Warperup Creek Water Condition Monitoring

Supplement 4 - Results for 2020 to 2022

Prepared for North Stirlings Pallinup Natural Resources Inc.

By Steve and Geraldine Janicke

Janicke Environmental Investigations

November 2022

This project was supported by funding from the Western Australian Government's State NRM Program.

Warperup Creek Water Condition Monitoring Results for 2020 to 2022

Prepared by Steve and Geraldine Janicke for North Stirlings Pallinup Natural Resources Inc. for part of their Waterways Restoration Project (CSGL19013).

Acknowledgements: The authors would like to thank Stevi Filipowski, Tegan Knowles, Freya Spencer and Kyle Townsend for their facilitation of and keen interest in the project and assistance in the field. We would like to express our appreciation to landholders Anthony Stanich, Emily and Ernie Jaekel, Paul O'Meehan, Fred Duncan, Richard Milne, Brendan Barrows, Freddy Gaze and Louise & Kyle Bailey, who contributed to this study by allowing water condition monitoring sites to be chosen on their properties.

This project was supported by funding from the Western Australian Government's State NRM Program.

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. *Management implications* are not recommendations, but present options for consideration and discussion.

Cover Photo: Geraldine Janicke and Tegan Knowles sampling on the Coromup Creek, site PAL530. *© Janicke*

CONTENTS

INTRODUCTION

The Warperup Creek Water Quality and Biodiversity Monitoring Framework is a component of the State NRM Project: Waterways Restoration (CSGL19013). It consists of two major components, with the following activities:

1. Warperup Creek Water Condition Monitoring (Year 1, 2 & 3)

Aim:

- To establish a selection of sites that reasonably represent the environmental condition of the riparian zone of Warperup Creek.
- To establish a database for collecting water chemistry data over time.
- To assess riparian health along the reaches at the selected sites.
- To provide a resource to track changes in the creek system over time.
- To improve community awareness of the management issues facing the creek and to gauge the effectiveness of management in the long term.

This report *(Warperup Creek Water Condition Monitoring. Supplement 4 - Results for 2020 to 2022)* looks at the monitoring data from the 10 reference sites as collected for the three annual assessments.

2. Warperup Creek Improvement Plan (WCIP) Feasibility Study (Year 2 - 3)

Warperup Creek is a significant tributary of the Pallinup River and passes largely through private land. The fragmented land tenure makes a catchment wide approach to riparian rehabilitation desirable, and any work done by landowners needs to be linked along the entire length of the creek. A Water Condition Improvement Plan (WCIP) requires collating information and raw data to enable an informed assessment of where investment would give the best return in terms of waterway quality and landholder gain. This builds on the investment which has been undertaken since the late 1990s.

This primary project aim was to produce a feasibility study for developing an Improvement Plan for the Warperup Creek through the following activities undertaken in 2020 - 2022:

- Community Survey Questionnaire
- Literature Review
- Aerial Imagery Analysis & Mapping
- Developing a Ground Assessment Approach.

The question posed for this study was; can the Warperup catchment community go beyond what has already been achieved to further improve the ecological condition of the catchment waterways? A reasonable answer will require a clearer and realistic definition of what 'improvement' might mean. This study is reported in the main document titled: *Warperup Creek Improvement Plan Feasibility Study 2022.*

Supplementary documents which should be read in conjunction with this report are:

- Supplement 1 - *Warperup Creek Landholder Survey 2022*
- Supplement 2 - *Warperup Creek Literature Review 2022*
- Supplement 3 - *Warperup Creek Water Condition Monitoring Framework*
- Supplement 4 - *Warperup Creek Water Condition Monitoring Results for 2020 to 2022*
- Supplement 5 – *Warperup Creek Photo Audit*

WARPERUP CREEK

Warperup Creek is a significant tributary of the Pallinup River and extends, as the fish swims, for 72 kilometres from east of the town of Ongerup to its confluence with the Pallinup west of Borden (See Figure 2). A significant storm event in 2017 particularly impacted the middle and lower reaches of Warperup Creek. The quantity of sand dumped along the river corridor implied that erosion and sedimentation risk in the catchment was still high. The banks and beds of the tributaries were thought to be the main sources of sediment with the large amounts already present from earlier floods being added to and transported by intermittent flood events. The authors consider excessive sediment loading to be as great, if not a greater contributor to the poor aquatic condition of the river than the salinity of what is a naturally salty river system, although salinity may have increased. The water quality monitoring component of the project involved visiting 10 sites in Spring of 2020, 2021 and 2022. The timing put certain limitations on how the data could be interpreted but it did provide an initial insight into conditions in the waterways and a basis for future water monitoring.

RAINFALL

Figure 1 shows the rainfall for the nine months leading up to the monitoring which for all three years took place in early to mid-October. Rainfall has a strong influence on water quality readings by influencing groundwater as well as surface water discharge into the waterways. 2021 was a wetter than average year and produced strong flows, and an estimated one in ten-year flood event. There was ample evidence that the sediment within the channel is still being actively reworked and moved downstream even during mild flood events.

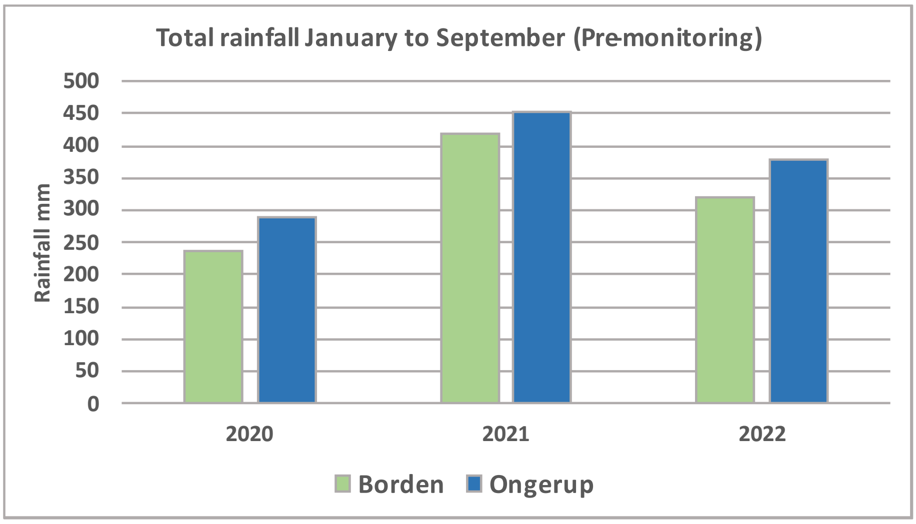


Figure 1: Borden and Ongerup rainfall for 2020, 2021 and 2022 during the nine months prior to water monitoring

MONITORING APPROACH

River monitoring is the regular observation and measurement of various factors that define river condition and how it changes over time. A range of indicators were used to assess condition at the ten reference sites (Figure 2). These were selected to reflect general conditions along the waterways. Six sites along the main trunk of Warperup Creek and four sites on four tributaries were selected. The type of ecological data and methods of collection were chosen to be within the capacity of community members to undertake in the long term without requiring a fixed monitoring schedule, overly expensive equipment nor a high level of scientific expertise.

This provides opportunities for community members to conduct monitoring to track changes in the condition of the riparian vegetation, channel, broad floodway, and aquatic environment. It should be emphasised that to track changes in water condition over time it is essential to take a consistent approach to long-term data collection. This is because natural variability across seasons and from year to year is usually high which tends to mask underlying trends.

Water monitoring sites

The ten *reference reaches* selected in 2020 were revisited in 2021 and 2022 for water quality and macroinvertebrate sampling (See Figure 2). Each reference reach was defined as a 300 to 500-meter length of the floodway and in 2020 each was assessed for riparian vegetation health and river channel features. This data is for longer term comparison and was not reassessed in 2021 and 2022. Water *monitoring sites* were at the lower end of each *reference reach*.

Photo point audit

In 2020, a systematic set of geo-referenced photo points (3 to 5 for each reference reach) was established to capture structural floodway features for longer term comparison. In 2021 only the sampling site photo point was re-photographed, but in 2022 all photo points were repeated to gain a better appreciation of what short-term changes to the floodway might be observed, especially following the much wetter year of 2021.

Water chemistry

Water chemistry was assessed at all sites and where a reference reach included the confluence with a tributary, in situ measurements of salinity, pH and temperature were taken upstream (US) of the confluence, within the tributary and downstream (DS) of the confluence at the primary water sampling site, for comparison with the main trunk of Warperup Creek.

Water chemistry parameters assessed were:

- *In situ measurements:* Salinity-electrical conductivity (EC), pH, temperature, and turbidity. (Meters used: Salinometer, Horiba LaquaTwin EC33 and pH33, turbidity tube). Meters were calibrated prior to the sampling each day and checked during the day.
- *Collected water samples*: Laboratory analysed for Total Nitrogen (TN), Nitrates and Nitrites (NOx-N) and Total Phosphorus (TP). Water samples were collected according to laboratory specifications, kept cool and sent to Analytical Reference Laboratory (WA) Pty Ltd. (Eurofins - ARL Group) for analysis at the conclusion of the field work.

Macroinvertebrate composition

Macroinvertebrate samples were collected at the lower end of each reach. A standard 250-micron D pond net was used to sweep through a 10 to 30 meter stretch of the waterway and included all habitat zones (edge, open water, emergent vegetation). All samples were passed through sieves and placed in white trays for live picking (about 30 minutes with two persons). The main macroinvertebrate groups were identified in the field and abundance estimated. Picked macroinvertebrates were placed in labelled vials and preserved in 75% ethanol and further identified in the laboratory.

Warperup Creek Water Condition Monitoring Results for 2020 to 2022

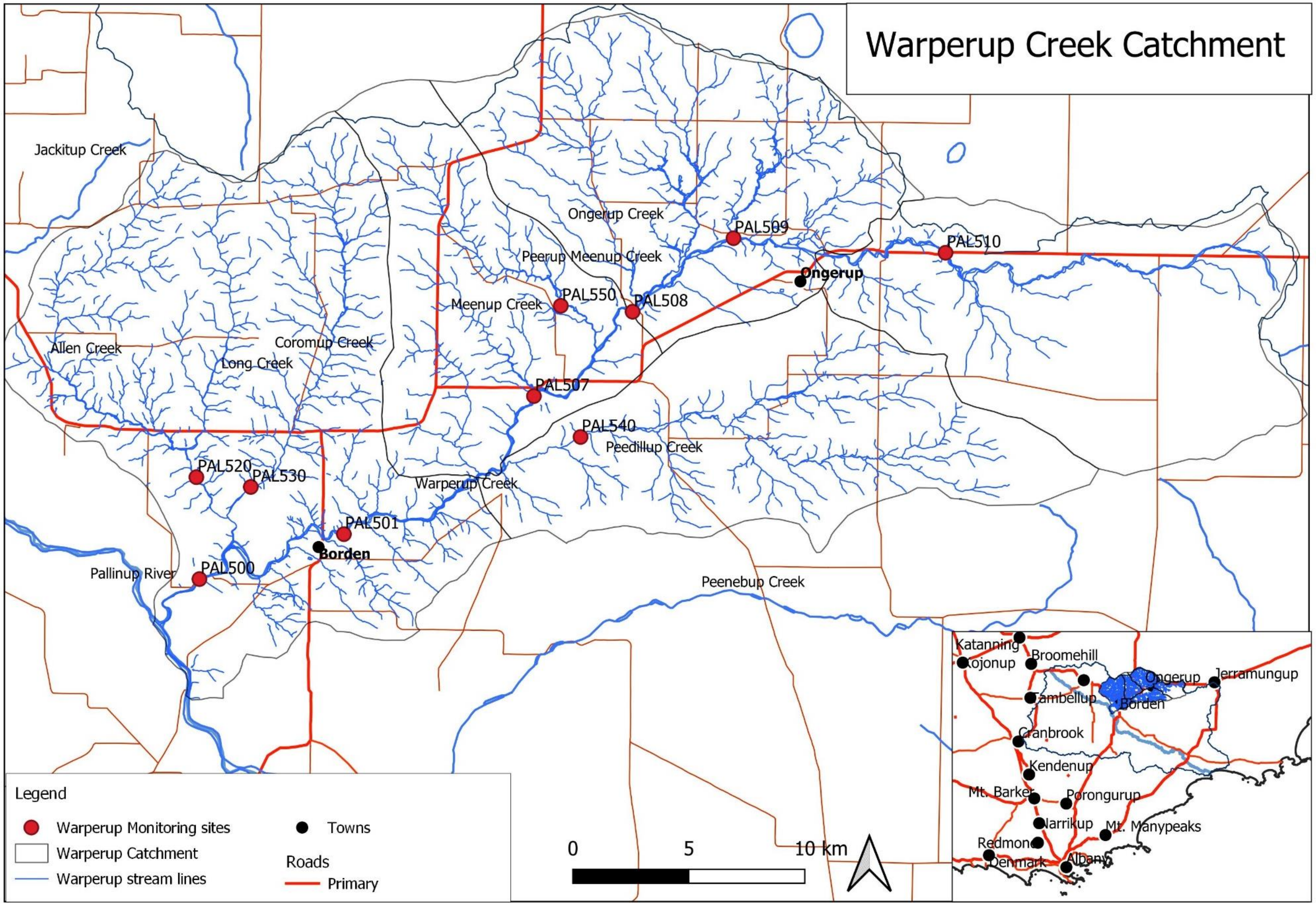


Figure 2: Warperup Creek catchment including minor and major tributaries and the monitoring sites.

Janicke Environmental Investigations

MONITORING RESULTS

Salinity

Between 1998 and 2000, the then Water and Rivers Commission (now the Dept of Water and Environmental Regulation - DWER) conducted regular water sampling at three sites (PAL500, PAL501 and PAL510) on Warperup Creek. This was part of a wider sampling program for the Pallinup River catchment and four other South Cost catchments. The graphs (Figure 3) below show the variation in salinity values which occurred during the 1998-2000 site visits to PAL500 and PAL510, at the lower and top ends of the catchment respectively. There were over 60 sampling occasions for the Warperup, and this clearly reveals how values tend to increase or decrease as seasons progress, due primarily to rainfall, evaporation and groundwater discharge. In addition, specific events such as summer storms can cause rapid changes. A comprehensive water monitoring program would aim to capture seasonal variations.

