Mannus Lake cyanobacteria study – monitoring of stratification, nutrients and phytoplankton and determining the effectiveness of mixer

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Summary

Algal blooms of potentially toxic cyanobacteria have been an issue at Mannus Lake and blooms formed in the summers from 2017/18 to 2019/20. Thermal stratification has been identified as an important factor influencing blooms and mixing of the lake was suggested as a management option. A mixer was installed in December 2019 at Mannus Lake while a bloom was present and this did not reduce this bloom. In the 2 subsequent summers 2020/21 and 2021/22 no red alert level algal blooms have occurred. The influence of the mixer on this reduction is not yet clear as these years have also been wet with considerable inflow events to the lake influencing mixing events and lake flushing. Inflows were much higher in magnitude and more frequent in the summers of 2020-21 and especially 2021-22 compared to previous years due to above average rainfall resulting from *La Nina* weather patterns. Thermistor chain data suggests that the mixer is not stopping the formation of strong thermal and dissolved oxygen stratification as stratification formed for brief periods between mixing events. However, other mechanisms such as circulation of algal cells through the water column of the lake may influence algal growth. With 3 more years of monitoring planned it should become clear as to whether the mixer is working as a summer with few inflows is required to better understand the performance of the mixer at reducing algal blooms.

Background

Mannus Lake underwent a series of severe cyanobacterial (blue-green algal) blooms, affecting the water quality of the lake and downstream Mannus Creek. Dense blooms were first reported in late 2017 and recurred in subsequent summers. The potentially toxic *Chrysosporum ovalisporum* is the dominant species during these events, while *Microcystis* sp., *Woronichinia* sp. and *Dolichospermum* sp. have also been observed in high concentrations on occasions. UTS were engaged by Snowy Valleys Council to study the blooms to determine the causes and possible management solutions. Several factors were identified that are likely contributing to the formation of the bloom. Thermal stratification, a separation of the water column due to differences in temperature, occurs over summer in the dam. These conditions appear to favour cyanobacteria who can regulate their buoyancy in the water column. *Chrysosporum ovalisporum* appears to be particularly successful under these conditions. Thermal stratification also leads to anoxic conditions in the bottom water and release of sediment-bound nutrients. These nutrients can increase in concentration when the water column mixes (due to rain, wind action or an inflow event) following a period of extended stratification. In the summers of 2017-2019 extended periods of stratification were observed, and the water column consistently re-stratified after mixing events. This combination of adequate nutrients and strong thermal stratification may have provided the right niche for the toxic cyanobacteria *Chrysosporum ovalisporum* to flourish.

Given that thermal stratification of the water column is a key factor in stimulating the bloom, a possible management approach is to artificially mix the water column with a propeller, air curtain or pump. This needs to be done to a level where it stops stratification from forming and reduces the ability of cyanobacteria to float to the water surface. It can also reduce anoxia in the bottom waters and subsequent nutrient release from sediments. In December 2019, a mixer was installed at Mannus Lake by which time a cyanobacterial bloom had already formed. UTS was again engaged in December to monitor the bloom dynamics and evaluate the effectiveness of the mixer. Early observations of the mixer indicate that thermal stratification was still forming. Given that the mixer was not showing desired performance initially, the position of the mixer was adjusted based on the bathymetry of the lake. This report addresses the state of Mannus Lake through 2021-22 and also within the context of previous years. The effectiveness of the mixer in reducing thermal stratification is discussed.

Cyanobacterial growth

Algal samples have been taken regularly from the dam at both the Outlet and near the Pontoon (mid-dam) since November 2018. Cyanobacteria are not typically present in the cooler months, but dominated the phytoplankton community in the summers of 2018-19 and 2019-20 (Figure 1). The magnitude of these blooms were very large at both sites, reaching biovolumes of >75 mm^3/L, representing a threat to public health. However in the summers of 2020-21 and 2021-22 cyanobacteria were present in small biovolumes and did not reach recreational guideline red alert levels.

