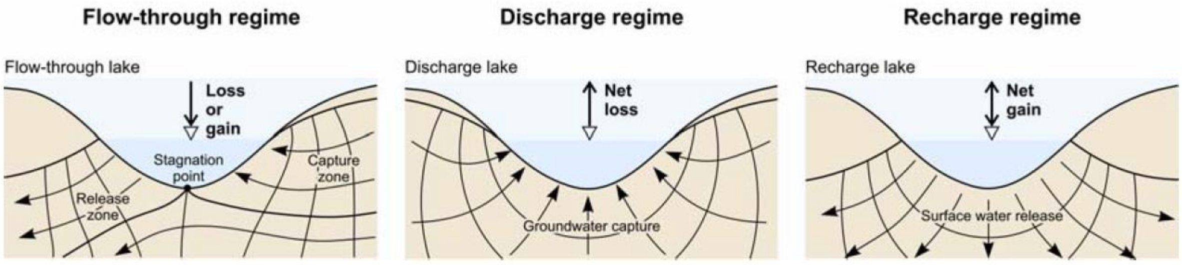

Figure 5: Flow-through, discharge and recharge regimes relevant to Lake Nunijup [8].

It was suggested that restoring the 'freshness' of the Kent River would require a lowering of the catchment water table by 3m. As far as the lakes are concerned, promoting fresh storm water inflow may be sufficient to maintain a high degree of freshness. An understanding of how the salinity varies in the catchment runoff during storm flows would be necessary to test the feasibility of 'engineering' this outcome.

Geology

Quaternary sediments mainly occur in the broad flat landscape of the upper catchment. These consist of clay, ferricrete and sand. They overlie Tertiary sediments such as Werillup Formation or the weathered profiles of basement rocks.

The Werillup Formation also occurs in the broad flat landscape of the upper catchment, especially where there are lakes and swamps, and consists of fine to coarse-grained sand, clay, carbonaceous clay or lignite. These sediments represent the palaeo-channel deposits of Eocene age (about 45 million years ago). Groundwater entering this aquifer from adjacent weathered bedrocks may discharge vertically into surface sediments.

[8] Bari, MA & De Silva, J 2009, *Hydrology of Lakes Nunijup, Poorrarecup and Carabundup, Salinity and Land Use Impacts Series*, Report No. SLUI 26, Department of Water, Perth

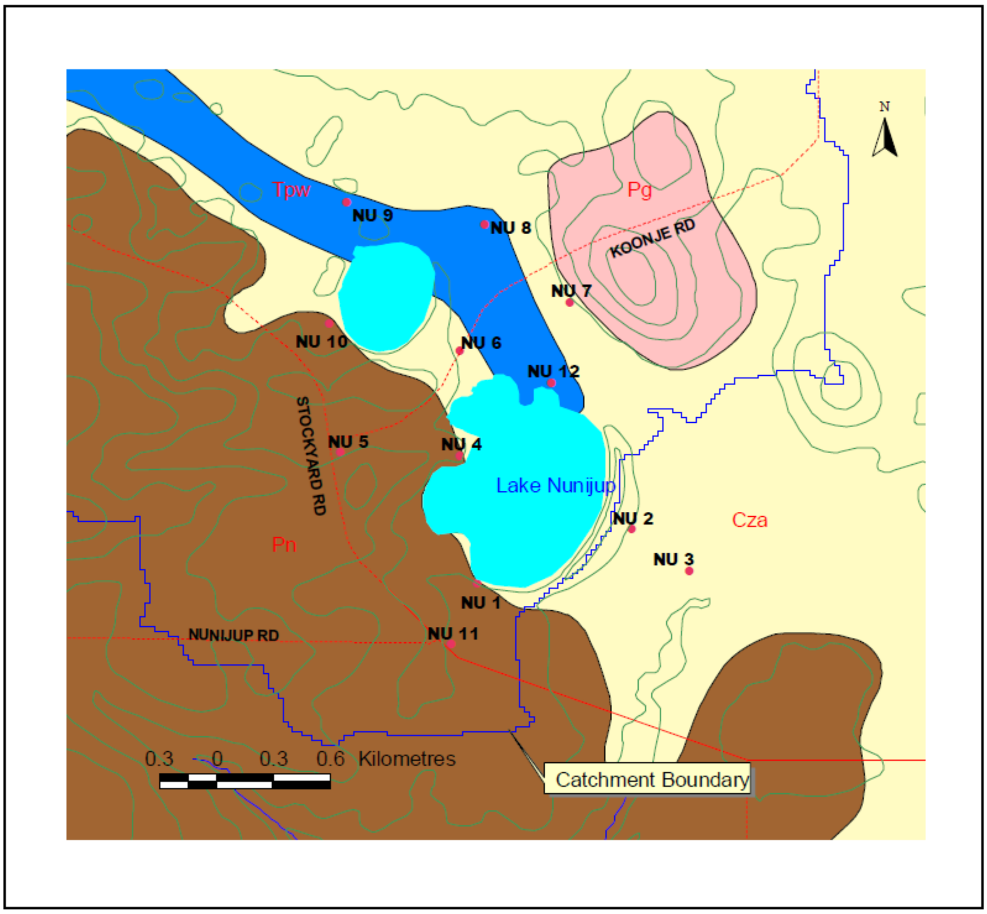

Figure 6: Hydrogeology of Lake Nunijup[9]: Cza – Superficial aquifer Cainozoic sediments, Tpw – Paleochannel sediments, Werillup Formation, Pg – Proterozoic granites, Pn – Fractured and weathered Proterozoic gneisses.