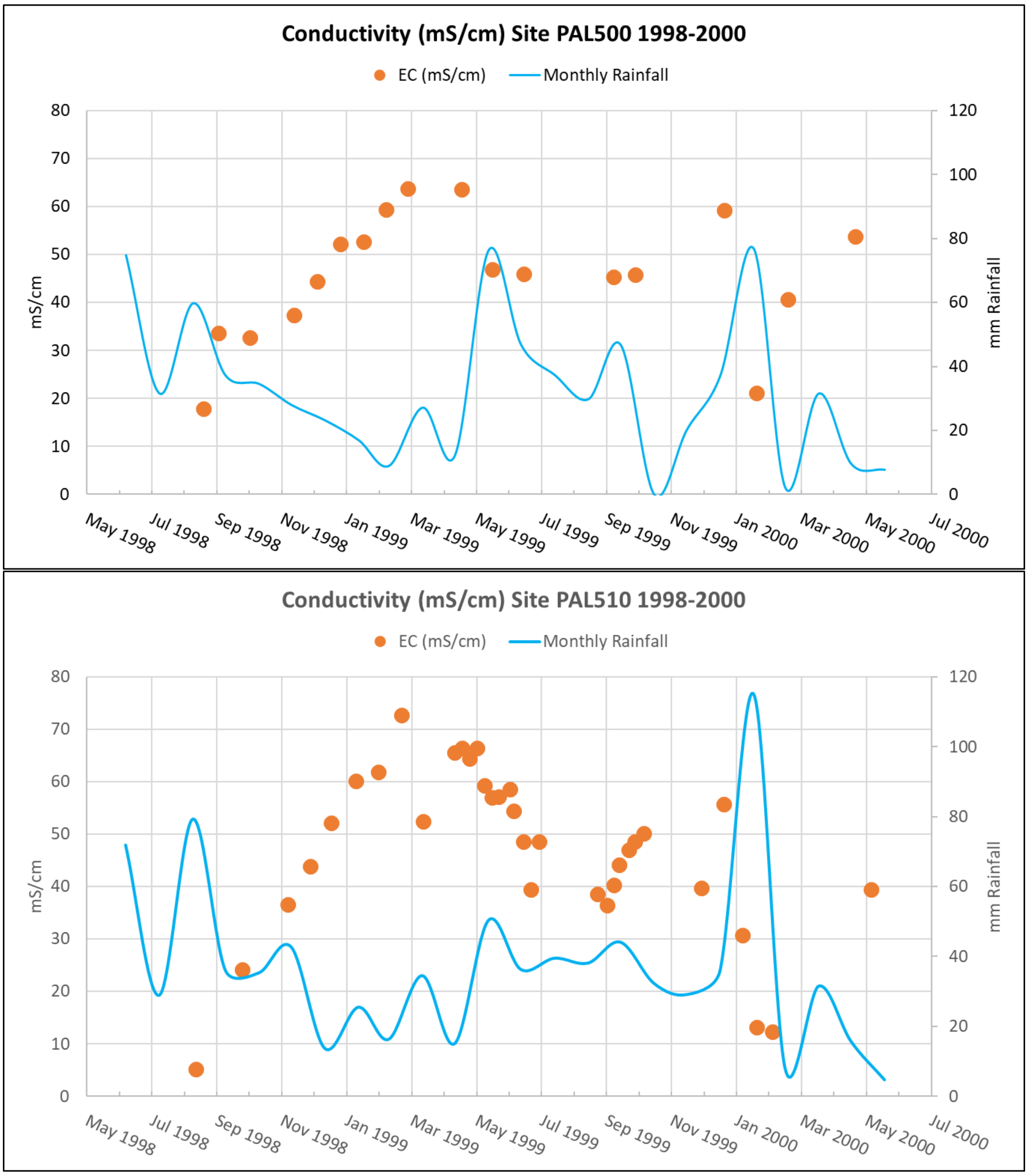


Figure 3: Salinity as measured in electrical conductivity (mS/cm) during 1998 to 2000 sampling program for two sites at the lower and top ends of Warperup Creek. Monthly rainfall over the period is shown as a blue line.

The data collected during 1998-2000 provided an opportunity to compare values with the recent measurements at two of the sites, PAL500 at the lower end of the catchment and PAL510 on the main trunk upstream of Ongerup. Figure 4 gives a pictorial comparison of water quality values, but care should be taken to avoid reading more into the data than is advisable given the low numbers. The obvious features are first, the twenty-year period in which no consistent water monitoring took place and secondly the few measurements made in 2020-22 compared with 1998-2000. The 2020-22 sites were only visited in mid-Spring and for this reason the recent and the 1998-2000 Spring values are both coloured red. Notice that the three more recent measurements are in the same range as their equivalents in 1998-2000. The results give no obvious indications that conditions have changed a great deal in the intervening twenty years. Ideally the 1998-2000 monitoring could be repeated at some stage and the results given to a statistician to determine if there has been a significant change in values at each of the two sites.

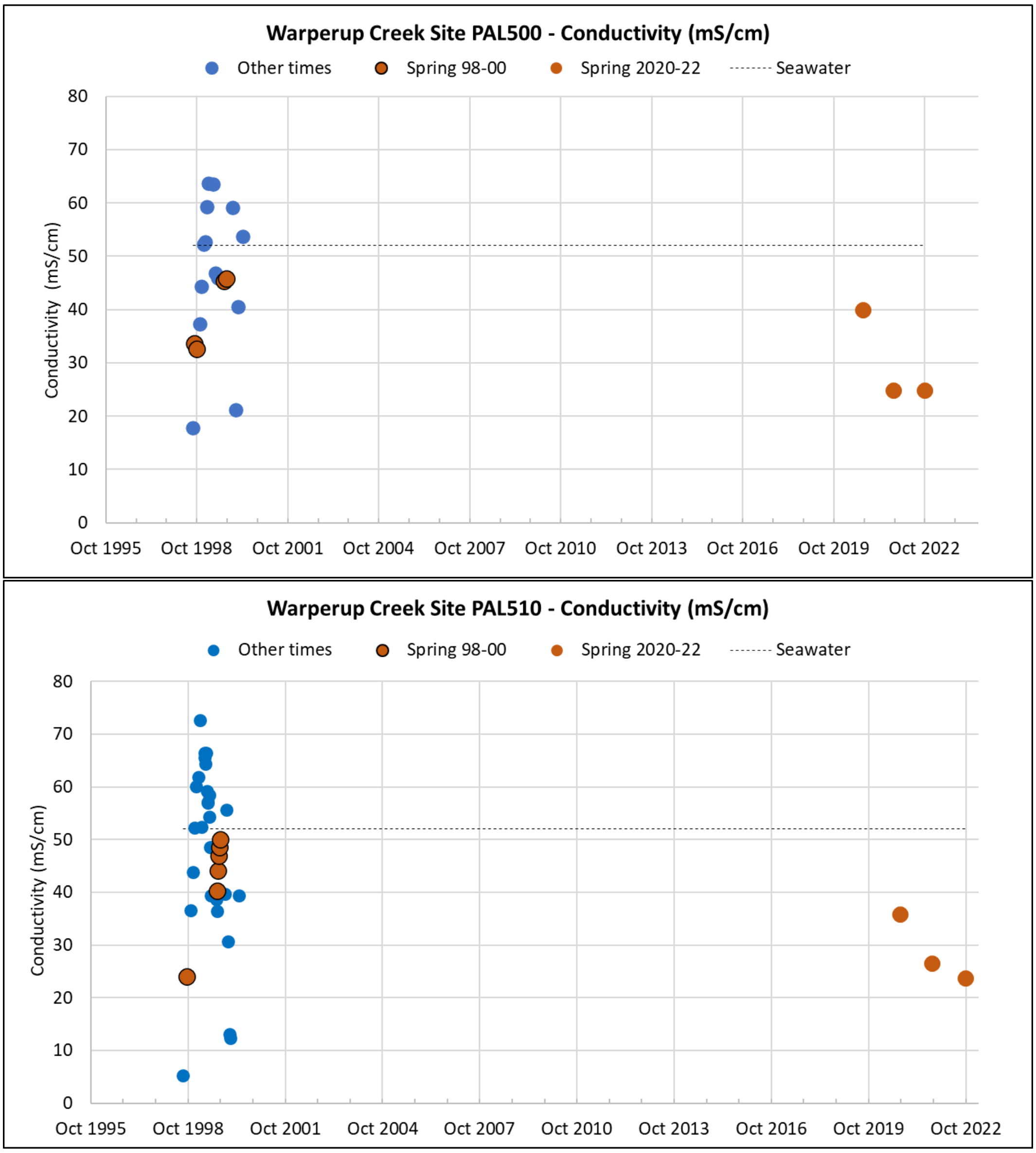


Figure 4: Salinity comparisons between 1998-2000 and 2020-2022 at sites PAL500 and PAL510.

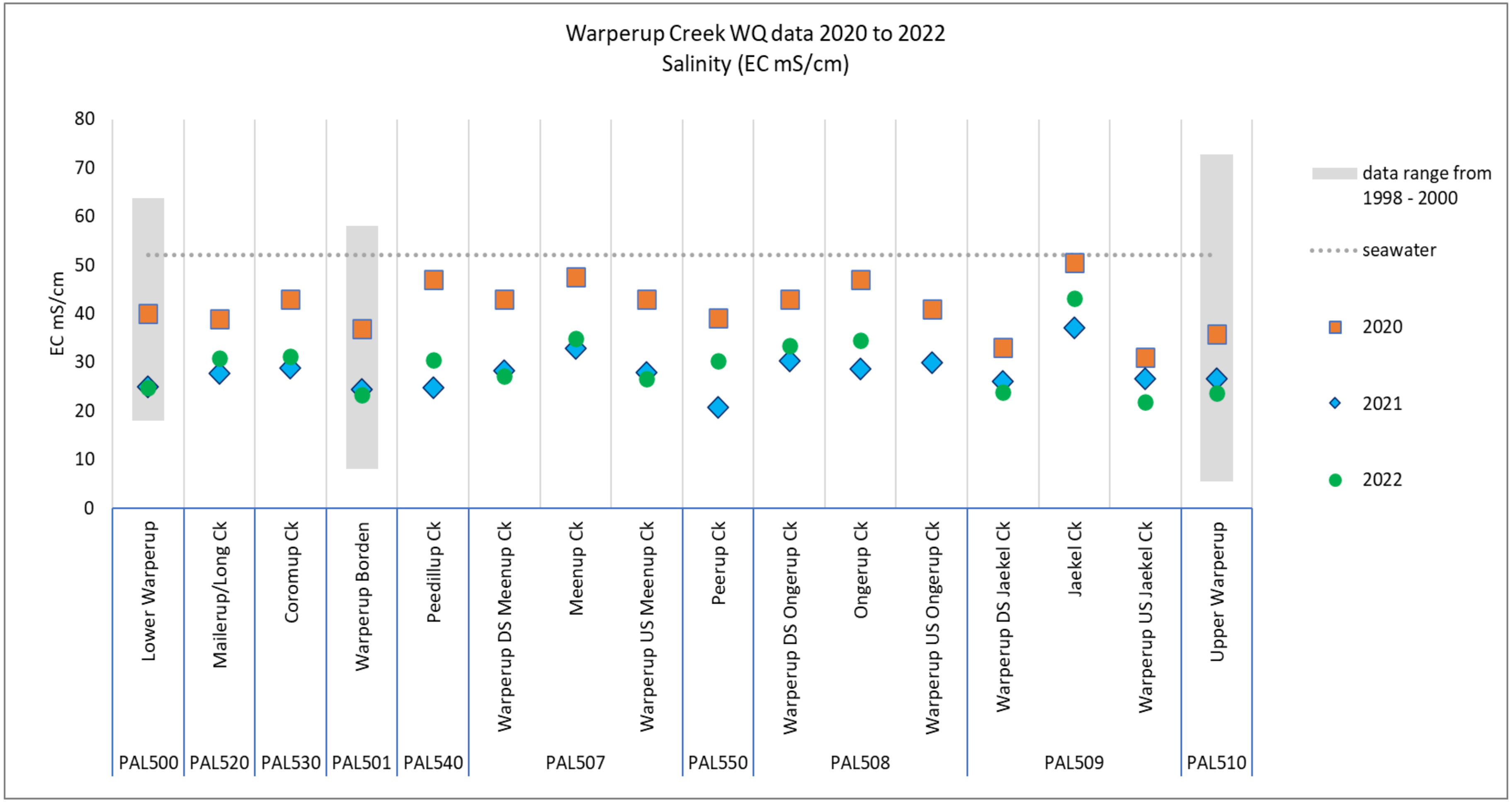


Figure 5: Salinity, as represented by Electrical Conductivity, of Warperup Creek and selected tributaries, October 2020, 2021 & 2022. The data range from sampling three sites between 1998 and 2000 is shown as a grey bar.

Salinity implications

The conductivity results suggest annual rainfall has a strong influence on surface water salinity values in the Warperup catchment. The 2020 spring conductivity values were substantially higher than in the subsequent 2 years. This level of sensitivity confirms conventional hydrographic wisdom that using salinity to detect persistent changes in water quality requires data to be gathered over a long period of time. This would be true for demonstrating improvements due to management initiatives. In addition, the variability revealed in the 1998-2000 data suggests that seasonal monitoring would be required. For example, a minimum of 3 sampling events per year would be more adequate rather than one. Although the 2020-2022 data shows lower values than for spring 1998-2000 the small number of values cannot reliably be assumed to reveal a decrease in general salinity levels.

Overall, conductivity appears remarkably similar along the length of the main trunk of Warperup Creek and in the sub-catchments at the time of the 2020-2022 monitoring. Variations were within a relatively tight range. This may say something about the geological foundation of the creek system and the nature of the groundwater system, but clarification of these influences would warrant further investigations.

The conductivity results indicate that salinity levels can vary more over time (temporally) than between sites in the catchment (spatially). The implication is that the ten water monitoring sites paint a reasonable picture of water salinity in the waterway system and future monitoing may reasonably require a lesser number of sites to be visited in any one year, at least on the main trunk.

pH data

pH is measured on a scale from 0 to 14 with values below 7 referred to as *acidic* and above 7 are referred to as *basic* or *alkaline* and pH 7 being considered neutral. The pH values tell us what sort of chemical reactions may or may not take place in the water. Generally, the saline rivers on the south coast of WA are basic with a pH above 7.5.