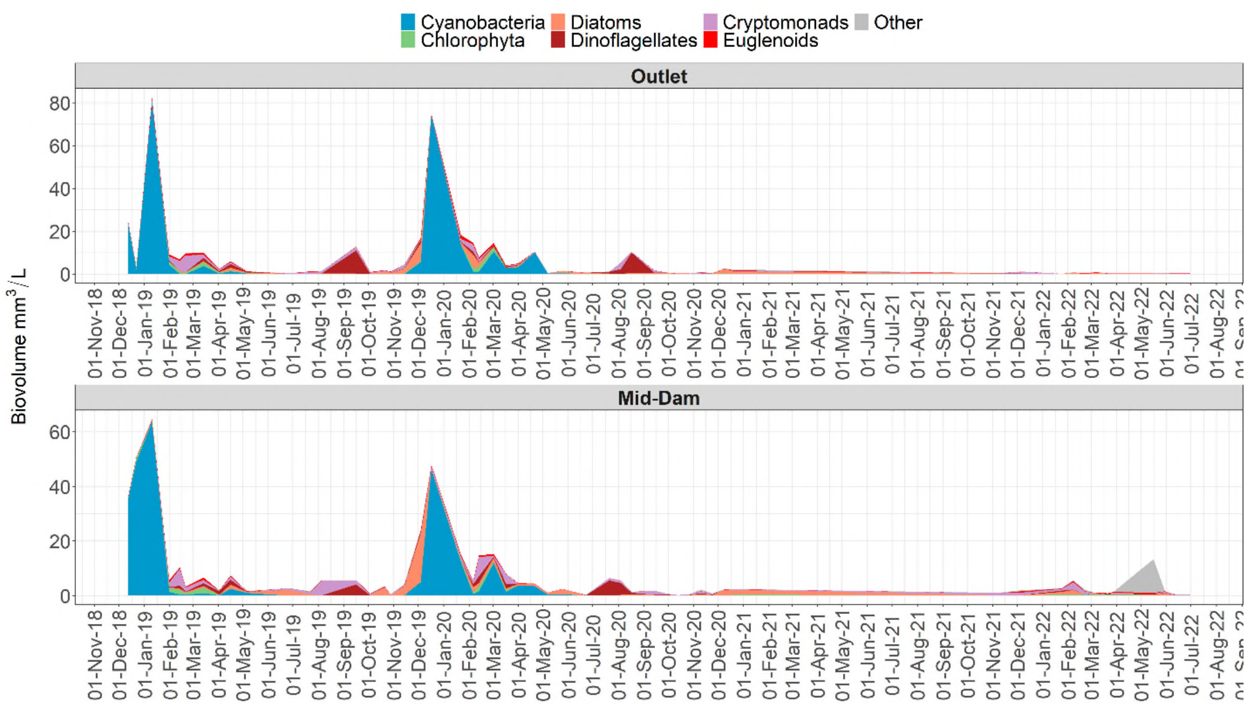

Figure 1. Biovolume of various phytoplankton groups throughout the sampling period. The blue colour represents cyanobacteria.

As discussed in previous reports, *Chrysosporum ovalisporum* is typically dominant from December to February under thermally stratified conditions. Following the breakdown of strong stratification, *Microcystis* and *Woronichinia* can dominate. In the summers of 2020-21 and 2021-22, *Chrysosporum* biovolume remained negligible. *Microcystis* was present at times but at significantly lower numbers than in the summers of 2018-19 and 2019-20 (Figure 2).