Water Quality 2018-2019

Reconnaissance survey water quality data

	Nunijup 14th Dec 2018	Nunijup 1stFeb 2019	Nunijup 20th Feb 2019	Little Nuniup 20th Feb 2019	Comment
Salinity	10 ppt	17 ppt	22 ppt	20 ppt	Salinometer
Conductivity			30.8 mS/cm	30mS/cm	Horiba EC33 meter
pH	9		9.4	9	Horiba pH33 meter
Turbidity	Clear	clear	< 5 NTU	20 NTU	Turbidity tube
Maximum depth	2.5			1.9	

[9]Figure after Born et al. 1979 in Bari, MA & De Silva, J 2009, *Hydrology of Lakes Nunijup, Poorrarecup and Carabundup, Salinity and Land Use Impacts Series*, Report No. SLUI 26, Department of Water, Perth

Wetland salinity categories (Pinder et al, 2005).

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

Note: seawater is usually 35 ppt (52ms/cm).

The condition in both lakes appeared moderate with no obvious problematic extremes. The sub-saline to saline water in the lakes appeared consistent with the dry summer season. Water levels were decreasing in Lake Nunijup and salinity was increasing through evaporation. The abundant aquatic vegetation and macroinvertebrates found are tolerant of a range of salinities up to hypersaline.

The pH around 9 for both Lakes is common to saline lakes in the region. In lakes with high levels of aquatic vegetation, the pH can vary over the day as high rates of photosynthesis consumes carbon dioxide. On sunny days, photosynthetic consumption of carbon dioxide has been known to diurnally increase the pH of a wetland by up to 2 pH units[10].

The high turbidity and dun colouring of the water in Little Nuniup Lake indicate a phytoplankton bloom that was not present in Lake Nunijup. This implies that Little Nuniup Lake had higher nutrient levels to sustain the phytoplankton and the lake bed vegetation. Water samples were not taken for analysis of nitrogen and phosphorus content but would be required to confirm their levels. The large numbers of water birds present and their input of nutrients from droppings may provide a significant source of nutrients for Ruppia and algal growth. However, there were equally large numbers of birds in both lakes with indications of nutrient enrichment only in Little Nuniup Lake.

Surface water flows into Little Nuniup Lake at the north-west corner and exits nearby on the north-east corner. Sediment carried by surface flows from the catchment could enter the greater cross-sectional area of the lake and as the flow slows material can settle out. The lake may thus act as a sediment retention basin. The nutrient Phosphorus is known to attach to sediment particles and this can become available for phyto-plankton growth within the lake. Sources of nutrient enrichment would need to be examined by testing the catchment inflow.

Fringing vegetation

The main fringing vegetation for both lakes are Salt paperbark, *Melaleuca cuticularis* and *Eucalyptus spp*. Both lakes have remnant patches of the emergent sedge, *Baumea articulata*. This large sedge tolerates inundation deeper than 1m but can also tolerate growing above the water level provided it has its roots into abundant water. It prefers fresh water but can tolerate brackish to slightly saline water (10ppt)[11]. The increase in salinity since 1970 will have impacted the extent of this sedge with the present extent of the sedge above the water line as the lake evaporation over summer lowers the water line and increases the salinity.

[10] https://ozcoasts.org.au/indicators/biophysical-indicators/ph_coastal_waterways/ Accessed November 2018

[11] Jones S. M., Francis C. J., Halliday D. L., Leung A. E. (2009). *The potential effects of groundwater disposal on the biota of wetlands in the Wheatbelt, Western Australia*. Prepared for the Avon Catchment Council by the Department of Environment and Conservation, Perth.

Figure 7: An inundated clump of Baumea articulata on the northern edge of Lake Nunijup and a larval exoskeleton shed by a damselfly.

Aquatic plants

Both lakes had healthy meadows of aquatic vegetation, Swan Grass (*Ruppia* spp.) and Foxtail Stonewort (*Lamprothamnium* sp. in the Charales order). The clarity of water in Lake Nunijup made snorkelling over the meadows very pleasant and two species of Swan Grass and two species of Stoneworts were observed. The other Charales belongs to the genus *Nitella* sp.. When canoeing over Lake Nunijup on 14^{th} December 2018, the water clarity was such that Stoneworts could be observed covering the whole lake bed, even at 2.5 m depth.

These aquatic plants are very important to the overall quality of the lake water and to faunal ecology. The dominant Swan Grass (*Ruppia megacarpa*) is tolerant of a wide range of salinity levels however the other Ruppia sp. which was only found in occasional small clumps, is likely to be not so tolerant of high levels of salinity. Also, potentially present although not observed, is *Athenia* sp. (Formally known as *Lepilaena* sp.).

Many of the Swan Grass species produce rhizomes and vegetative propagules (turions) which are eaten by waterbirds. Their seed are eaten along with the rest of the plant however they are resistant to digestion and are defecated promoting plant dispersal[12].