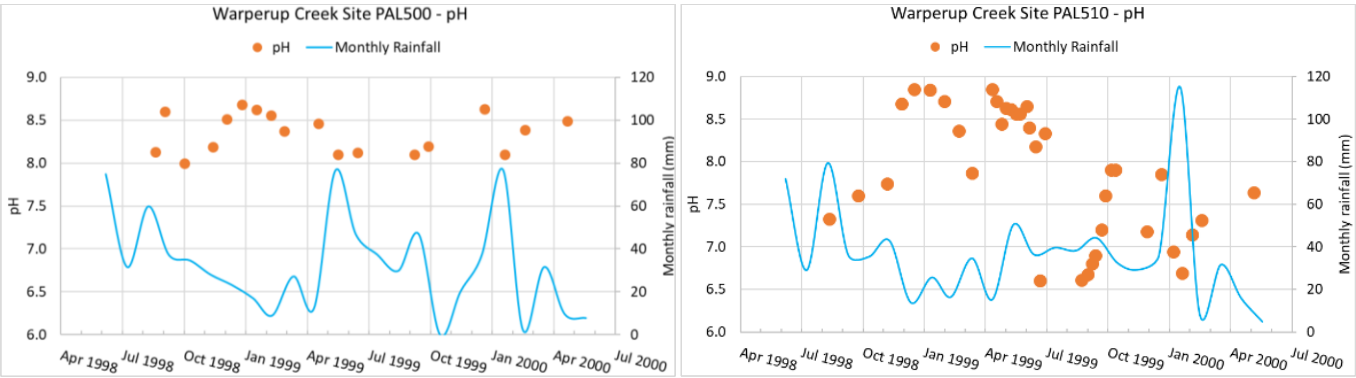


Figure 6: pH during the 1998 to 2000 sampling program for two sites at the lower and top ends of Warperup Creek. Monthly rainfall over the period is shown as a blue line.

The pH data collected during 1998-2000 shows that the upstream pool at Site PAL510 recorded variable pH values including slightly acidic water (down to 6.6) whereas PAL500 remained consistently alkaline (Figure 6).

Figure 7 shows the comparison between the two sampling projects. The recent and the 1998-2000 Spring values are both coloured red. At both sites the recent values are generally lower than the 1998-2000 Spring values. However no reliable conclusion can be made regarding a trend in pH over the twenty-two-years from 1999 to 2022.

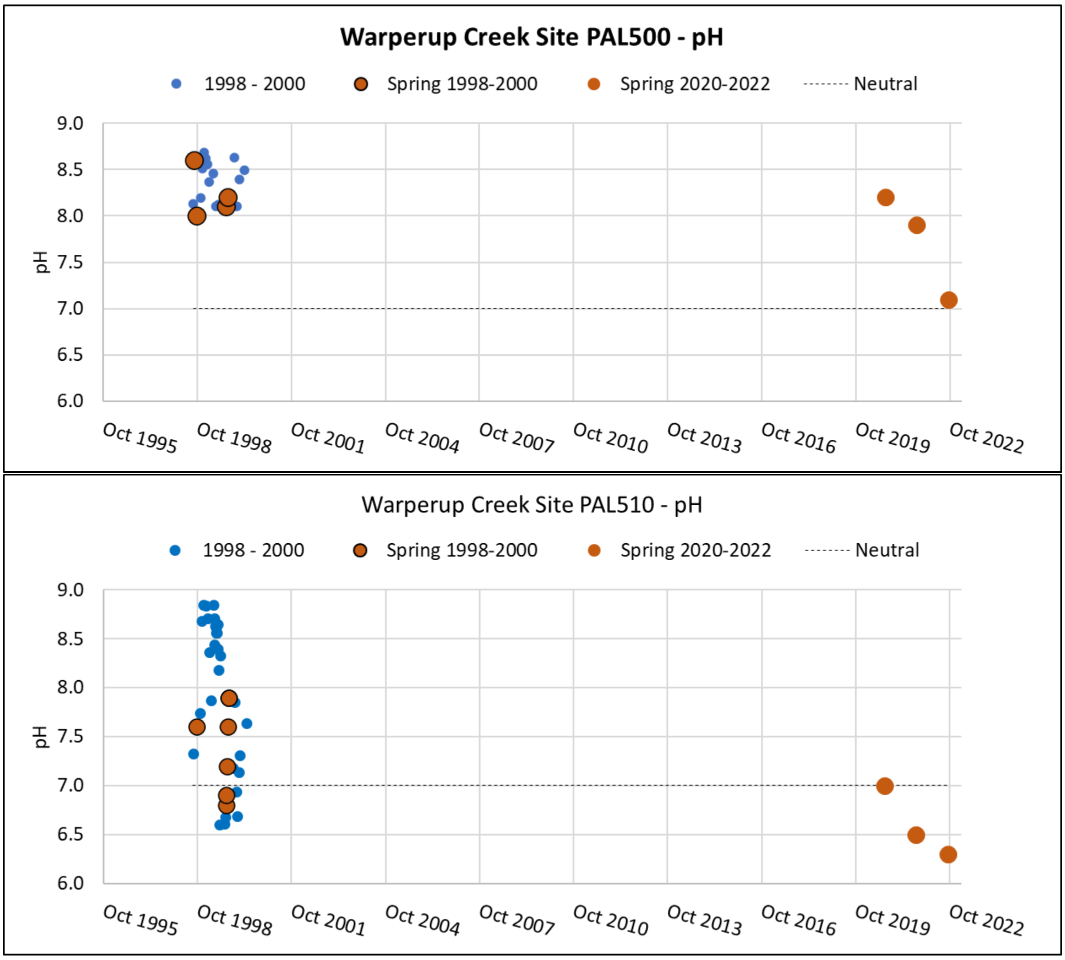


Figure 7: pH comparisons between 1998-2000 and 2020-2022 at sites PAL500 and PAL510.

Figure 8 shows the pH values at the reference reaches for 2020 to 2022. During the 2020 and 2021 sampling events, the upstream pool was more acidic and in 2020, the influence appeared to extend down to site PAL509, at the confluence with Jaekel Creek.

The 2020-2022 pH values from the upper Warperup catchment were tending slightly to the acidic indicating that there is potential for further acidification of the waters although the degree of risk is uncertain. The 1998-1999 values varied considerably across the seasons suggesting a dependency on seasonal and even weekly rainfall. The lack of data post 1999 shows the deficiencies of conducting water quality monitoring in an inconsistent way over time. If consistent low level annual monitoring is not feasible, there is, as mentioned for salinity, a case for conducting another short term (2 to 3 year) seasonal monitoring program to collect data to compare with the 1998-1999 values at the PAL500 and PAL510 sites. If a trend is suspected, routine monitoring can be undertaken.

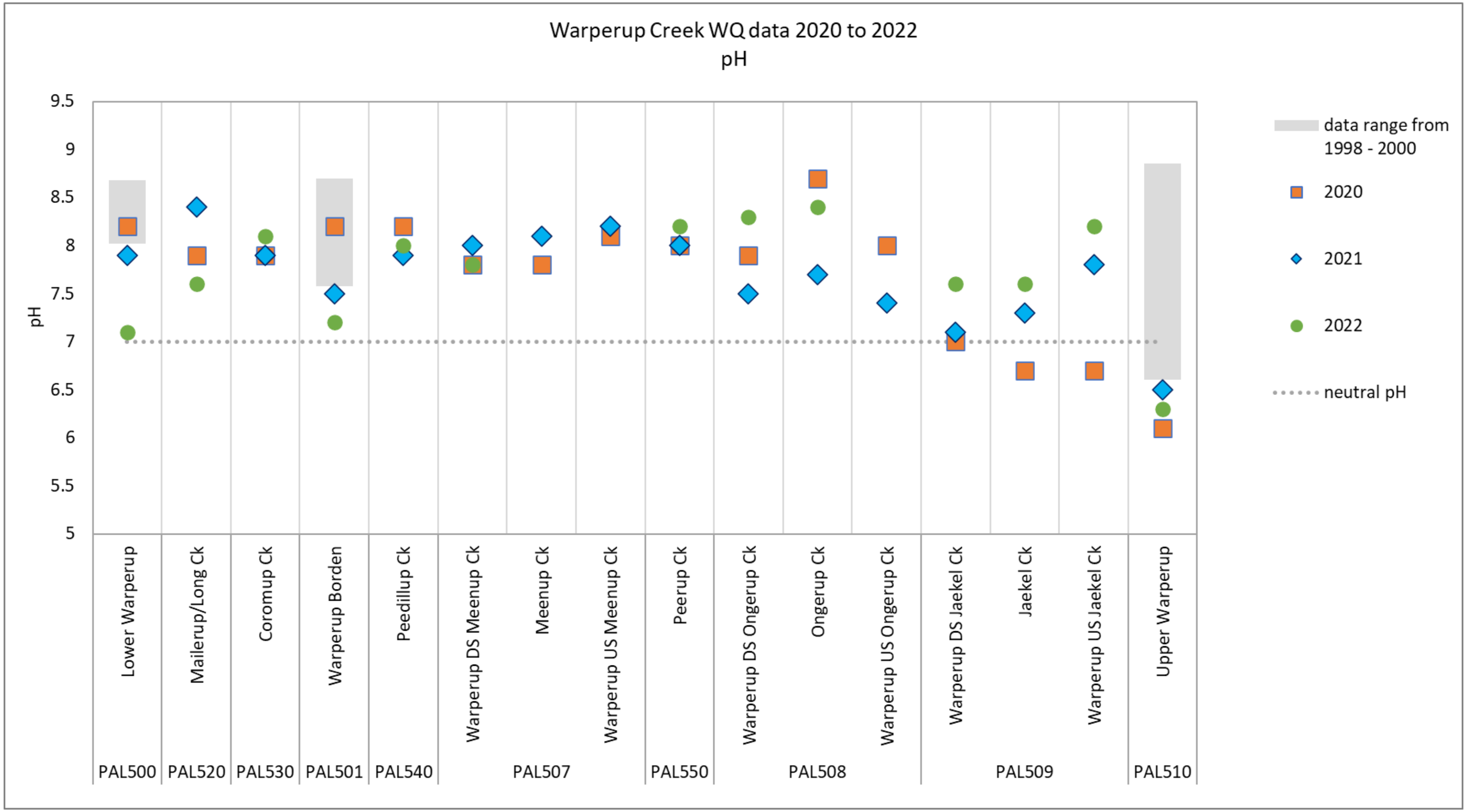
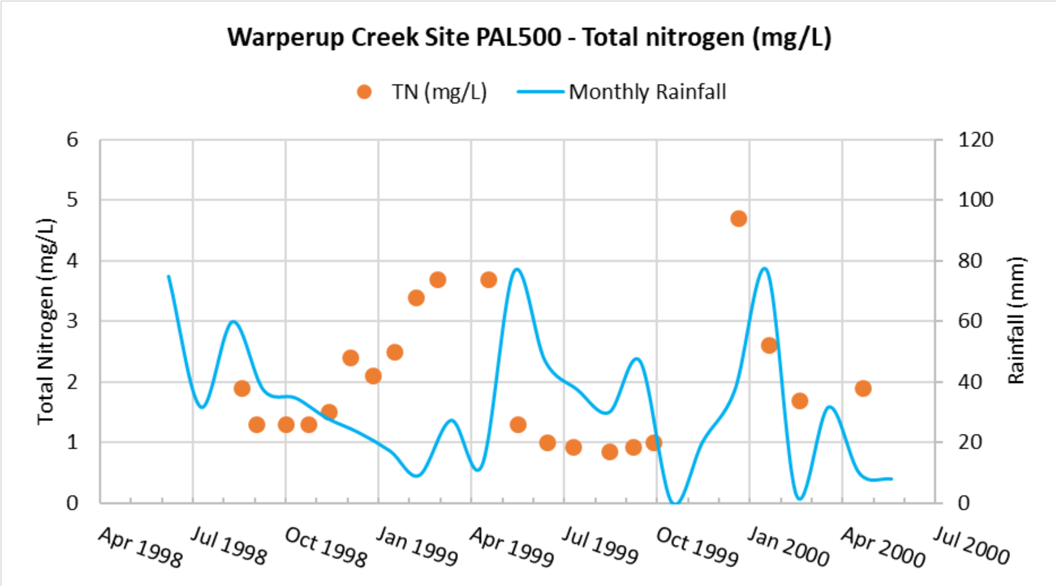


Figure 8: The pH of Warperup Creek and selected tributaries for 2020 to 2022. The data range from sampling three sites between 1998 and 2000 is shown as a grey bar.

Nitrogen

Total nitrogen consists of both dissolved mineral and organic forms of nitrogen. Nitrogen compounds are mostly quite soluble in water and for that reason are mobile in the landscape. Water samples were analysed for Total Nitrogen as an indicator of nutrient status at the reference reaches. Dissolved Inorganic Nitrogen (DIN) is mostly nitrates and nitrites (NOx-N), but also includes ammonia and dissolved molecular nitrogen gas (N_2). DIN infiltrates readily into groundwater and can be an important nitrogen source when surface flows decline. Nitrate fuels spring and summer phytoplankton and algal blooms.



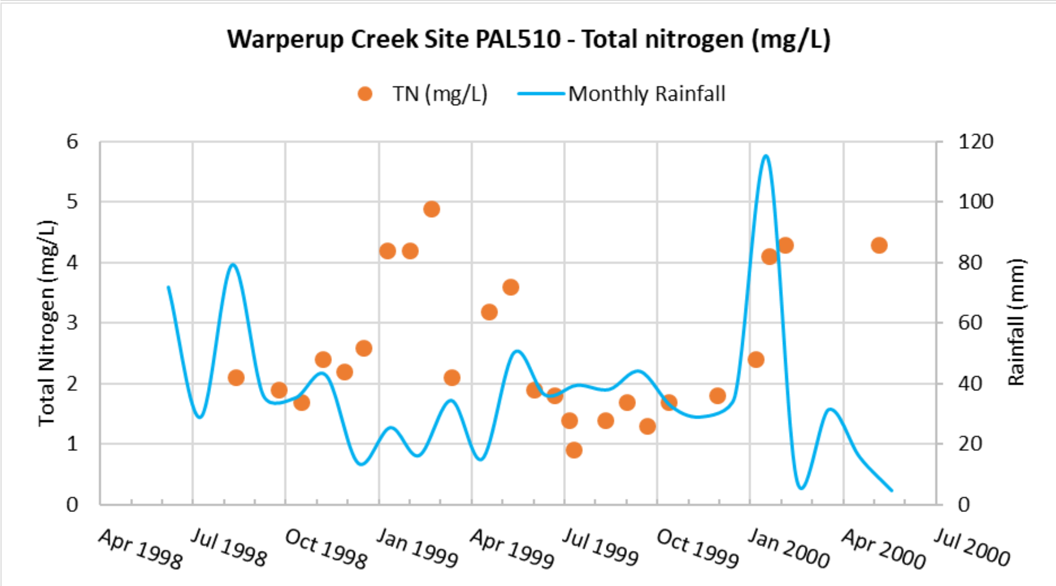


Figure 9: Total nitrogen values during the 1998 to 2000 sampling program for two sites at the lower and top ends of Warperup Creek. Monthly rainfall over the period is shown as a blue line.

Figure 9 shows that there was a strong seasonal relationship of increasing nitrogen values over summer and autumn during the 1998 to 2000 sampling program. These high values are often reflected by increased algal production in the creeks over this time.