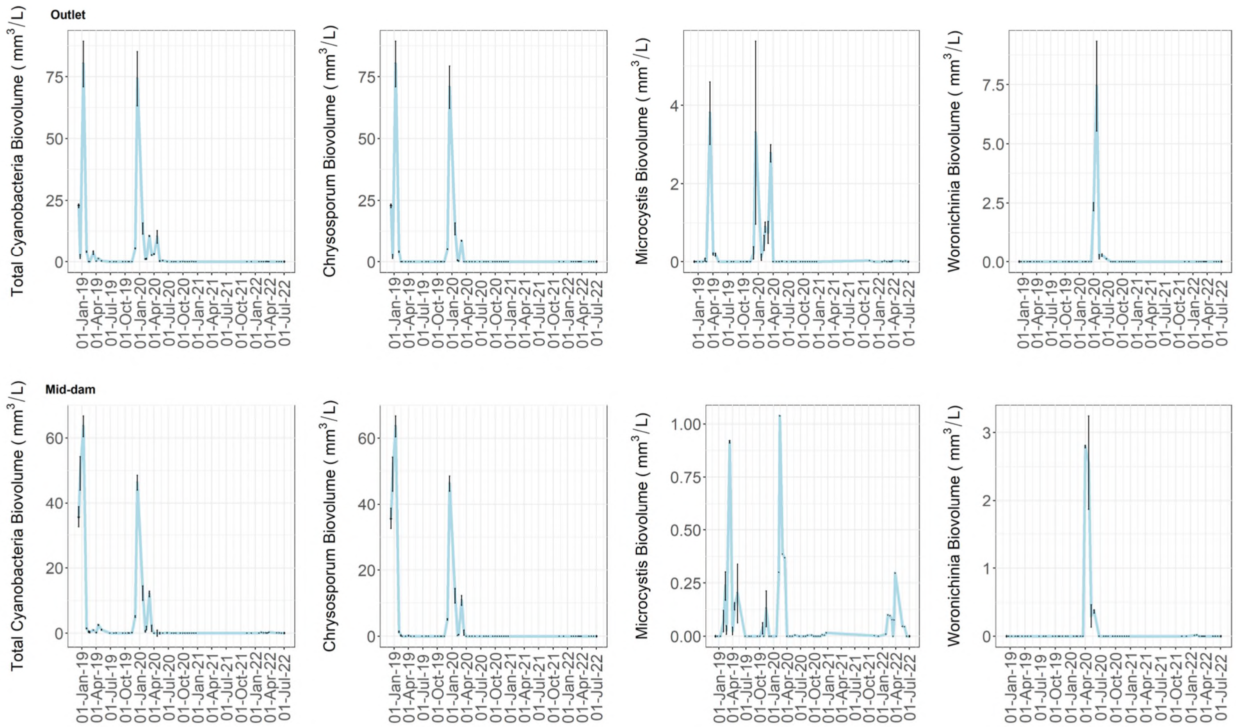

Figure 2: Growth of total cyanobacteria and individual species throughout the study period at Mannus Lake.

Thermal stratification

Thermistor data has been presented from the Outlet site, as this is the deepest and most likely to undergo stratification. It is also closest to the mixer so most accurately examines the efficacy of the unit in mixing the reservoir. Data is recorded every 30 minutes and at 1 m intervals. Thermal stratification is indicated by a change in colour with greater depth in Figure 3. Figures 4 and 5 display thermal stratification in more detail, with a greater gradient of water temperature indicating stratification. Thermal stratification broke down repeatedly throughout the warmer months of 2021-22 (Figures 3, 4, 5). However following mixing events the water column appeared to restratify for short periods during the summer. It is likely that these periods of re-stratification were not long enough in duration for positively buoyant genera such as *Chrysosporum* to reach high densities. This provides further evidence that *Chrysosporum* is predominantly successful under persistently stratified conditions.