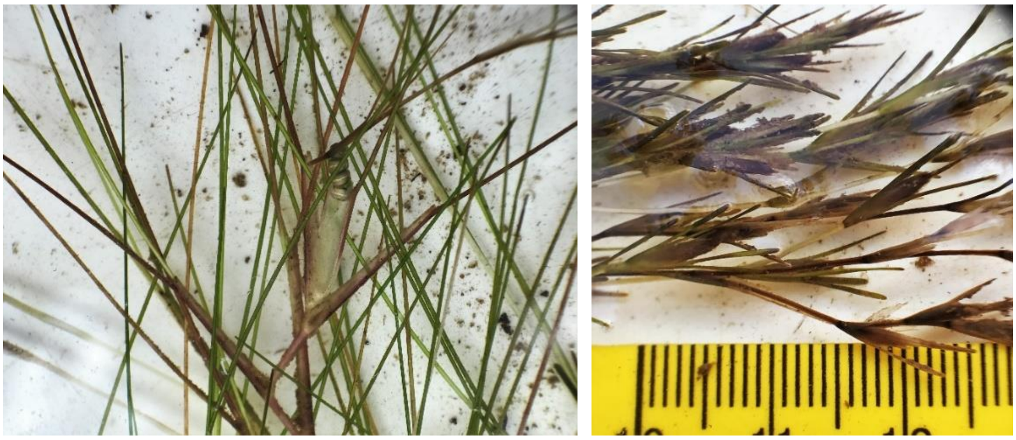

Figure 8: The dominant Swan Grass, *Ruppia megacarpa* and less frequently observed *Ruppia* of unknown species.

[12] Charalambidou, I., L. Santamaria and O. Langevoord (2003) *Effect of ingestion by five avian dispersers on the retention time, retrieval and germination of Ruppia maritima seeds.* Functional Ecology 2003 17, 747–753 © 2003 British Ecological Society Blackwell Publishing Ltd.

Similarly, the dominant Stonewort (*Lamprothamnium* sp.) is also tolerant of a wide range of salinity levels. Originally the Stonewort was given the specific name of *Lamprothamnium papulosum*, however recent studies have shown that there are at least 13 species of *Lamprothamnium* in Australia and *L. papulosum* was not one of them. The Stonewort in Lake Nunijup was not identified to species level A second species of macroalgae, *Nitella* sp. was also observed in a few isolated clumps but their relative distribution over the lake bed was not noted. Nitella are generally less tolerant of high levels of salinity.

The Foxtail stonewort frequently develop spherical bulbils (starch-filled cells) on their rhizoidal filaments (spreading root like structures), which are the main form of vegetative reproduction in permanent waterbodies such as these two lakes. The bulbils are an attractive and nutritious food for the coots, swans and other diving birds.

Figure 9: The dominant Stonewort, *Lamprothamnium* sp. and the less dominant *Nitella* sp.

Macroinvertebrates

Macroinvertebrates were sampled from several sites at Lake Nunijup on 14th December 2018, 1st and 20th February 2019. Little Lake Nuniup was sampled on 19th and 20th February 2019.

The differences in macroinvertebrate diversity between the two lakes at different times and in different habitats can be seen in Figure 10. There were in total 17 species collected from Lake Nunijup and 15 species from Little Nuniup Lake with a total of 22 species from both lakes. The Department of Water Wetland Monitoring Project[13] sampled Lake Nunijup between 2000 and 2007 and found between 7 and 14 macroinvertebrate groups. They found that macroinvertebrate diversity tended to be highest in fresher waters and decreased as the water became increasingly saline.

The main difference between the two lakes was the presence of the introduced fish *Gambusia holbrookii*. When the lakes were fresh, the local farmers had introduced Perch into the lake however as they have become more saline and dried out on a few occasions, these fish have disappeared. Gambusia are hardy fish that reproduce abundantly and thrive in the warm shallows of slightly saline waterways. The juvenile fish can be trapped on the feathers of ducks and travel to other lakes with the ducks. Since the lake was dry in 1980s, it can be assumed that these Gambusia have arrived since. It is interesting that they have not yet 'flown' across to Little Lake Nuniup.

The other interesting difference was the presence of midge larvae in Little Lake Nuniup and not in Nunijup. Midge larvae are tolerant of nutrient enriched environments and are often an indication of eutrophication. There were two Coxiella snails collected from Lake Nunijup on the two sampling occasions in February and would be expected to be in Little Nuniup Lake also. There would need to be more sampling to be able to find more definitive differences between the Lakes.

[13] Lake Nunijup Report Card, DOW 2008, South Coast Wetland Monitoring Project

Quotes

from research papers

on the benefit of having submerged aquatic vegetation in lakes.

Submerged aquatic vegetation supports high productivity and maintains a stable lake bed. They contribute to sediment being oxygenated through the roots which prevents the release of phosphate, sulphide and other nutrients and toxic ions into the water[14]*. Submerged aquatic vegetation are also thought to preserve lakes in a clear-water state while stabilizing the sediment and reduce water flow. An increase in submerged aquatic vegetation also leads to increased surface available for periphytic algae (micro-algae that attached to surfaces) increases, thus leading to an increased nutrient competition between phytoplankton (micro-algae that floats in the water column) and periphytic algae*[15].