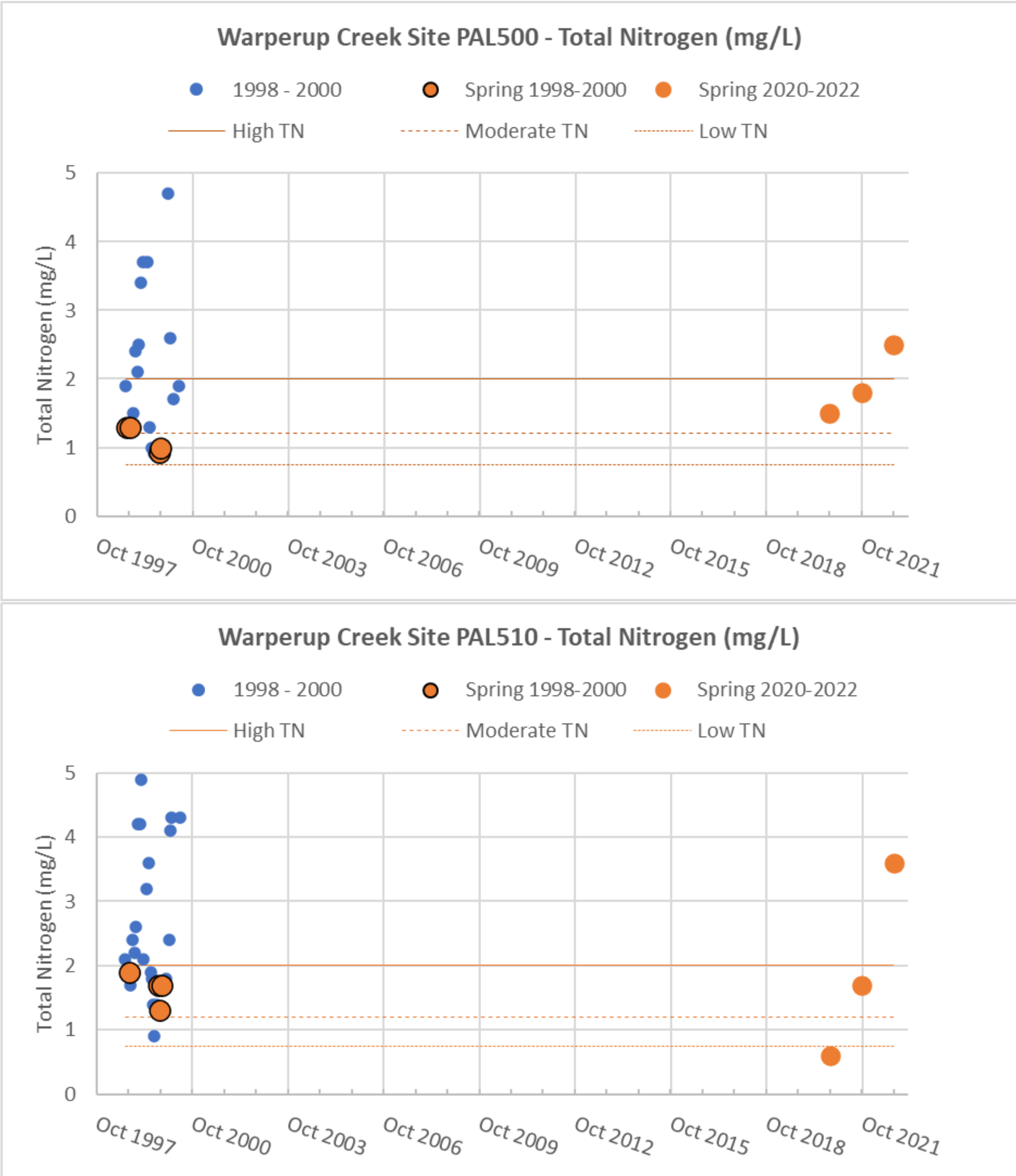


Figure 10: Total Nitrogen comparisons between 1998-2000 and 2020-2022 at sites PAL500 and PAL510.

Figure 10 shows the comparison between the two sampling projects with the spring values coloured red. Notice that the three more recent measurements cover a broader range than during spring in 1998-2000, with the highest values this year (2022). Without data from the twenty-year period in which no consistent water monitoring took place it is inadvisable to assume a trend or otherwise.

Figure 11 shows the Total Nitrogen (TN) of Warperup Creek and selected tributaries for October 2020 to 2022. The values from 2021 and 2022 are high to moderately high for rivers in the south west of Western Australia. Values of TN that considered low, moderate, and high were taken from the Department of Water and Environmental Regulation FARWH Report No. 39[1]. The high nitrogen values promote algal growth in the waterway and a reduction in aquatic biodiversity.

[1] Storer, T, White, G, Galvin, L, O'Neill K, van Looij, E & Kitsios, A 2011, The Framework for the Assessment of River and Wetland Health (**FARWH**) for flowing rivers of south-west Western Australia: project summary and results, Final report, Water Science Technical Series, **Report No. 39**, Department of Water, Western Australia.

The reason for the higher Total Nitrogen levels in 2022 is unclear, but the variation suggests that seasonal sampling for Nitrogen concentrations may provide a clearer picture of potential nutrient impacts in the waterways and how this relates to rainfall and factors such as fertiliser applications.

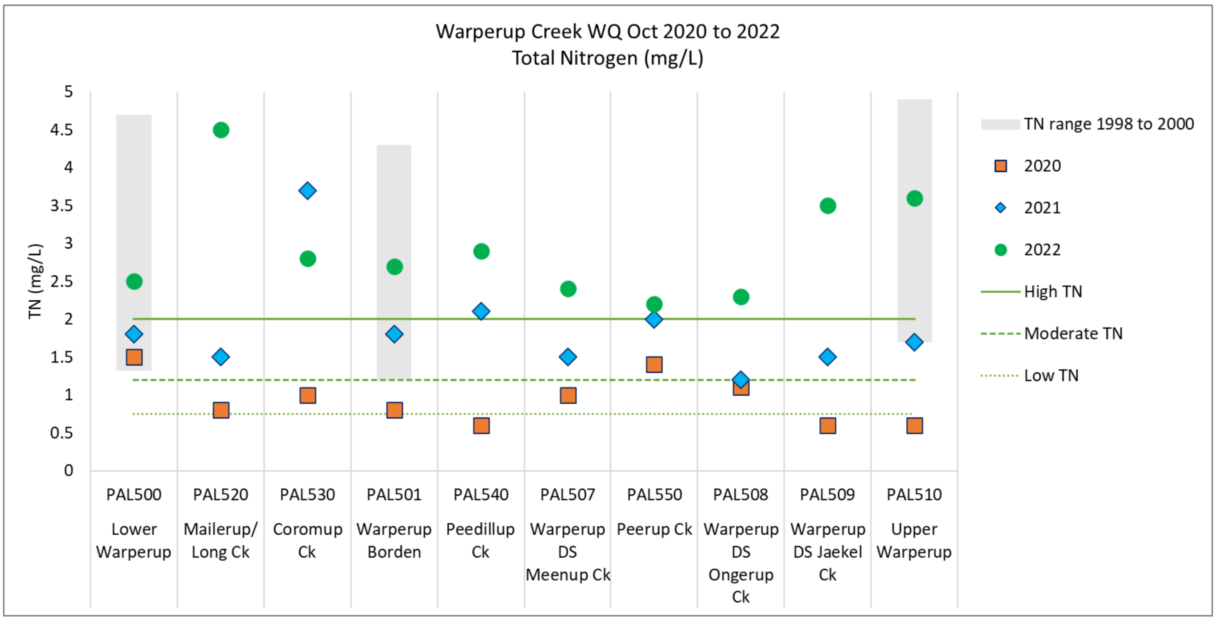


Figure 11: The Total Nitrogen (TN) of Warperup Creek and selected tributaries for October 2020 to 2022. The data range from sampling three sites between 1998 and 2000 is shown as grey bars.

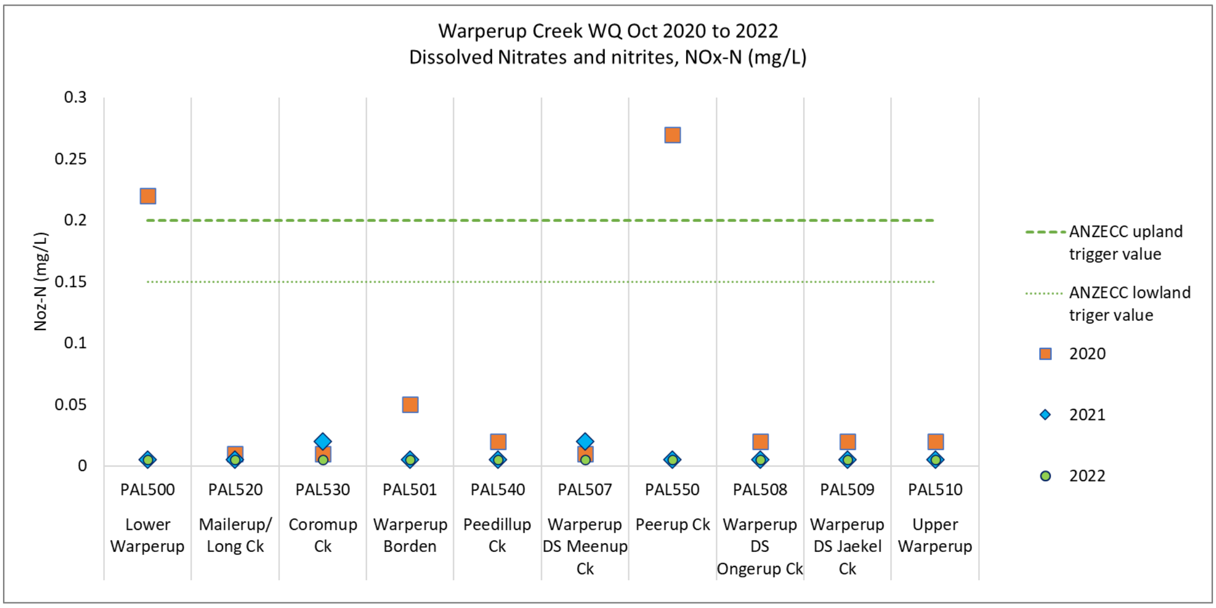


Figure 12: Nitrate and nitrite N (mg/L) in water samples collected from Warperup Creek and tributaries, October 2020 to 2022 and the ANZECC trigger guidelines[2].

Dissolved nitrates and nitrites were very low to not detectable in all sites except for site PAL500 at the lower end of Warperup Creek and site PAL550 on the Peerup Creek. With 2020 being a drier year, more nitrates and nitrites (NOx-N), may possibly have entered the creek through groundwater. Nitrate fuels spring and summer phytoplankton and algal blooms.

---

[2] Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines (October 2000) Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Total Phosphorus

Total Phosphorus (TP) includes both dissolved and particulate forms of phosphorus. Although dissolved orthophosphate (soluble reactive phosphorus) is the form generally available for phytoplankton and algal uptake, phosphorus uptake and turnover rates are fast and total phosphorus is considered a better indicator of eutrophication risk.

Figure 13 shows there was a strong seasonal variation in TP values with the highest values at the end of summer and before the winter rains, i.e., when the stream flow is at its lowest level. It is unknown what caused the two spikes of very high TP in January 1999 and 2000 at PAL500 at the lower end of Warperup Creek. Bureau of Meteorology historical rainfall data for Borden show that there were no rainfall events in the two weeks prior to both sampling events.

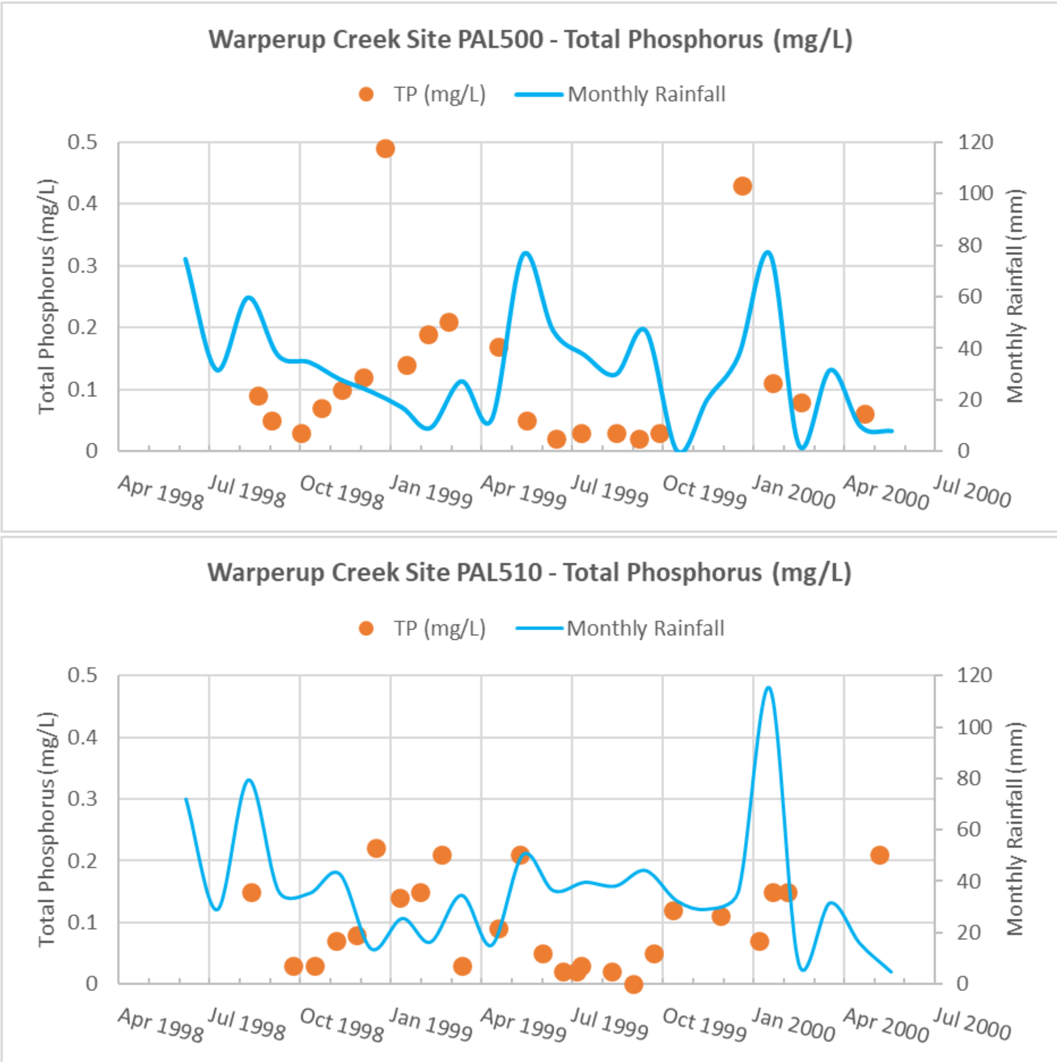
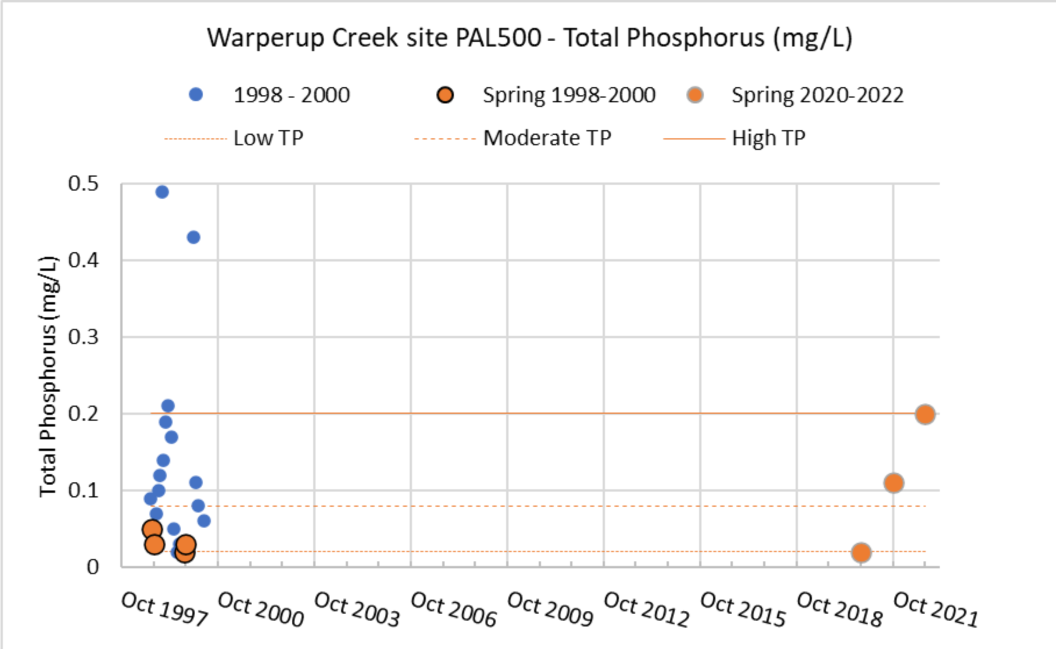