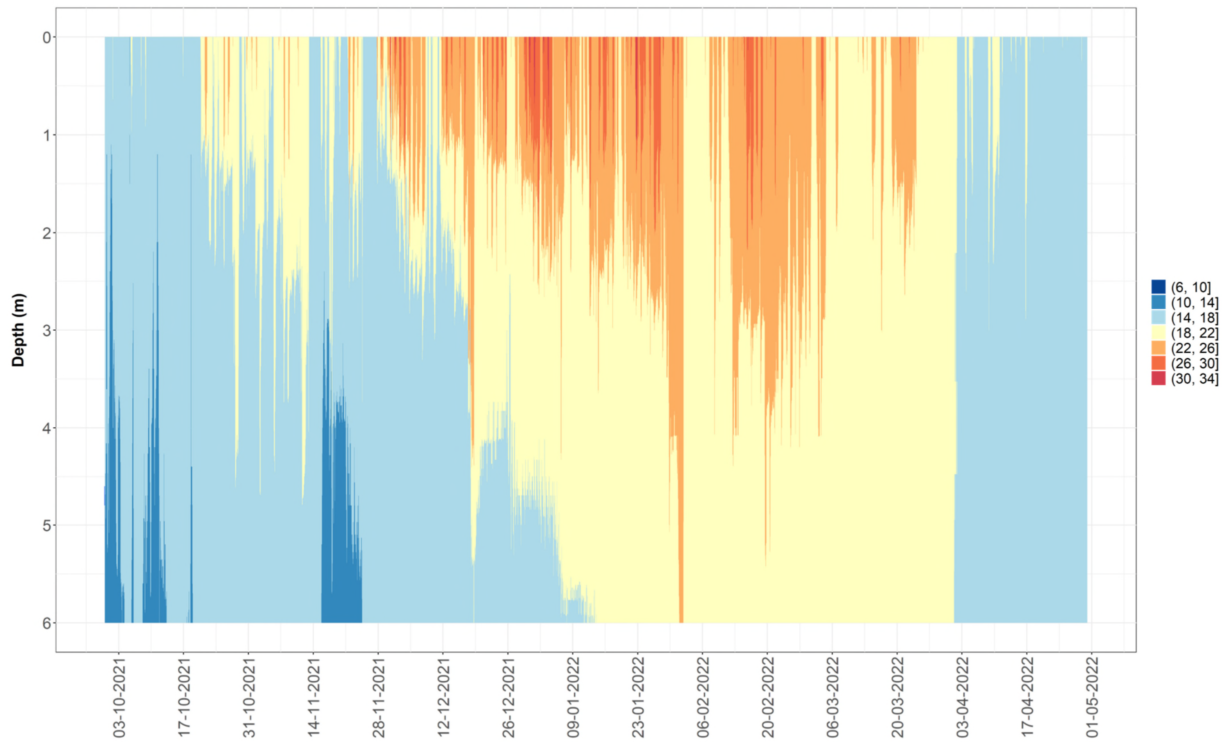

Figure 3: Temperature profile of Mannus Lake at the Outlet

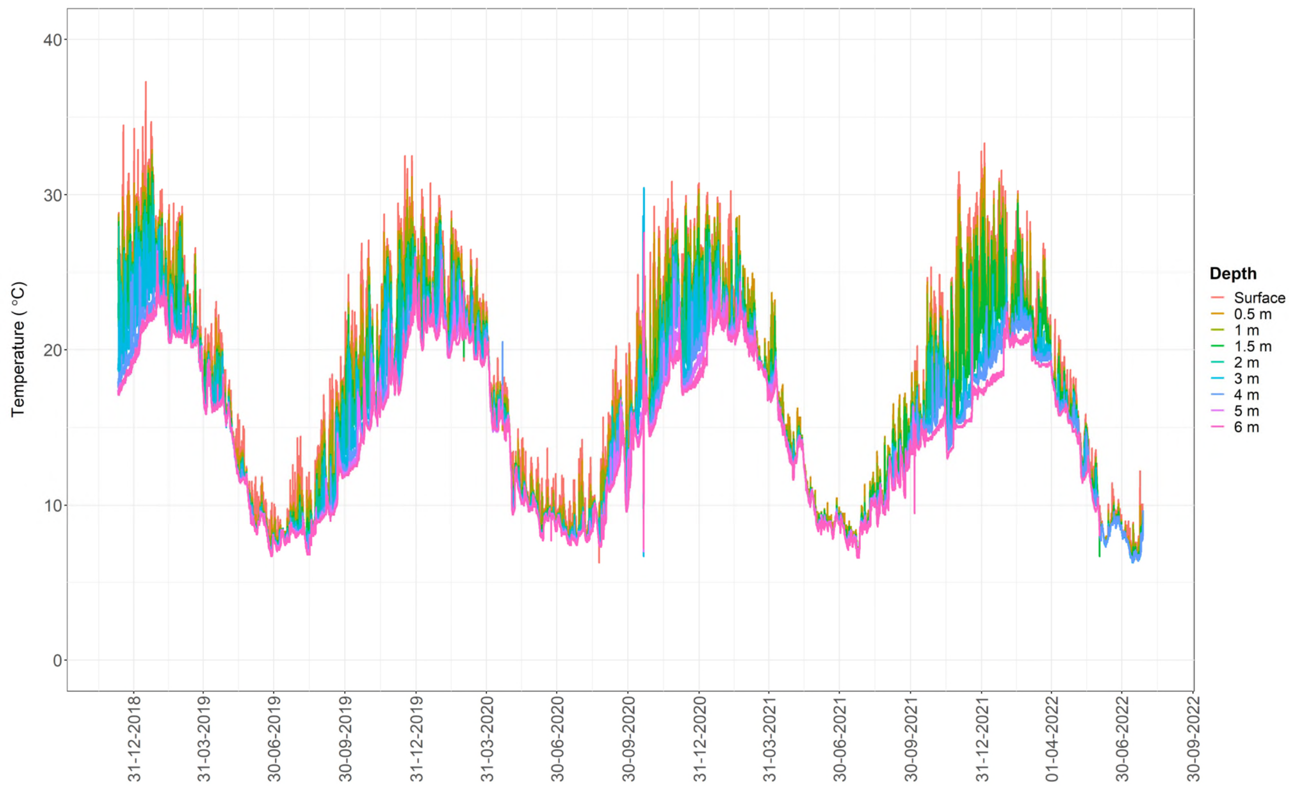

Figure 4: Detailed illustration of thermal stratification at Outlet during whole study period.