Submerged macrophytes (aquatic vegetation) *are crucial for the stabilization of the clear water state in shallow, mesotrophic and eutrophic lakes. Especially, charophytes* (Stoneworts) *often play an important role because they are typically rapid colonizers and because charophyte meadows are believed to have a particularly strong positive effect on water transparency compared to other macrophytes.*

Firstly, macrophytes are themselves part of the food web, and compete for nutrients and other resources with phytoplankton (micro-algae that floats in the water column) *and periphyton* (micro-algae that attached to surfaces). *Furthermore, the conditions inside macrophyte beds may increase denitrification, contributing to a decreased availability of nitrogen for phytoplankton growth. Secondly, macrophytes provide structure and shelter for organisms; they are inhabited by very specific communities of periphyton and plant-associated invertebrates and provide a spatial refuge against predators for zooplankton. Thirdly, submerged macrophytes may reduce mixing of the water column inhibiting sediment resuspension and erosion.*

In nutrient-rich systems, macrophytes may promote phosphorus release from the sediment for example due to enhanced pH, caused by high photosynthetic activity.[16]

[14] Viaroli P., Bartoli, Fumagalli and Giordani (1997) *Relationship between benthic fluxes and Macrophyte cover in a shallow brackish lagoon.* Water, Air and Soil Pollution **99** 533-540*,* The Netherlands

[15] Strand, John A. (1999) The development of submerged macrophytes in Lake Ringsjön after biomanipulation Hydrobiologia 404: 113–121, 1999.

[16] van Donk, Ellen, and Wouter J. van de Bund (2002) Impact of submerged macrophytes including charophytes on phyto- and zooplankton communities: allelopathy versus other mechanisms Aquatic Botany 72 (2002) 261–274

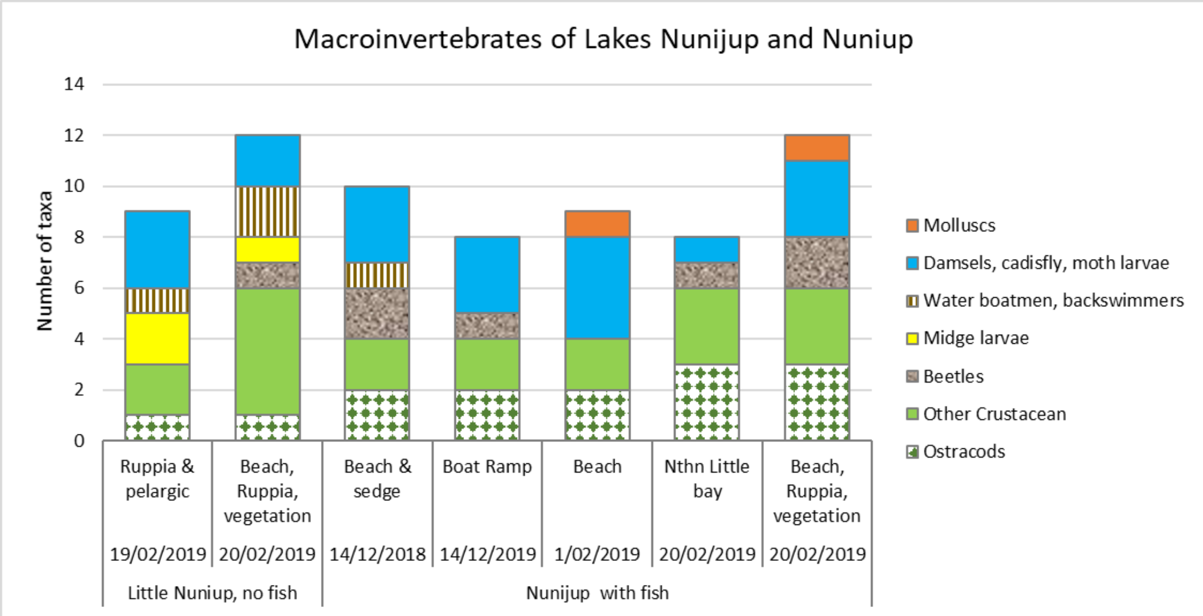

Figure 10: Differences in macroinvertebrate diversity between the two lakes at different times and in different habitats.

One of the initial questions was; *Are the macroinvertebrate populations uniform around the lakes?* Both lakes are quite large and in a strong wind, a circulating current can develop with the surface water moving downwind and the deeper water circulating back. When there are many pelagic (inhabiting the water column) macroinvertebrates, they can be swept to the downwind side of the lake. On 19th February 2019, sampling for the pelagic macroinvertebrates was done at various locations but none were found. There were no significant differences in the presence of other crustaceans and insects amongst the Ruppia and foxtail stonewort meadows at various locations around the lake.

Between the two lakes there were 22 species collected with 17 species collected in Nunijup and 15 species in Little Nuniup. Most of the macroinvertebrates are tolerant of fresh to moderate levels of salinity. There were only two ostracods (seed shrimp) that are mainly salt-water crustaceans. This would be consistent with both lakes being secondarily salinised systems. The salt loving ostracods may have 'hitched' a ride to the lakes in the feathers of waterbirds.

The dominant insects were the damselfly larvae from three species which were more numerous in December than in February. These larvae are predators, feeding on the numerous ostracods and other invertebrates. The large green seed shrimp, *Mytilocypris ambiguosa* were also numerous across the whole lake. They are omnivores, feeding on periphyton (micro-algae attached to the Ruppia) and detritus.

Figure 11: The dominant species were the damselfly larvae from three species and the large green seed shrimp (Ostracod).

Of interest is the Pond Moth caterpillar (*Hygraula nitens*) which is aquatic, feeding on the Ruppia. They make a protective covering using lengths of Ruppia stems and leaves held together with silk. The caterpillar has branching gills on each segment to enable it to breath.

Figure 12: Aquatic larvae of the Pond Moth *Hygraula nitens*.

Macroinvertebrates form an important component of shallow lake ecosystems; they are important as detritus decomposers, grazers and predators and constitute a food source for birds.