Figure 13: Total Phosphorus values during the 1998 to 2000 sampling program for two sites at the lower and top ends of Warperup Creek. Monthly rainfall over the period is shown as a blue line.

Janicke Environmental Investigations



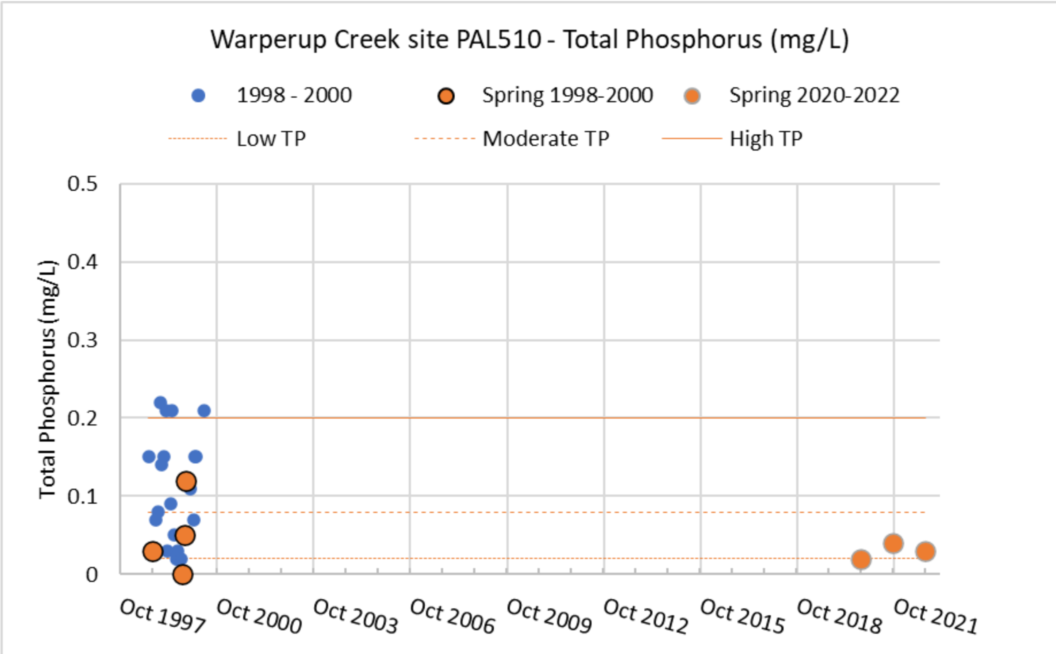


Figure 14: Total Phosphorus comparisons between 1998-2000 and 2020-2022 at sites PAL500 and PAL510.

The above graph shows most of the values for TP between 1998 and 2000 were at low to moderate concentrations with only a few values rated as high concentrations. The values for spring 2020 to 2022 are broadly within the range of historical values.

Low, moderate, and high TP values were taken from FARWH Report No. 39[3] for rivers of south-west Western Australia.

[3] Storer, T, White, G, Galvin, L, O'Neill K, van Looij, E & Kitsios, A 2011, The Framework for the Assessment of River and Wetland Health (**FARWH**) for flowing rivers of south-west Western Australia: project summary and results, Final report, Water Science Technical Series, **Report No. 39**, Department of Water, Western Australia.

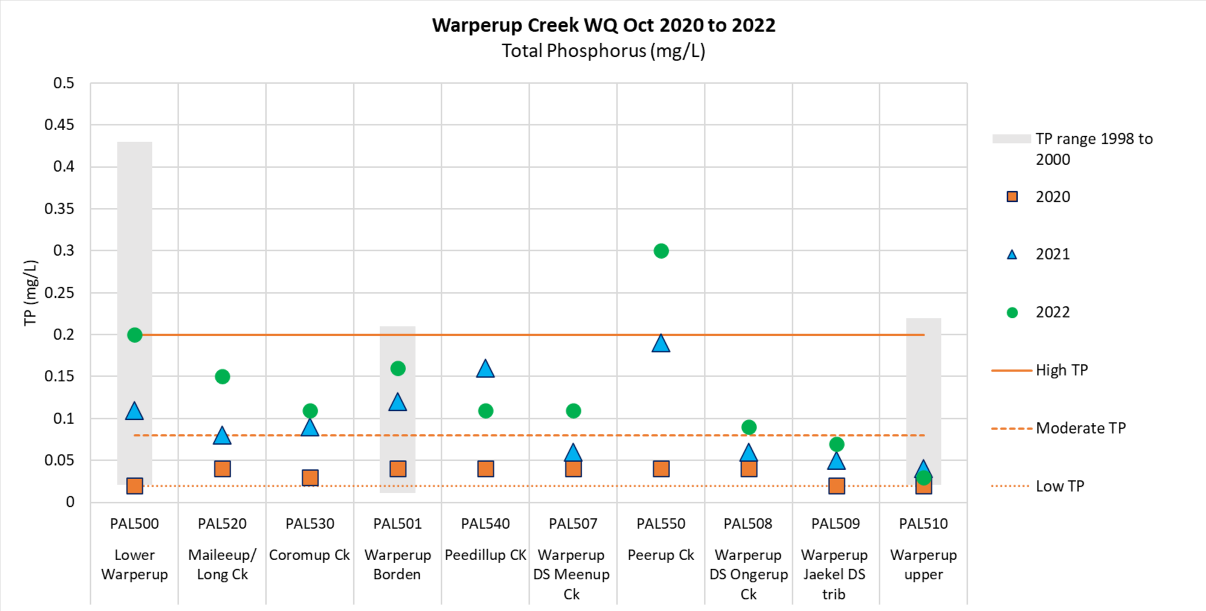


Figure 15: Total Phosphorus (mg/L) in water samples collected from Warperup Creek and tributaries, October 2020 to 2022. The data range from sampling three sites between 1998 and 2000 is shown as grey bars.

Most of the ten reference sites had TP values in the low to moderate range with the last 2021 and 2022 values tending towards high TP concentrations.

The TN to TP Ratio (TN:TP)

Nutrient pollution can compromise aquatic ecosystems directly and indirectly. The most common problem is the stimulation of growth of cyanobacteria (a component of benthic algal mats) which can dominate and change the dynamics of an aquatic ecosystem.

In 1934, Alfred Redfield analysed nitrate and phosphate data from many oceans around the world and discovered that the N:P atomic ratio of the oceans was the same as most phytoplankton in the ocean, i.e., 16:1. This ratio has become known as the Redfield ratio[4].

The ratio of TN:TP has commonly been used to evaluate the nutrient status of a water body. For example, when the TN:TP atomic ratio is greater than 16 then the waterbody is said to be Phosphorus deficient, and when it is less than 16, it is Nitrogen deficient. The latter situation is considered to favour the growth of N_2 fixing cyanobacteria[5]. The TN:TP ratio provides an assessment of the risk of eutrophication of water bodies.

TN:TP ratios for the 1998-2000 and 2020-2022 water samples were generally high implying that Phosphorus concentrations are an important limiting factor with respect to eutrophication risk.

Despite the higher levels of TP in the system in 2021, there was no evidence of strong phytoplankton blooms with the turbidity levels low to moderate. This may reflect the cooler weather leading up to sampling time. Controlling Phosphorus inputs into the waterways is important for reducing eutrophication of the waterways.

[4] https://en.wikipedia.org/wiki/Redfield_ratio

[5] Australian and New Zealand guidelines for fresh and marine water quality. Volume 2, Aquatic Ecosystems – Rationale and Background Information (October 2000) Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

The variation in nutrient values suggests that seasonal sampling for both Nitrogen and Phosphorus concentrations is necessary to provide a clearer picture of potential nutrient impacts in the waterways and how this relates to natural factors such as rainfall and temperature, but also the potential for riparian rehabilitation to reduce eutrophication risk.

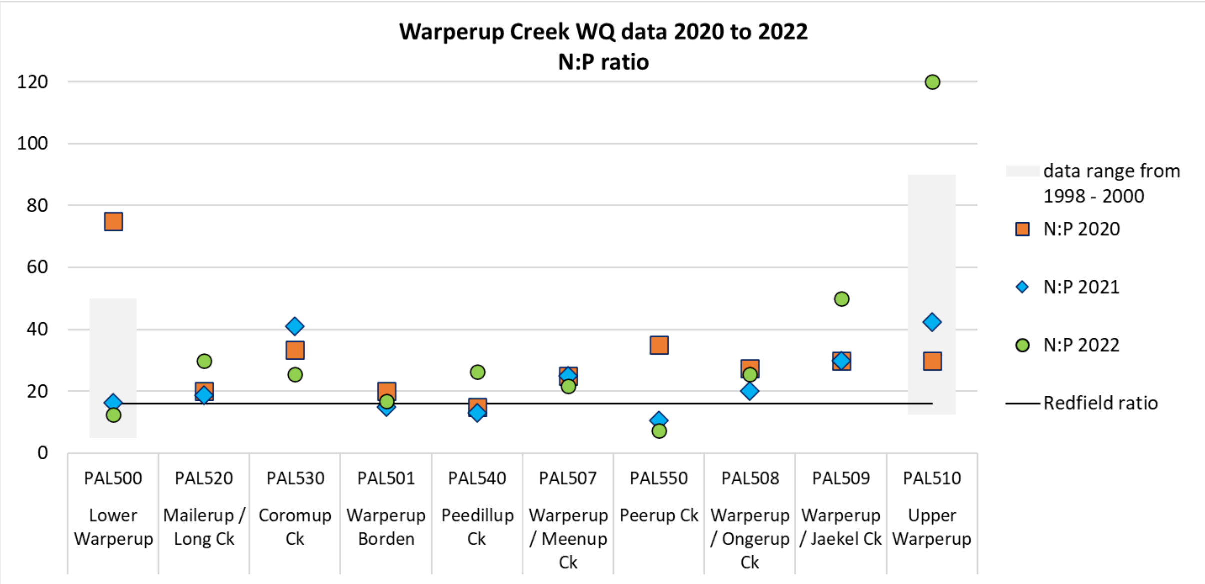


Figure 16: The Total Nitrogen: Total Phosphorus ratio (TN:TP) in water samples collected from Warperup Creek and tributaries, October 2020 to 2022. The data range from sampling two sites between 1998 and 2000 is shown as a grey bar.

Turbidity

Turbidity values at all sites were low to moderate, as was stream discharge for all three years. The values were interpreted as a good sign that potential improvements to water quality could be made and maintained. The lowest data point obtainable using the Turbidity tube was 10 NTU.

Table 1: Turbidity Categories in the table from FARWH Report No. 39

Turbidity (NTU)	Turbidity category
< 5	Low
5 - 10	Moderate
10 - 25	High
>25	Very high

Janicke Environmental Investigations

Aquatic diversity

Macroinvertebrate composition

There were 40 different taxa observed over the three years of sampling in Warperup Creek and its tributaries. The diversity was dominated by insects, and specifically Dipterans, i.e., larvae from midge, mosquitos and various flies. However, in terms of abundance, Crustaceans dominated with 'Scuds' (i.e., the Amphipod, *Austrochiltonia subtenuis*), various species of seed shrimp (Ostracoda) and micro-crustaceans (Copepods).

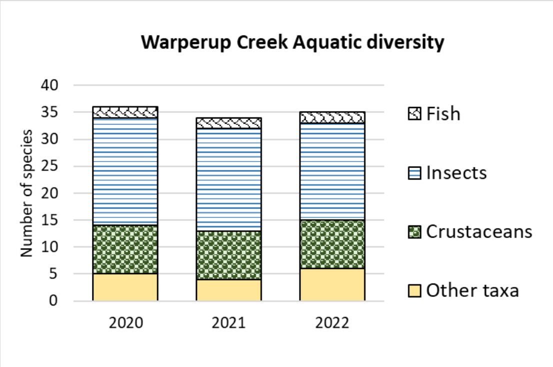


Figure 17: Aquatic diversity in Warperup Creek and its tributaries combined for each year.

There were no significant differences between the three years in terms of aquatic diversity and only minor differences between sites within each year.

No comparable aquatic macro-invertebrate data was collected during the 1998-2000 monitoring period and therefore the 2020-2000 data provides a baseline for future investigations.