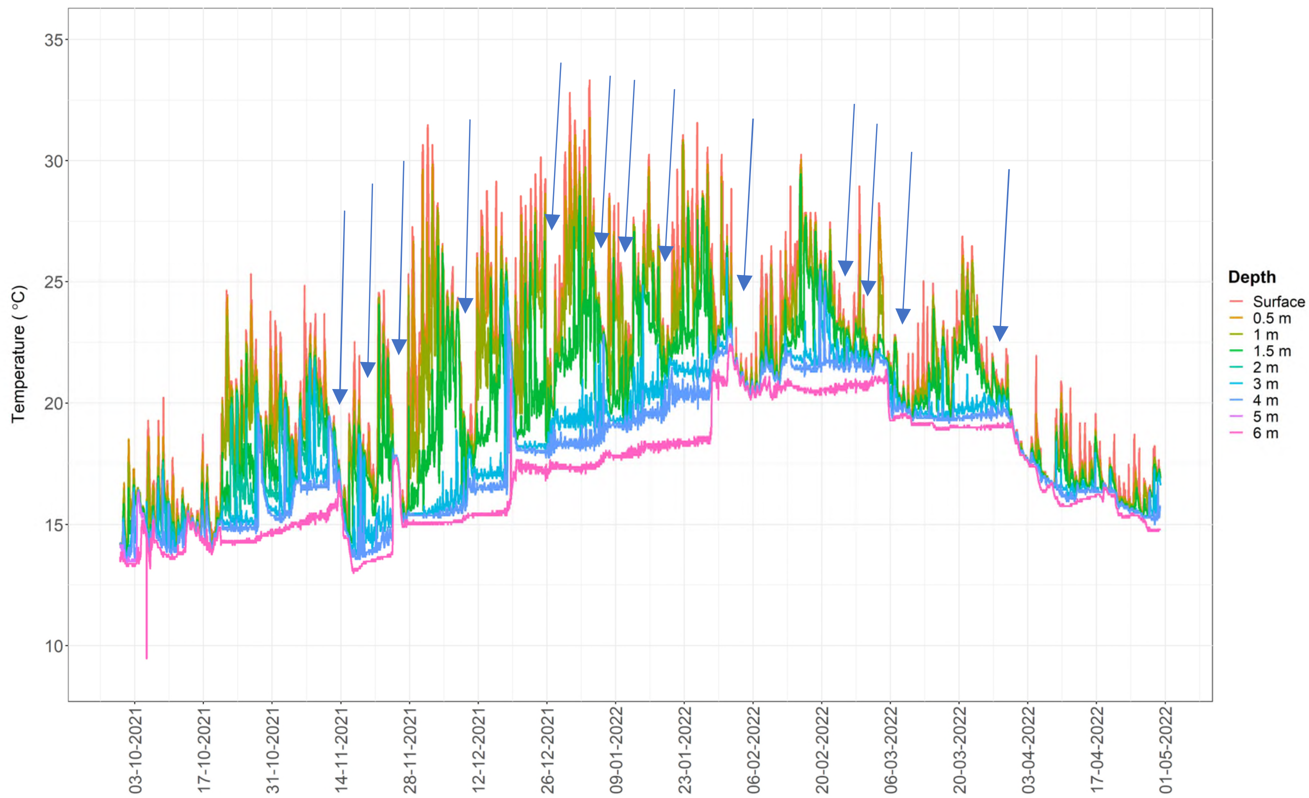

Figure 5: Detailed illustration of thermal stratification at Outlet in latest summer 2021/22. Blue arrows indicate periods when the water column mixed fully or partially.