Bird Observations

Bird observations on wetlands by Bruce Buchanan was reported in the September 200 edition of Quarterly Newsletter of Birds Australia Western Australia Inc (a division of Royal Australasian Ornithologists Union). It included Little Nuniup Lake –"*While not expecting much from a 'crater' and water-ski lake, as we were passing we visited. It was a pleasant surprise to observe Blue-billed Duck 29, Hoary-headed Grebe 1, Great Crested Grebe 7 (including 2 immatures loudly pursuing an adult for food), Musk Duck 8, Australian Shelduck 6, Little Black Cormorant 18, Great Egret 1, Silver Gull 8."*

Bird counts for Lake Nunijup and Little Nuniup were conducted by Brad Kneebone on 11th February 2019. All observations and counts were by Telescope from the Shoreline. His observations are listed in Table 1. After the bird survey, a number of questions were posed regarding the lake and its use by the variety of waterbirds. Brad Kneebone has commented against these questions before the ecological investigation (in italics below) and I add to these comments based on observations from the ecological investigation.

While canoeing on Little Nuniup Lake (19th February 2019) there was a large flock (over 50) of Pink-eared ducks which flew off and circled the lake with a characteristic whistled tweeting. A solitary Spoonbill was observed at the same time.

Table 1: Bird counts were conducted by Brad Kneebone on 11th February 2019.

	Water bird feeding guild	Lake Nunijup	Little Nuniup Lake
Black Swan	herbivore	88	36
Australian Shelduck	herbivore	*3	4
Eurasian Coot	specialist	1140	269
Australasian Shoveler	Filter feeder	*4	2
Pink-eared Duck #	Filter feeder		8
Grey Teal	dabbler	*60	16
Chestnut Teal	dabbler	*3	2
Pacific Black Duck	dabbler	*4	
Blue-billed Duck	diver		3
Musk Duck	diver	*15	3
Hoary-Headed Grebe	diver	*17	68
Little Black Cormorant	piscivore	3	
Little Pied Cormorant	piscivore	2	
White-faced Heron	generalist	2	1
Spoonbill #			1
TOTAL No. individuals		1341	411
Total No. species		**12**	**11**

Notes for Lake Nunijup

Water level high (95%) Swan, coot actively feeding on aquatic submerged plant/s. *Indicates feeding/roosting in far western arm of lake

Birds only found in Lake Nunijup

Notes for Little Nuniup Lake

Most species well distributed over lake area. Pink-Eared Duck in southern wing. Blue billed Duck around centre (Listed Threatened Species i.e. "Vulnerable")

Birds only found in Little Nuniup Lake

Why are so many birds using the lakes at this time?

Brad Kneebone's comment *"Two most likely reasons; One being the distribution and abundance of the aquatic plants (didn't identify these) as a food source. Second, birds can aggregate in numbers when other wetland habitats dry or decline to the point where the water quality is unsuitable. For these two lakes it is fortunate that as well as having relatively high-water levels as a refuge in dry conditions they also have the necessary food sources at this time."*

Other lakes in the region were either dry (Martagallup Lake) or had low water levels and more saline (Lake Poorarecup). This would support Brad's comments.

What different food sources are the individual species likely to be feeding on in the lakes?

Brad Kneebone's comment *"Primarily the plant matter itself is the food source for the mainly vegetarian Swan, Coot, Black Duck, Shoveler and Teal. With the plant matter will come the invertebrates e.g. water beetles etc and vertebrates e.g. small fish, frogs, though some of these would be present in the water column and the benthic without the plant matter which are the preferred food for the diving ducks Musk Duck, Blue-billed Duck and the Cormorants. To this can be added the crustaceans and molluscs for the divers."*

There was plenty of food for the grazing and dabbling waterbirds in the Ruppia and Foxtail Stonewort. There was also an abundance of larger macroinvertebrates in the damselfly larvae and the large seed shrimp (Ostracods).

No frogs were observed. There may be tadpoles during and after winter when fresh water would be present in areas around the lake, however the salinity level of the lake itself would rarely be low enough for frogs in this region.

The introduced mosquito fish (*Gambusia holbrookii*) was only found in Lake Nunijup which would account for the presence of cormorants only in Nunijup and the higher numbers of Musk Duck in Nunijup.

The Blue-billed Duck is shy and secretive and could have been disturbed by the presence of ski boats and other lake users most weekends over summer hence it's preference for the quieter Little Nuniup Lake.

Why in particular so many Eurasian Coots and Black Swan on both lakes?

Brad Kneebone's comment *"The first two replies above provide the obvious reasons for these two species. We observed some busy feeding activity from these species in particular. There may be some other factor to attract those numbers e.g. if the plant matter was at a specific stage of growth and/or carried seed which would be more nutritious and more attractive".*

As Brad commented, there was an abundance of aquatic vegetation for these birds.

The Foxtail stonewort frequently develops spherical bulbils (starch-filled cells) on their rhizoidal filaments (spreading root like structures), which are the main form of vegetative reproduction in permanent waterbodies such as these two lakes. The bulbils are an attractive and nutritious food for the coots, swans and other diving birds.

Ruppia spp. produce rhizomes and vegetative propagules (turions) which are eaten by waterbirds but not starchy bulbils. Their seed are eaten along with the rest of the plant however they are resistant to digestion and are defecated promoting plant dispersal[17].

Why does the Little Nuniup Lake have Pink Eared and Blue Billed Ducks while Lake Nunijup doesn't?