Macroinvertebrate diversity was consistently highest at Site PAL509, downstream of Jaekel Creek. This is despite Jaekel Creek influencing the salinity of the site. It may reflect the rocky riffles and diverse pool habitat upstream. The macroinvertebrate diversity has been consistently lowest on Mailerup/Long Creek, site PAL520. This site is a broad, shallow, and sandy bottom run with little habitat diversity. Sediment infill of pools creates a blander environment for aquatic life.

The Amphipod, *Austrochiltonia subtenuis* was found at all sites and was the most abundant species. It is a widespread species found throughout southern Australia in both freshwater and saline waterways and lakes. They grow up to one centimetre in length and feed on detritus and plankton. In turn, they are a food source for many different species. These crustaceans, unlike the seed shrimps, do not produce drought resistant eggs and must survive burrowed in the damp soil until there is water flow again. Juvenile forms can also 'hitch' a ride from one waterway to another in the feathers of a waterbird.

Figure 18: The widespread scud or Amphipod, *Austrochiltonia subtenuis* (the grid is 1mm squares).

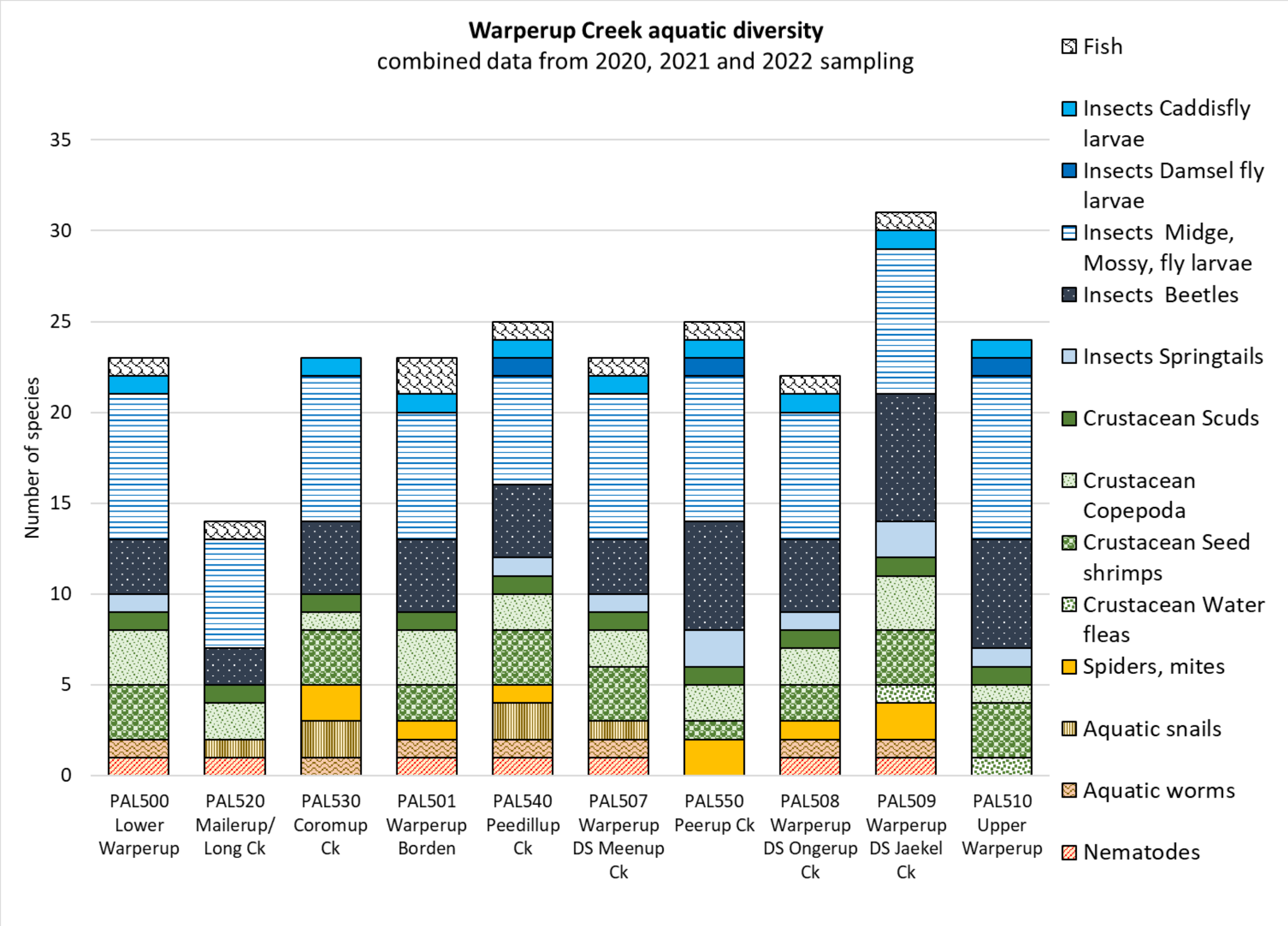


Figure 19: Macroinvertebrate diversity in Warperup Creek and some tributaries, combined data for 2020, 2021 and 2022.

Midge larvae (Chironomidae) are a diverse group of insects that are found in the sediments of most waterbodies. The dominant midge larvae found in the Warperup was *Tanytarsus barbitarsus* and is halophilic (i.e., a salt water loving species) although it can tolerate lower salinity levels. They mostly feed on detritus and micro-algae and are found in association with *Procladius paludicola* which is predatory, feeding on other midge larvae, nematodes and small invertebrates. Midge larvae can occur in very high numbers and become food for beetles, beetle larvae, damselfly and caddisfly larvae and for many wading birds.

Figure 20: Red midge larvae *Tanytarsus barbitarsus* and a diving beetle larva with a green midge larva in its mouth.

Blue-Ringtail Damselfly (*Austrolestes annulosus*) larvae were found in the Peedillup Creek, Peerup Creek and the lovely pool in the upper Warperup. The larvae are predators and have a hinged mask-like appendage that they use to capture their prey. Blue Ringtail's are common across southern Australia and occur in fresh and saline waterbodies.

Figure 21: Larvae (left) and male adult (right) Blue Ringtail damselflies (*Austrolestes annulosus*) (image on right: Doug McDougie, Western Australian Insects Facebook page).

Coxiella snails are endemic (unique to) to Australia and are mostly found in salt lakes, so it is interesting to find them in the three tributaries to Warperup. Their shells are thick, often with a tall spire and can be found in huge numbers on the 'beaches' of many saline waterbodies. They feed on detritus and benthic algae. They can block the opening of the shell with an operculum to avoid drying out when the waterbody is too saline or dry. They provide a food source for many water birds and have been found to make up to 90% of the diet of Hooded Plovers[6].

[6] Lawrie, Chaplin and Pinder (2021) *Biology and conservation of unique and diverse halophilic macroinvertebrates of Australian salt Lakes.* Marine and Freshwater Research. Published online.

Fish

The Blue-spot Goby, *Pseudogobius olorum* also known as the Swan River Goby was found at all sites except in Coromup Creek, site PAL530 and the uppermost pool, site PAL510. This is a bottom dwelling (benthic) species that can tolerate a wide range of salinities. With the first rains of winter, they can be found moving upstream to be ready to place their eggs (spawn) amongst submerged aquatic vegetation. The female spawns about 150 eggs and the male guards and fans the eggs. They will use their pectoral fins to help them 'climb' over rapids on their journey upstream. They feed mostly on algae, fungi and bacteria, and small bottom dwelling microcrustaceans.

The introduced Eastern gambusia - *Gambusia holbrooki* was found in large numbers at site PAL501 near the Borden Golf Club. 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 waterbodies. They can seriously reduce native fish populations.

Figure 22: The Blue-spot Goby, *Pseudogobius olorum (left),* the introduced Eastern gambusia - *Gambusia holbrooki* (right) and the Common Jollytail - *Galaxias maculatus*

Other native fish, e.g., the Common Jollytail - *Galaxias maculatus* and the Western Hardyhead - *Leptatherina wallacei* may also be present in the waterway, however they are fast moving and would not be collected in a macroinvertebrate sweep net. A small school of Common Jollytail were observed in the Warperup near the Hart Road crossing. They have a broad salinity tolerance, and it can be assumed they are elsewhere present in Warperup Creek, although their extent and abundance is unknown.

Other fauna observations

A variety of ducks were observed using the waterway, often with ducklings which indicated the use of the river pools for breeding. Observations included:

- Dabbling ducks, including the Grey Teal and the Pacific Black Duck. Dabbling ducks upend for food in the shallow water and littoral zone, feeding on aquatic plants, insects, crustaceans as well as the salt-lake snail, *Coxiella* sp.
- Diving ducks including the Hardhead and Hoary-headed Grebe. These birds dive for bottom dwelling macroinvertebrates, plant material and small fish.
- Other birds including the White-Faced Heron had been observed occasionally. These are generalist feeders, feeding on frogs, insects, small fish and crustaceans found in shallows or in open grassy areas. A variety of song birds were heard at various sites.
- Terrestrial riparian fauna was not assessed.

Riparian Vegetation Health

The simplest method of assessing riparian health is using the Pen-Scott rapid assessment of riparian condition. The Pen-Scott riparian condition grading uses a simple A - B - C - D scale, A being pristine and D being highly degraded. There are also three degrees within each grade, for example B1 – B2 – B3. The process of degradation is rated by considering the relative levels of native plants and weeds, their health and the amount of soil disturbance. See Appendix 3 for a description of the Pen-Scott rating.

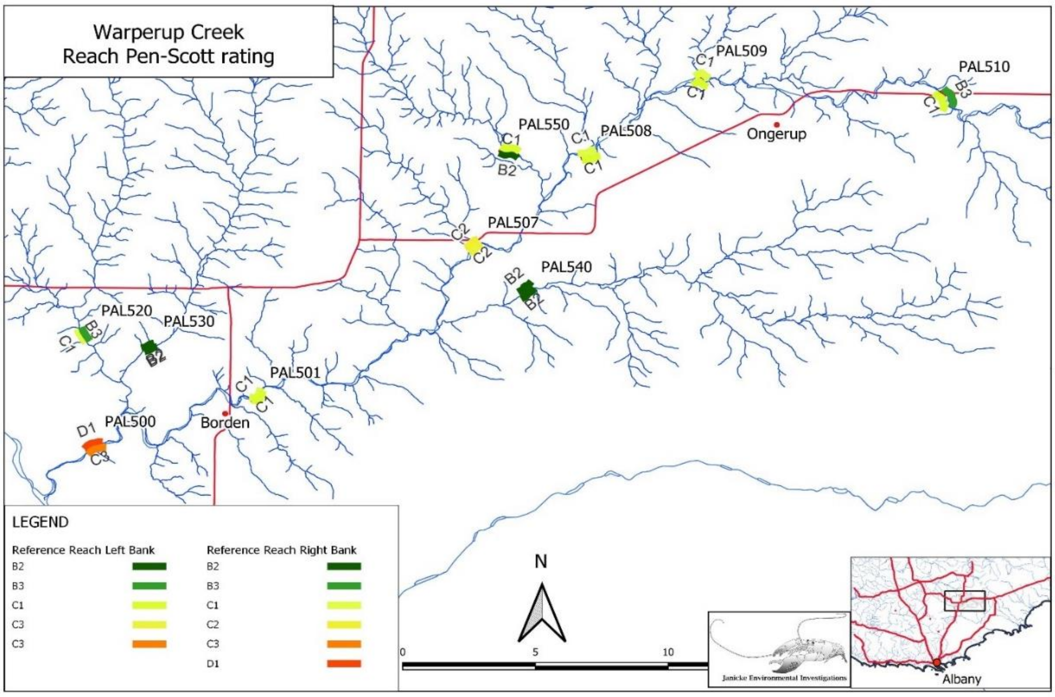


Figure 23: Pen-Scott riparian condition rating for the left and right banks at the ten reference reaches along Warperup Creek, October 2020.

In general, the riparian vegetation along the reference reaches of the tributaries were in better condition than along the main trunk of Warperup Creek. The lower end of Warperup Creek was in the poorest condition with annual grasses dominating the sandy riparian verge. The two reaches on Coromup Creek and Peedillup Creek appeared to be in the best condition compared with the other reference reaches, with trees and shrubs over a mainly grassy understory.

Table 2: Pen-Scott rating for left and right bank along the reference site reach.

Reference reach	Left bank	Right bank
PAL500 Lower Warperup	C3	D1
PAL501 Warperup Borden	C1	C1
PAL507 Warperup Meenup Creeks	C3	C3
PAL508 Warperup Ongerup Creeks	C1	C1
PAL509 Warperup Jaekel Creeks	C1	C1
PAL510 Upper Warperup	C1	B3
PAL520 Mailerup/Long Creek	B3	C1
PAL530 Coromup Creek	B2	B2
PAL540 Peedillup Creek	B2	B2
PAL550 Peerup Creek	C1	B2

MONITORING SITE PHOTOS & CHARACTERISTICS

The water monitoring site photos below reveal the variety of habitat types in the Warperup, and these can be quite subtle but no less important for biodiversity.

PAL500 – lower Warperup Creek

This reach is at the lower end of Warperup Creek on the south side of Maileerup Road and runs parallel to it. In the late 1990s the accuracy of GPS devices was poor and location coordinates could vary by up to several hundred meters at different times. This site was sampled in the days of the Waters and Rivers Commission (1998-2000), most probably at the Maileerup Road crossing near the top end of the reference reach rather than at the current site at the downstream end.

Figure 24: Sampling site PAL500, lower Warperup Creek on 6 October 2021 and 13 October 2020.

This shallow pool had moderate to high Total Nitrogen values and high dissolved nitrates and nitrites in 2020. Total Phosphate levels in 2022 were high and the TN:TP ratio was low (13) indicating that potential eutrophication was controlled by Nitrogen inputs. Figure 25 shows water seeping out from under a sandy bank at the sampling site. The high algal growth within the seepage indicates higher nutrient levels.

Figure 25: Water seeping from under a sandy bank at PAL500 in October 2022. The high algal growth indicating high nutrient levels.

PAL 520 - Mailerup / Long Creek

The Allen and Long Creeks are large tributaries that join to become Mailerup Creek which in turn joins with Coromup Creek to enter the lower reaches of the Warperup from the north west.

This site had the lowest aquatic diversity, and the most abundant taxa were midge, mosquito and brine fly larvae. Seed shrimps were present in abundance in 2020 and 2022 but were noticeably absent in 2021. In 2022, the TN values were very high, but the TP values were low. There was a benthic algal mat present in sections of the stream.

Figure 26: Sampling site PAL520, Maileeup / Long Creek in October 2020 above and 2022 below.