There were notable differences in the trends of weather data (average daily temperature and rainfall) (Figure 6) and high inflows (Figure 7) in 2021-22 compared to previous years when blooms occurred. High inflows from Mannus Creek consistently corresponded with mixing of Mannus Lake. Inflows were much higher in magnitude and more frequent in the summers of 2020-21 and especially 2021-22, compared to previous years. Six flow events greater than 1000 ML/d occurred during 2021/2022 and several greater than 500 ML/d occurred in 2020/21 compared to almost no large events from 2017/18-2019/20 (one occurred through winter). This was due to above average rainfall resulting from *La Nina* weather patterns (Figure 6). Mixing events coincided with inflows from Mannus Creek >150 ML/d. Maximum summer temperatures were also notably lower than previous years, likely contributing to the reduced prevalence of persistent thermal stratification.

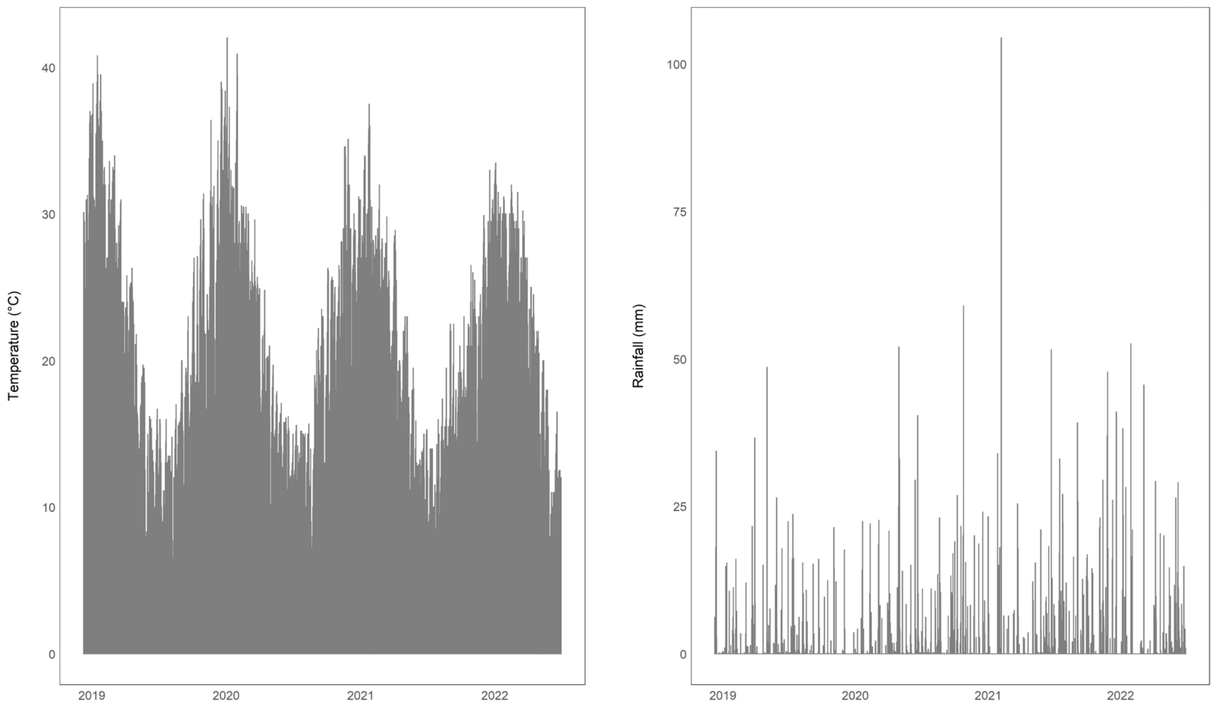

Figure 6: Summary of temperature and rainfall patterns in 2019-2022.