Brad Kneebone's comment *"Could be food source differences from Nunijup e.g. plant growth stage. Plant matter on Little Nuniup was more obvious at surface and emergent in parts, perhaps accessibility. There can be easy interchange between these lakes for the birds, these two species (or others) could have been on Nunijup the day before or tomorrow if there are not very distinct differences in food supply and water quality. Another point, Nuniup was more protected from the wind on that day than Nunijup which was quite choppy away from the shoreline That can be important for birds if all other things are similar*."

As mentioned earlier, the Blue-billed Duck is shy and secretive and could have been disturbed by the presence of ski boats and other lake users most weekends over summer hence it's preference for the quieter Little Nuniup Lake.

The Pink-eared duck may also be shy and secretive. When canoeing over Little Nuniup Lake to conduct bathymetry, the large flock of Pink-eared ducks were the first to fly, calling with their characteristic whistled tweets.

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[17] Charalambidou, I., L. Santamaria and O. Langevoord (2003) *Effect of ingestion by five avian dispersers on the retention time, retrieval and germination of Ruppia maritima seeds.* Functional Ecology 2003 17, 747–753 © 2003 British Ecological Society Blackwell Publishing Ltd.

Why does the Little Nuniup Lake have more Hoary-Headed Grebe than Lake Nunijup?

Brad Kneebone's comment *"These are not vegetarians, there food source of invertebrates, small fish and frogs may be more abundant and accessible on Nuniup."*

The invertebrates in Little Nuniup were not more abundant than in Nunijup and there were no fish in Little Nuniup which leaves the question hanging.

Again, it may be a shyness and the regular disturbance by ski boats and visitors to Nunijup that deters them from this lake.

Are there any wetland bird species that should be present but are not? And if so, why not?

Brad Kneebone's comment *"Possibly the Wood Duck just using either lake as a loafing site, but they do prefer farm dams more with short green grass available. Possibly Hardhead as a diver they could easily be expected given the food supply for other divers. So why not? They are simply not that common in that locality or elsewhere for that matter though I would think Nunijup would suit them more given its greater depth."*

Hardheads are nomadic following rains. Although there were the right food sources in abundance in both lakes, it may be that they had migrated further north over the summer months. Their numbers are declining on the east coast and probably in the south-west also.

Crakes and Rails were not observed however these are secretive birds of the water's edge preferring to hide in dense vegetation and reeds. They are most active, feeding at dawn and dusk. The decline in the clumping sedge *Baumea articulata* would see a decline in Crakes and Rails should they have been present.

Management questions.

How would both lakes benefit from substantial planting of fringing low vegetation (sedges etc) to provide cover and food supply?

The State of Australia's Birds 2004: Water, Wetlands and Birds.[18] reported that waterbird diversity increases by 14% with each additional wetland feature, such as:

- Shallow flats, as well as deep pools.
- Old trees and fallen trees in the water and around the wetland.
- Tree cover and dense, shrubby vegetation surrounding and overhanging the water.
- Islands where birds can nest and roost.
- Exclusion of stock from a 40–50 m strip either side of creeks and up to 100 m from farm dams and rivers.

Stuart Halse[19] commented that: It is interesting that some waterbirds can use brackish to hypersaline water bodies. Salinity is not the only cause of changes in the biodiversity values of Wheatbelt wetlands. Clearing of fringing vegetation, eutrophication and other factors have probably affected waterbird and invertebrate use of many Wheatbelt wetlands.[20] These changes can also be influenced by climate change and variability.

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[18] THE STATE OF AUSTRALIA'S BIRDS 2004: Water, Wetlands and Birds. Compiled by Penny Olsen and Michael Weston, Supplement to Wingspan, vol. 14, no. 4, December 2004

[19] Halse, S. A., Williams, M. R., Jaensch, R. P. and Lane, J. A. K. (1993c). *Wetland characteristics and waterbird use of wetlands in South-western Australia.* Wildlife Research 20, 103-126

[20] Cale, DJ et al (2004) *Wetland monitoring in the Wheatbelt of south-west Western Australia: site descriptions, waterbird, aquatic invertebrate and groundwater data.* Conservation Science W. Aust. 5 (1) : 20–135 (2004)

It would appear that fencing to exclude stock and revegetating around both lakes would benefit the waterbirds in providing not only potential food sources but also potentially nesting habitat. The 20% decline in rainfall over the past 30 years attributed to climate change is potentially one of the causes of waterbird decline in south-west wetlands. The choice of vegetation will need to take into account this decline in rainfall and the potential for increasing salinisation.

Would both lakes benefit from installing artificial islands?

The variable water depths of the lake with season and the overall depth of both lakes could make artificial islands either dry or flooded at nesting times. However, anchored floating islands may be beneficial even during high water levels.

The report from "State of Australia's Birds 2004: Water, Wetlands and Birds.[21]" commented on the use of duck nesting boxes attached to poles. Many of our ducks utilise tree hollows for nesting and boxes either attached to adjacent trees or on poles around the edges of the lake could be tested for both lakes.

The locations of both nesting boxes and floating islands would have to be outside the gazetted recreation and skiing areas.