PAL530 – Coromup Creek

Coromup Creek is a large tributary, joining with Maileeup - Long Creek to enter the lower reaches of Warperup Creek from the north west.

The water level at this site is controlled by a rocky bar a short distance downstream. The upstream reach is dominated by bedrock. Despite the high rainfall in June and July 2021 compared to 2020, the water depth was reduced in 2021 (see Figure 27 and Figure 28) due to an influx of sand. The Bureau of Meteorology daily weather observations for Ongerup show that in 2020 the area received 10.8mm rain in the four days preceding the 2020 sampling and in 2021 only received 3.4mm of rain. It should be noted that variations in water level can give the casual observer a misleading assessment of sediment quantities and movement.

This site had a high Total Nitrogen concentration in the 2021 sampling round and a dense benthic algal mat on all sampling occasions (See Figure 29, right image). Despite this, the site had a reasonably high aquatic macroinvertebrate diversity with an abundance of seed shrimp, copepods, scuds, midge, and mosquito larvae. However, no fish were observed. This highlights the fact that ecosystems are defined by a wide range of features some of which may be quite subtle.

Figure 27: PAL530B, Coromup Creek in October 2020 and 2022 showing increase in sediment in the waterway

Figure 28: Sampling site PAL530C, Coromup Creek in October 2020 and 2021 showing increase in sediment in the waterway

Figure 29: Left: Constraining rock-bar at site PAL530, Coromup Creek. Steve collecting a water sample. Right: a dense benthic algal mat producing Oxygen bubbles through photosynthesis which is lifting the mat off the sandy bottom.

PAL501 – Warperup Creek, Borden Golf Course

A water monitoring site was established at the Chester Pass Road Crossing in 1998-2000 by the then Water and Rivers Commission. For the 2020 monitoring program, the floodway adjacent to and extending upstream from the Golf Club house was chosen as the reference reach. The sampling location in 2020 and 2021 was downstream of the Club House but it was felt that the location was too difficult to access due to a very steep bank and the monitoring site was relocated to a site upstream in 2022. See Figure 30 below.

Figure 30: Sampling site PAL501, Warperup Creek in October 2020 (above) and the new location PAL500A, upstream from the original site (below).

This reach of Warperup Creek is the only site where the introduced Mosquito fish *Gambusia holbrooki* was collected.

PAL540 - Peedillup Creek.

Peedillup Creek is a major tributary entering the middle Warperup Creek from the south east. There was moderately healthy riparian vegetation adjacent to the reach (Pen-Scott rating of B2) with samphires overhanging the banks of the river pool.

Aquatic diversity was slightly higher than most of the other monitoring sites with an abundance of *Coxiella* snails, copepods, scuds and midge larvae.

Figure 31: Site PAL540 on Peedillup Creek in October 2020 and 2021

PAL507 - Warperup and Meenup Creeks

Meenup Creek is a small tributary entering near the upstream end of the reference reach on Warperup Creek. In-situ water quality was measured in Meenup Creek and Warperup Creek upstream of their confluence for comparison with the reference reach downstream on Warperup Creek. Although Meenup Creek was slightly more saline than Warperup upstream of the confluence, it seemed to have no impact on the salinity of Warperup downstream of the confluence. Surface flow however, was little more than a trickle at the time.

Sediment on near right bank (See Figure 32) had been stripped away during the previous 12 months and more sediment had been deposited at the downstream end of the pool. The water level in the pool in 2021 was higher than in 2020 which may be due to the sediment bar at the downstream end of the pool constraining the flow. The aquatic environment included an abundance of seed shrimps, scuds and midge larvae.

Figure 32: Site PAL507 on Warperup Creek in October 2020 and October 2022.

Janicke Environmental Investigations

Interestingly this site corresponded to a photograph from the 1930s (Figure 33 below) and it illustrates how photographs can contain objective information that is useful for increasing our understanding of how river systems work.

Figure 33: Comparison between a photo taken in 1930s[7] and one from the same location in 2022.

[7] Accessed from State Library of Western Australia, https://purl.slwa.wa.gov.au/slwa_b3523166_11

Figure 33: The different features shown at the site after an interval of 80 to 90 years tell a story. In the 1930s the banks were largely denuded of vegetation which suggests high stock use of the area. The exposed soils would have been primed for flood erosion. The presence of a clump of sedges in the 1930s indicates these were present in the riparian zone but by 2020 ground cover has become dominated by veldt grass which nevertheless may serve a similar stabilising function. Large trees had been present close to the water but by the 1930s had died and in 2022 wattles have replaced Eucalypts although these are still present in patches.

The increase in cropping activity in the catchment over time can be said to have had a positive effect on floodway stability since the reduction in stock grazing pressure allow vegetation to recolonise the floodway, even if is largely by weed species. It is uncertain how extensive the earlier highly degraded conditions were throughout the catchment, but in one sense the location shown appears to have 'improved' in an ecological sense.

The image below (Figure 34) of a crossing on Warperup Creek also suggests that stream banks had been quite denuded.

Figure 34: A flood damaged crossing on Warperup Creek or Pallinup River 1955. (Source unknown)

PAL550 – Peerup Creek

Peerup Creek is a moderate sized tributary flowing from the northwest part of the catchment to Warperup Creek main channel. The site is on the east side of Peerup Road and extends downstream from just below a granite cascade. The flows were negligible to very low during all three site visits. The stream bed consisted of various small cut-off pools overhung with samphire.

This site had the highest total phosphate level in 2022 and the highest NOx-nitrogen level in the 2020 sampling round. The aquatic environment was dominated by midge larvae, copepods and aquatic beetles.

Figure 35: Conditions at this site had remained much the same from 2020 to 2022

Janicke Environmental Investigations

PAL508 – Warperup and Ongerup Creeks

Ongerup Creek is a moderately large tributary entering Warperup Creek from the north near Hart Road crossing. There are revegetation plantings on both sides and these works were probably undertaken in the late 1990s to early 2000s. Several local tree and shrub species have done well. Although grasses continue to dominate the ground cover, leaf and bark litter in moderately shaded areas have inhibited these from taking over.

The sediment in this pool has been very mobile. See Figure 36 and Figure 37 below. The rocks in the foreground (2022) were exposed and sediment deposited in the downstream end of the pool. This indicates flows are actively moving large sand plumes. The aquatic macroinvertebrate diversity in 2021 was reduced compared to 2020 with fewer crustacean species but a higher dipteran fly and midge larvae diversity and abundance.

Figure 36: Site PAL508 on Warperup Creek downstream of Ongerup Creek in October 2020 and October 2021.

Figure 37: Zoomed in to the end of the pool at Site PAL508 on Warperup Creek, 2020 and 2021. Although the photo in 2021 was from a slightly different angle, the extent of sediment deposition can be seen.

In-situ salinity measured in Ongerup Creek and Warperup Creek upstream of their confluence for comparison with the reference reach downstream on Warperup Creek. There was no difference of note in the salinity of the two creeks.

PAL509 – Warperup Creek and Jaekel tributary entry

The bed upstream of this reach on Warperup Creek is largely a series of granite-based pools and rapids. The tributary entering from the north (in this report named Jaekel Creek) arises in a strongly saline landscape to the north-east.

The in-situ salinity was measured in Jaekel Creek and Warperup Creek upstream of their confluence for comparison with the reference site downstream. The salinity in Jaekel Creek was higher than Warperup and there was a slight increase in salinity downstream of the confluence.

Despite Jaekel Creek being more saline, and in 2020 more acidic, the downstream site had the highest diversity of aquatic macroinvertebrates of all sites and on all sampling occasions. In 2021 it was dominated by a high diversity and abundance of crustaceans although there was also a high diversity of beetles, midge and mosquito larvae.

Figure 38: Site PAL509 on Warperup Creek downstream of Jaekel tributary in October 2020 and October 2022.

PAL510 – Warperup Creek upper reach

This site was sampled by the then Waters and Rivers Commission (1998-2000) and takes in the uppermost reaches of the Warperup catchment. The water sampling site is immediately upstream of the road crossing at the lower end of a relatively deep pool.

Acidic water (down to pH 6.6) was recorded during the sampling between 1998 and 2000. For 2020, 2021 & 2022 the water was likewise recorded as slightly acidic with pH at 6.1, 6.5 & 6.3 respectively. This implies there is a groundwater input that is distinctive to the upper catchment.

The aquatic environment was dominated by an abundance and diversity of seed shrimp, copepods, and scuds with midge larvae also abundant. The Goby was notably absent.

Figure 39: The upper most site on Warperup creek, Photo point PAL510 in October 2020 and October 2022.

APPENDIX 1: RAW WATER QUALITY DATA OCTOBER 2020, 2021 & 2022

Site Code	Waterway	Year	Date	Easting	Northing	Salinity (EC) ms/cm	Temp °C	pH	Turbidity tube NTU	Stream flow	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	NOx-N (mg/L)	Ammonia-N (mg/L)	Nitrate-N (mg/L)	Nitrite-N (mg/L)	Total Kjeldahl N (mg/L)
PAL500	Lower Warperup	2020	6/10/20	611285	6227733	40	15	8.2	<10	low ~10L/s	1.5	0.02	0.22				
PAL501	Warperup Borden	2020	6/10/20	617515	6229671	37	17	8.2	10	low	0.8	0.04	0.05				
PAL507	Warperup DS Meenup Ck	2020	6/10/20	625710	6235622	43	10	7.8	<10	low	1	0.04	0.01				
PAL507	Warperup US Meenup Ck	2020	6/10/20	625943	6235821	43	14	8.1	<10	trickle							
PAL507	Meenup Ck	2020	6/10/20	625845	6235819	47.5	13	7.8	<10	trickle							
PAL508	Warperup DS Ongerup Ck	2020	5/10/20	629965	6239257	43	19	7.9	10	low	1.1	0.04	0.02				
PAL508	Warperup US Ongerup Ck	2020	5/10/20	630373	6239391	41	18.5	8	<10								
PAL508	Ongerup Ck confluence	2020	5/10/20	630113	6239262	47	21	8.7	<10								
PAL509	Warperup Jaekel DS trib	2020	5/10/20	634316	6242426	33	17	7	<10	low	0.6	0.02	0.02				
PAL509	Warperup Jaekel US trib	2020	5/10/20	634364	6242386	31	17	6.7	<10	low							
PAL509	Jaekel tributary	2020	5/10/20	634355	6242430	50.5	19.5	6.7	<10	trickle							
PAL510	Warperup upper	2020	5/10/20	643460	6241800	35.9	15	6.1	<11	trickle	0.6	0.02	0.02				
PAL520	Maileeup/Long Ck	2020	6/10/20	613690	6231826	39	18.5	7.9	20	trickle	0.8	0.04	0.01				
PAL530	Coromup Ck	2020	6/10/20	613500	6231704	43	17	7.9	<10	low	1	0.03	0.01				
PAL540	Peedilup CK	2020	6/10/20	627721	6233859	47	15.5	8.2	<10		0.6	0.04	0.02				
PAL550	Peerup Meenup Ck	2020	5/10/20	626870	6239513	39.2	17.5	8	<10	Nil	1.4	0.04	0.27				
PAL500	Lower Warperup	2021	6/10/21	611285	6227733	24.9	15.5	7.9	12	low	1.8	0.11	0.005				
PAL501	Warperup Borden	2021	6/10/21	617515	6229671	24.5	13.5	7.5	10	low	1.8	0.12	0.005				
PAL507	Warperup DS Meenup Ck	2021	5/10/21	625710	6235622	28.2	19.5	8	10		1.5	0.06	0.02				
PAL507	Warperup US Meenup Ck	2021	5/10/21	625943	6235821	27.9	19	8.2		low							
PAL507	Meenup Ck	2021	5/10/21	625845	6235819	32.8	21	8.1		trickle							
PAL508	Warperup DS Ongerup Ck	2021	5/10/21	629965	6239257	30.4	15.5	7.5	<10	low	1.2	0.06	0.005				
PAL508	Warperup US Ongerup Ck	2021	5/10/21	630373	6239391	30	15.5	7.4		low							
PAL508	Ongerup Ck confluence	2021	5/10/21	630113	6239262	28.6	17	7.7		low							
PAL509	Warperup Jaekel DS of trib	2021	5/10/21	634316	6242426	26.1	17	7.1	12	low	1.5	0.05	0.005				
PAL509	Warperup Jaekel US of trib	2021	5/10/21	634364	6242386	26.6	16	7.8		low							
PAL509	Jaekel tributary	2021	5/10/21	634355	6242430	37.1	20.5	7.3		low							
PAL510	Warperup upper	2021	5/10/21	643460	6241800	26.6	15	6.5	12	low	1.7	0.04	0.005				
PAL520	Maileeup/Long Ck	2021	6/10/21	613690	6231826	27.8	16	8.4	<10	low	1.5	0.08	0.005				
PAL530	Coromup Ck	2021	6/10/21	613500	6231704	28.9	18	7.9	<10	low	3.7	0.09	0.02				
PAL540	Peedilup CK	2021	5/10/21	627721	6233859	24.8	18	7.9	<10	low	2.1	0.16	0.005				
PAL550	Peerup Meenup Ck	2021	5/10/21	626870	6239513	20.8	18.5	8	<10	low	2.0	0.19	0.005				
PAL500	Lower Warperup	2022	13-Oct-22	611285	6227733	24.8	15	7.1		low	2.5	0.2	<0.01	<0.02	<0.01	<0.01	2.5
PAL501	Warperup Borden	2022	13-Oct-22	617515	6229671	23.4	16.9	7.2		low	2.7	0.16	<0.01	<0.02	<0.01	<0.01	2.7
PAL507	Warperup DS of Meenup Ck	2022	14-Oct-22	625710	6235622	27.2	19	7.8	20	low	2.4	0.11	<0.01	<0.02	<0.01	<0.01	2.4
PAL507	Warperup US of Meenup Ck	2022	14-Oct-22	625943	6235821	26.7	19			trickle							
PAL507	Meenup Ck	2022	14-Oct-22	625845	6235819	34.9	22			trickle							
PAL508	Warperup DS of Ongerup Ck	2022	14-Oct-22	629965	6239257	33.4	21.5	8.3	10		2.3	0.09	<0.01	<0.02	<0.01	<0.01	2.3
PAL508	Warperup US of Ongerup Ck	2022	14-Oct-22	630373	6239391												
PAL508	Ongerup Ck confluence	2022	14-Oct-22	630113	6239262	34.5	22	8.4		trickle							
PAL509	Warperup Jaekel DS of trib	2022	14-Oct-22	634316	6242426	23.9	23	7.6	12	low	3.5	0.07	<0.01	<0.02	<0.01	<0.01	3.5
PAL509	Warperup Jaekel US of trib	2022	14-Oct-22	634364	6242386	21.9	20.5	8.2		low							
PAL509	Jaekel tributary	2022	14-Oct-22	634355	6242430	43.2	22	7.6		trickle							
PAL510	Warperup upper	2022	15-Oct-22	643460	6241800	23.7	18	6.3	12	nil	3.6	0.15	<0.01	<0.02	<0.01	<0.01	3.6
PAL520	Maileeup/Long Ck	2022	13-Oct-22	613690	6231826	30.9	21.5	7.6		low	4.5	0.20	<0.01	<0.02	<0.01	<0.01	4.5
PAL530	Coromup Ck	2022	13-Oct-22	613500	6231704	31.2	22	8.1	20	low	2.8	0.10	<0.01	<0.02	<0.01	<0.01	2.8
PAL540	Peedilup CK	2022	14-Oct-22	627721	6233859	30.5	19	8	12	low	2.9	0.10	<0.01	<0.02	<0.01	<0.01	2.9
PAL550	Peerup Meenup Ck	2022	14-Oct-22	626870	6239513	30.4	20	8.2	12	trickle	2.2	0.30	<0.01	<0.02	<0.01	<0.01	2.2