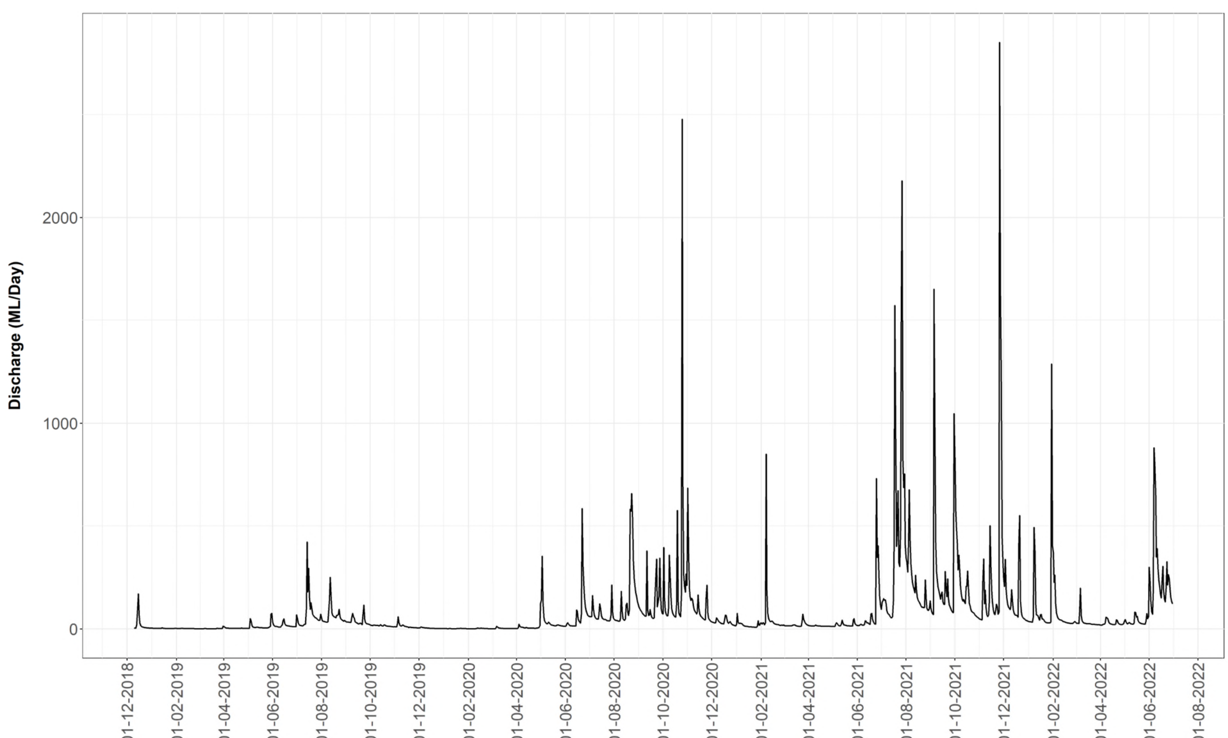

Figure 7: Discharge from upstream Mannus Creek at Yarramundi gauging station.

Dissolved oxygen was measured at the surface and bottom of the Outlet site where thermal stratification is typically the strongest. Often during thermal stratification, anoxia (a lack of oxygen) develops at the sediment-water interface and in the bottom waters. This occurs because no light is being transmitted into the bottom waters and photosynthesis cannot occur, instead heterotrophic processes dominate. This can threaten fish species when anoxia spreads to the surface water following a mixing event, or overnight when algae respire (use oxygen). Anoxia did occur occasionally during 2021-22. Despite frequent mixing events, persistent stratification did occur for shorter periods. The high frequency of inflow events likely brought a high organic carbon load into the lake which may have stimulated heterotrophic bacterial productivity. This may also have contributed to the fluctuations in oxygen level.