Figure 13: Duck nesting boxes stands high and dry during a drought. Photo by Michael Weston

[21] THE STATE OF AUSTRALIA'S BIRDS 2004: Water, Wetlands and Birds. Compiled by Penny Olsen and Michael Weston, Supplement to Wingspan, vol. 14, no. 4, December 2004

Appendix 1: Macroinvertebrates from Lakes Nunijup and Little Nuniup 2018 - 2019

		Lake Date Site	Little Nuniup 19 Feb 2019 pelagic	Little Nuniup 20 Feb 2019 Students	Nunijup 14 Dec 2018 Beach sedge	Nunijup 14 Dec 2018 Boat Ramp	Nunijup 1 Feb 2019 Beach	Nunijup 20 Feb 2019 Nthn Bay	Nunijup 20 Feb 2019 Beach FRSC
CLASSIFICATION	Taxon	Common name							
Crustaceans									
Amphipoda Chiltoniidae	*Austrochiltonia subtenuis*	Scuds	10	10	10	100	10	100	10
Cladocera Daphniidae	*Daphnia* sp.	water fleas		egg				egg	
Copepoda Calanoida	*Calamoecia* sp. pink metallic	pink copepod				1000		100	100
Copepoda Calanoida	*Calanoid* sp.	Copepods		10	100				
Copepoda Cyclopoidea	*Cyclopoid* sp.	Copepods		10					
Decapoda Palaemonidae	*Palaemonetes australis*	Glass Shrimp	100	100			100		10
Ostracoda Cyprididae	*Diacypris* sp.	Seed shrimp				100	10	100	1000
Ostracoda Cyprididae	*Mytilocypris ambiguosa*	Giant Ostracod	1000	100	10	100	100	100	100
Ostracoda Cyprididae	*Reticypris* sp.	Seed shrimp			10			10	100
Insects									
Coleoptera Dytiscidae	*Necterosoma penicilatus*	Diving beetles		5	10	1		2	10
Coleoptera Hydrophilidae	*Berosus discolor*	Scavenger Beetle			2				5
Diptera Chironominae	*Tanytarsus barbitarsus*	Midge larvae	10						
Diptera Tanypodinae	*Procladius paludicola*	Midge larvae	2	1					
Hemiptera Corixidae	*Agraptocorixa hirtifrons*	water boatman			1				
Hemiptera Corixidae	*Agraptocorixa parvipunctata*	water boatman		1					
Hemiptera Notonectidae	*Anisops* sp. juvenile	backswimmer	100	100					
Lepidoptera Crambidae	*Hygraula nitens*	Pond Moth	2				10		20
Odonata Lestidae	*Austrolestes alieson* adult	Western Ringtail			1				
Odonata Lestidae	*Austrolestes analis/io* larvae	Slender/Iota Ringtail	10		3	10	10		
Odonata Lestidae	*Austrolestes annulosis*	Blue Ringtail damselfly	10	10		10	10	2	20
Tricoptera Leptoceridae	*Symphitoneura wheeleri*	Caddisfly larvae		10	10	10	1		5
Molluscs									
Gastropoda Pomatiopsidae	*Coxiella* sp.	salt-lake snails					1		1
Fish									
Poeciliidae	*Gambusia holbrookii*	Mosquito fish			10	10	10	10	100
Total			9	12	10	8	9	8	12

Appendix 2: Water Birds dietary and nesting requirements

Information collated from:

- The Michael Morcombe & David Steward eGuide to Australian Birds, and
- Waterbirds of the Canning River, Sercul and Birdlife, November 2013
- Kingsford et al (2010)[22].

Grazing waterfowl

Grazing ducks eat algae, insects and molluscs or by grazing on grasslands.

Black Swan (Cygnus atratus)
Colonial or solitary bird which utilises diverse habitats, lakes, estuaries, rivers, including temporary wetlands. Feeds on aquatic vegetation of shallow waters.

Nest is a large pile of vegetation, largely reeds, in shallow water on an island or floating among reeds or other plants in deeper water.

Australian Shelduck (*Tadorna tadornoides*)
Fresh or brackish lakes, estuaries, dams, flooded paddocks. Largely terrestrial in habits, feeding on pasture and aquatic vegetation obtained in shallow wetlands. Comes frequently to water to loaf, preen.

Nest is a large hollow in a tree, usually high, often some distance from water; rarely on ground.

Eurasian Coot (*Fulica atra*)
Common, occurs widely on wetlands including rivers, lakes, swamps. Also, rarely marine wetlands. Feeds almost entirely on vegetable matter, supplemented with only a few insects, worms and fish. Forages in shallow to deep water where it up-ends or dives for plant material. Nests in wetlands surrounded by water, often building up a heap of water weeds and other vegetation. Nests float.

Filter feeder

Filters using special lamellae (grooves) along the edges of the bill to filter insects, crustaceans and a variety of plants from the water.

Australasian Shoveler (Anas rhynchotis)
Uses a variety of wetlands, prefers large permanent lakes or swamps that have abundant cover. The large bill is used to feed on small creatures filtered from the water. a semi-nocturnal feeder, during the day floats with other ducks far out on open water.

Nest is a depression in the ground, on occasions a log or low hollowed stump. It is usually well concealed being either underneath or surrounded by long grass rushes etc.

Pink Eared Duck (Malacorhynchus membranaceus*)*
Found on shallow open muddy wetlands and temporary floodwaters. Groups work through shallows. Filter feeder of microscopic plants, animals and small seeds.

Flooding may trigger breeding any time of year: nests site over water in a tree hollow on a stump or in the old nest of another waterbird.

[22] Kingsford, R. T, D. A. Roshier and J. L. Porter (2010) Australian waterbirds - time and space travellers in dynamic desert landscapes in *Marine and Freshwater Research*, 2010, 61, 875–884

Dabbling ducks

Dabbling is upending for food in the shallow water and littoral zone. Food includes: Aquatic plants and animals and invertebrates, as well as gastropods and crustaceans.