APPENDIX 2: MACROINVERTEBRATE COMPOSITION

Class	Species	Common name	Three-year combined abundance figures for each site									
			PAL 500	PAL 520	PAL 530	PAL 501	PAL 540	PAL 507	PAL 550	PAL 508	PAL 509	PAL 510
Nematoda	Nematoda spp.	Roundworms	2	2		1	1	3		1	1	
Oligochaeta	Oligochaeta spp.	Segmented worms	1		1	2	2	2		2	1	
Gastropoda	Pomatiopsidae *Coxiella/Coxiellada* spp.	Snails		6	3		5					
	Hygrophila Limnaeidae *Lymnaeid/Succineid* sp.	Snails			1		1	1				
Arachnida	Araneae Tetragnathidae *Leucage* sp.	Solver Orb spider			1	1	1		1	1	2	
	Acarina unknown mites	Aquatic mites			1				1		1	
Crustacea	Cladocera Daphniidae *Daphinopsis pusilla*	Water fleas									3	1
	Ostracoda Cyprididae *Mytilocypris mytiloides*	Seed shrimps	1		5		1	2			6	3
	Ostracoda Cyprididae *Diacypris/Sarcipridopsis* spp.		6	6	11	1	4	4	2	5	8	6
	Ostracoda Cyprididae *Platycypris* sp.				2						1	3
	Ostracoda Cyprididae *Kennethia* sp.						1					
	Ostracoda Limnocytheridae *Limnocythere* sp.		2			3		2		2		
	Unidentified Calanoid copepods	Copepods	3			3					1	
	Unidentified Cyclopoid copepods		2	9	6	3	7	6	7	6	9	10
	Unidentified Harpacticoid copepods		6	4		1	1	2	4	2	4	
	Amphipoda Ceinidae *Austrochiltonia subtenuis*	Sand fleas	7	8	10	8	4	5	7	7	8	7
Insecta	Collembola Hypogasturidae spp.	Springtails	1				1	1	1	1	4	1
	Collembola Isotomidae spp.								1		3	
	Coleoptera Dytiscidae *Necterosoma penicillatum*	Diving beetles	3	3	5	2	4	5	6	5	6	6
	Coleoptera Dytiscidae *Necterosoma* sp. (larvae)		7	5	5	1	5	4	5	3	7	7
	Coleoptera Hydrophilidae *Berosus dallasae*	Water scavenger beetles							2			
	Coleoptera Hydrophilidae *Berosus discolor*				1						1	2
	Coleoptera Hydrophilidae *Berosus* sp. (larvae)				0	1					2	1
	Coleoptera Hydrophilidae *Helochares tenuistriatus*					1			1			
	Coleoptera Hydrophilidae *Laccobius zeitzi*		2		2		1	3	1	1	1	1
	Coleoptera Hydrophilidae *Laccobius zeitzi* (larvae)						1		1	1	1	

Warperup Creek Water Condition Monitoring Results for 2020 to 2022

Class	Species	Common name	Three-year combined abundance figures for each site									
Class	**Species**	**Common name**	**PAL 500**	**PAL 520**	**PAL 530**	**PAL 501**	**PAL 540**	**PAL 507**	**PAL 550**	**PAL 508**	**PAL 509**	**PAL 510**
Insecta	Coleoptera Scarabidae (larvae)	Scavenger beetle									1	
	Diptera Chironomidae/Orthocladiinae *Paralymnophyses pullulus*	Non-biting midge larvae										3
	Diptera Chironomidae/Tanypodinae *Procladius paludicola*		4	3	2	1		1	4		4	5
	Diptera Chironomidae/Chironominae *Tanytarsus barbitarsus*		10	8	8	5	8	7	9	7	7	7
	Diptera Chironomidae/Chironominae *Chironomus alternans*								3			
	Diptera Chironomidae/Chironominae *Dicrotendipes* sp. (graze algae)		1		1	6	1	1				2
	Diptera Ceratopogonidae spp. (larvae)	Biting midge larvae	2	2	4	2	2	2		2	5	4
	Diptera Culicidae *Aedes (Ochlerotatus) camptorhynchus*	Mosquito larvae	1	3	5	1	4	2	5	5	4	4
	Diptera Ephydridae Brine fly (larvae/pupae)	Brine fly	2	5	2	1	2	5	3	3	2	1
	Diptera Ephydridae Brine fly (adults 2 species including *Neoscutella* sp.)		1	1			2	2	1	2		1
	Diptera Muscidae spp. (larvae)	Fly larvae			1							1
	Diptera Stratiomyidae (larvae)	Soldier fly larvae			2	1		4	2	4	3	
	Diptera Tabanidae spp.	March fly larvae								1	1	
	Diptera Tipuliidae spp.	Tipulid fly larvae	1						1		1	
	Odonata Lestidae *Austrolestes annulosus*	Damselfly larvae					1		2			2
	Trichoptera Leptoceridae *Symphitoneuria wheeleri* (larvae/pupae/adults)	Caddisfly larvae	2		2	5	4	2	2	5	2	2
Actinopterygii Fish	Gobiiformes Oxudercidae *Pseudogobius olorum*	Blue-spot goby	1	3		4	3	5	2	3	2	
	Cyprinodontiformes Poeciliidae *Gambusia holbrooki*	Gambusia				6						
		Total number of taxa	**23**	**15**	**24**	**23**	**25**	**23**	**25**	**22**	**31**	**23**

APPENDIX 3: PEN-SCOTT FORESHORE CONDITION RATINGS

The concept of general waterway condition along South-West streams was developed by Dr Luke Pen and Margaret Scott and their definition has been widely used to illustrate the quality of riparian vegetation along our rivers and creeks. The stream condition rating is based on the form and stability of natural channels rather than botanical biodiversity considerations, although the quality of the natural biodiversity is implied in the grading. A consideration for developing a monitoring framework the Warperup was whether this rating would be sufficient to detect ecological condition improvements to the waterways.

The Pen-Scott riparian condition grading uses a simple A - B - C - D scale, A being pristine (A) and D being highly degraded. There are also three degrees within each grade, for example B1 – B2 – B3. The process of degradation is rated by considering the relative levels of native plants and weeds their health and the amount of soil disturbance. B Grade corresponds to a situation where native plant species and exotic weeds are both common and bed and bank erosion is starting to become significant. It is safe to say that original A Grade rated stream reaches in WA, once degraded to B, C and D categories, will not be returned to A1 grade given the change of stream flow pattern due to land clearing, the proliferation of weeds, feral animals, and other irreversible disturbance factors. Nevertheless, improvements to stream condition would ideally reverse various degrading processes and the floodway would move from D grade to C grade and possibly to B grade.

The Pen-Scott assessment is very broad by definition, and its main use is for prioritising stream reaches for rehabilitation, especially in an environment where funding is limited. The classifications are subject to the discretion of the observer and ratings will often differ from person to person. For this reason, using the rating to track improvements is questionable. The main limitation is that it only describes riparian condition in general terms. For these reasons a more detailed waterway condition monitoring framework is considered a much more useful management tool.

A description of the Pen-Scott riparian condition grades is given below.

A Grade

Foreshore has healthy native bush (ie. similar to that found in nature reserves, state forests and national parks).

A1. Pristine

The river embankments and floodway are entirely vegetated with native species and there is no evidence of human presence or livestock damage.

A2. Near Pristine

Native vegetation dominates. Some introduced weeds may be present in the understorey but not as the dominant species. Otherwise, there is no evidence of human impact.

A3. Slightly Degraded

Native vegetation dominates, but there are some areas of human disturbance where soil may be exposed, and weeds are relatively dense (i.e. along tracks). Native vegetation would quickly recolonise if human disturbance declined.

B Grade

The foreshore vegetation had been invaded by weeds, mainly grasses and looks similar to typical roadside vegetation.

B1. Degraded – weed infested

Weeds have become a significant component of the understorey vegetation. Native species are still dominant, but a few have been replaced by weeds.

B2. Degraded – heavily weed infested

Understorey weeds are nearly as abundant as native species. The regeneration of trees and large shrubs may have declined.

B3. Degraded – weed dominant

Weeds dominate the understorey, but many native species remain. Some trees and large shrubs may have disappeared.

C Grade

The foreshore supports only trees over weeds or pasture. Bank erosion and subsidence may occur in localised areas.

C1. Erosion prone

Trees remain with some large shrubs or tree grasses and the understorey consists entirely of weeds (ie. annual grasses). There is little or no evidence of regeneration of tree species. River embankment and floodway are vulnerable to erosion due to the shallow-rooted weedy understorey providing minimal soil stabilisation and support.

C2. Soil exposed

Older trees remain but the ground is virtually bare. Annual grasses and other weeds have been removed by livestock grazing and trampling or through humans use and activity. Low level soil erosion has begun.

C3. Eroded

Soil is washed away from between tree roots. Trees are being undermined and unsupported embankments are subsiding into the river valley.

D Grade

The stream is little more than an eroding ditch or a weed infested drain.

D1. Ditch – eroding

There is not enough fringing vegetation to control erosion. Remaining trees and shrubs act to impede erosion in some areas but are doomed to be undermined eventually.

D2. Ditch – freely eroding

No significant fringing vegetation remains, and erosion is out of control. Undermined and subsided embankments are common. Large sediment plumes are visible along the river channel.

D3. Drain – weed dominant

The highly eroded river valley has been fenced off, preventing control of weeds by stock. Perennial weeds have become established, and the river has become a simple drain.

Warperup Creek Water Condition Monitoring Results for 2020 to 2022

The following diagram is a pictorial representation of the four basic foreshore condition grades and also illustrates the structural changes to riparian areas as typical Australian streams degrade from their former pristine state.

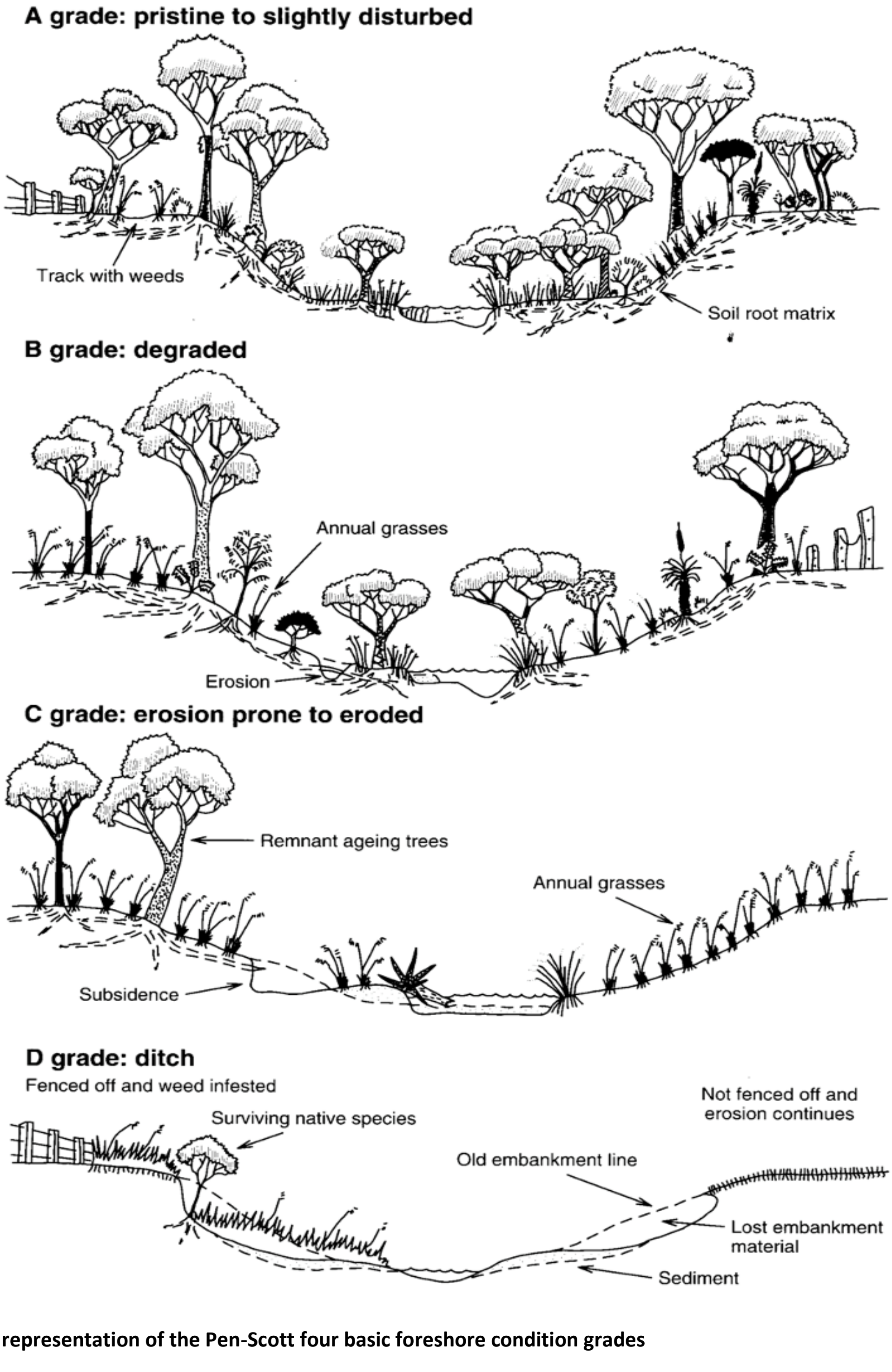


Figure 40: Pictorial representation of the Pen-Scott four basic foreshore condition grades