Chestnut Teal (*Anas castanea*)

Found on wetlands, with preference for salt and brackish coastal estuaries, lakes, salt marshes etc. Feeds mostly at dusk and dawn, dabbling and upending in the shallows. small flocks loaf for much of the day beside the water. Preferred nest site is a tree hollow 6-10m high. Alternatively, it may be on the ground under dense grass near the water's edge.

Grey Teal (*Anas grcilis*)

Lives in varied habitat, uses almost any wetlands, permanent or temporary. In pairs or small to huge flocks: Mainly aquatic, feeds among floating aquatic vegetation usually in the shallows. Highly mobile and opportunistic.

Nests usually in a hollow limb but will nest on ground or in low vegetation.

Pacific Black Duck (*Anas superciliosa*)

utilises almost any and every wetland habitat throughout Aust. Feeds by upending in shallow water for plant or animal food.

Nest sites vary, tree hollows preferred, but will use old nests of other waterbirds.

Diving Ducks

Dives for bottom dwelling animals, invertebrates, plant material, small fish.

Hoary Headed Grebe (Poliocephalus poliocephalus)

Inhabits wetlands including fresh water and estuaries. Usually on large open areas of permanent or temporary water. Prey includes small crayfish, water bugs, dragonflies, spiders, small fish and some water plants.

Nest is a floating platform of water weeds, usually some distance out from shore among sparse reeds or other plants, anchored to and at least partly supported by them.

Blue billed Duck (Oxyura australis*)*

Although endangered in Victoria, the conservation status in WA is secure[23].

Prefers deep densely vegetation freshwater lakes, swamps when breeding, open waters in winter. Dives for plants and insects.

Usually shy and secretive. Female builds in old dense Typha reedbeds where masses of old dead leaves tangle near water level. At times builds into dense thicket or scrub of tee-tree low over water.

Musk Duck (Biziura lobata)

Mostly solitary bird which inhabits lakes and deep swamps with both reeds and open water. Generalist feeder, plankton, small invertebrates, plant material and dives for frogs, gilgies, and insect larvae.

Builds nest into old, dense reed clumps standing in water at least 1m deep. Reeds are bend and trampled to make a water-level platform.

[23] Birdlife Australia (http://www.birdlife.org.au/bird-profile/blue-billed-duck)

Generalist

White faced Heron (Egretta novaehollandiae)
A colonial or solitary bird which may be seen in many habitats, usually in or near shallow wetland, margins of swamps, dams and lakes. Generalist feeders - frogs, insects, small fish and crustaceans found in shallow wetlands or in open grassy areas.

Nests in a tall tree and can be 2-3km from water.

Piscivores

Little Black Cormorant (Phalacrocorax sulcirostris*)*
Most common on inland water. Gregarious, large flocks fish cooperatively. Prefers deep open water greater 1 m, feeding on fish and invertebrates

Colonies tend to be in well-vegetated swamps and lakes, nest on trees standing in water.

Little Pied Cormorant (Microcarbo melanoleucos)
Uses small lakes, dams, swamps etc. Feeds on fish, including introduced fish and invertebrates. Fishes alone but breeds in colonies.

Appendix 3: Selected photos

Note: A short video "Lake Nunijup beneath the surface" can be viewed on YouTube at:
https://www.youtube.com/watch?v=9EfSSicIPBY

Little Nuniup Lake Bathymetry by canoe 19th February 2019

Imagery: Geraldine Janicke

Preparing to take the canoes onto Little Nuniup Lake.

Remnant *Baumea articulata* sedge on the bank.

Sampling for pelagic macroinvertebrates.

Bare bank for part of Little Nuniup Lake.

Little Nuniup Lake Citizen Science Event

Imagery: Basil Schur

Geraldine demonstrating sampling technique and the TAFE students sampling various habitats.

Geraldine explaining to the TAFE students and Citizen Scientists the growth habit of Swan Grass, *Ruppia* sp.

Citizen Scientists and TAFE students picking out macroinvertebrates and learning to identify them.

Lake Nunijup Bathymetry

Imagery: Steve and Geraldine Janicke

Geraldine and Steve using the canoes to measure the depths in Lake Nunijup.

Lake Nunijup Frankland River Primary School Event

Imagery: Geraldine Janicke and Basil Schur

Basil showing students photos of ducks in the area.

Steve explaining about water quality.

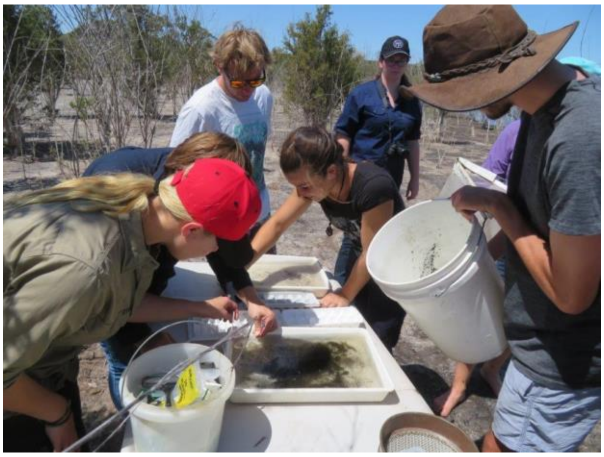
Geraldine pointing out different habitat.

Students finding macroinvertebrates.

TAFE students sampling on Lake Nunijup

Imagery: Basil Schur


Certificate 111 Conservation and Land Management Students from TAFE Albany sampling for macroinvertebrates in the northern bay.




TAFE students picking macroinvertebrates for later identification.