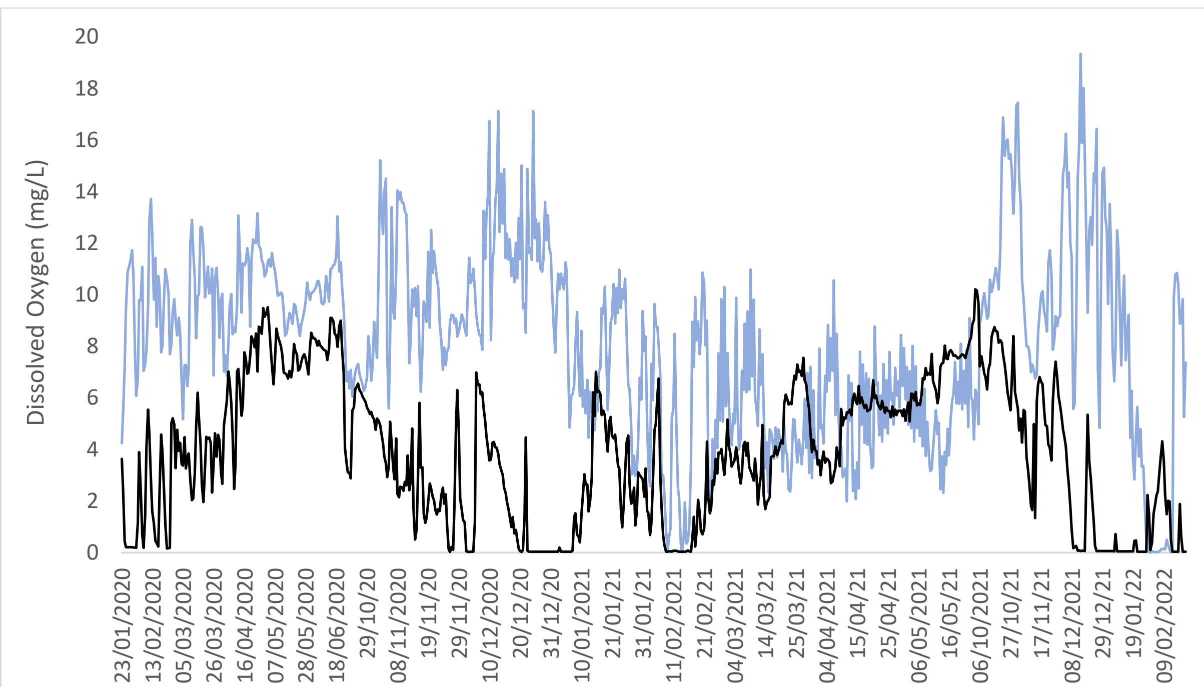

Figure 8: Daily average dissolved oxygen concentrations at the Outlet site. Bottom water concentration is the black line, surface water concentration is the blue line.

Nutrients

Dissolved oxygen concentration can also indicate when nutrients may be released from sediments. Persistent anoxic conditions in the bottom waters can cause nutrients stored in the sediments to be released into the overlying bottom waters. The released nutrients are generally held within the dense bottom water and separated from the less dense warmer waters by a zone of rapid temperature change (known as the thermocline). Nutrients can leak into surface waters during stratification or 'upwell' into surface waters when mixing events occur. This increases the availability of nutrients to cyanobacteria which are concentrated in the surface waters.

As the Outlet site is the deepest, it is the most likely to undergo thermal stratification and subsequent nutrient release from anoxic sediments. There were no notable differences between nitrate and phosphate concentrations in surface and bottom waters in 2021-22 (Figure 9), suggesting that the sediments are not a large source of these nutrients, even during anoxia. However ammonia (a highly bioavailable form of nitrogen) was notably high during January 2022 when anoxia was present at the water-sediment interface. This trend also occurred at the Mid-Dam site but was less pronounced, likely due to its lesser depth and tendency for the water column to mix. There was no evidence of sediment loading of nitrate or phosphate at the Mid-Dam site in the latest study period. At both sites, the concentrations of phosphorus (the key limiting nutrient for algal growth) was less than 20 ug/L on all sampling occasions in 2020. These levels are moderate. Concentrations may have been slightly elevated due to the regular inflow events. Although, given the small size of the dam relative to the size of the inflows nutrients likely had a short residence time in the lake. Mannus Creek continued to have generally higher levels of nitrate compared to Munderoo Creek. Conversely, Munderoo Creek has notably higher concentrations of phosphate. This likely reflects different land-use characteristics in the catchments of the creeks. Nutrient concentrations in the creeks were within a similar range to Mannus Lake.

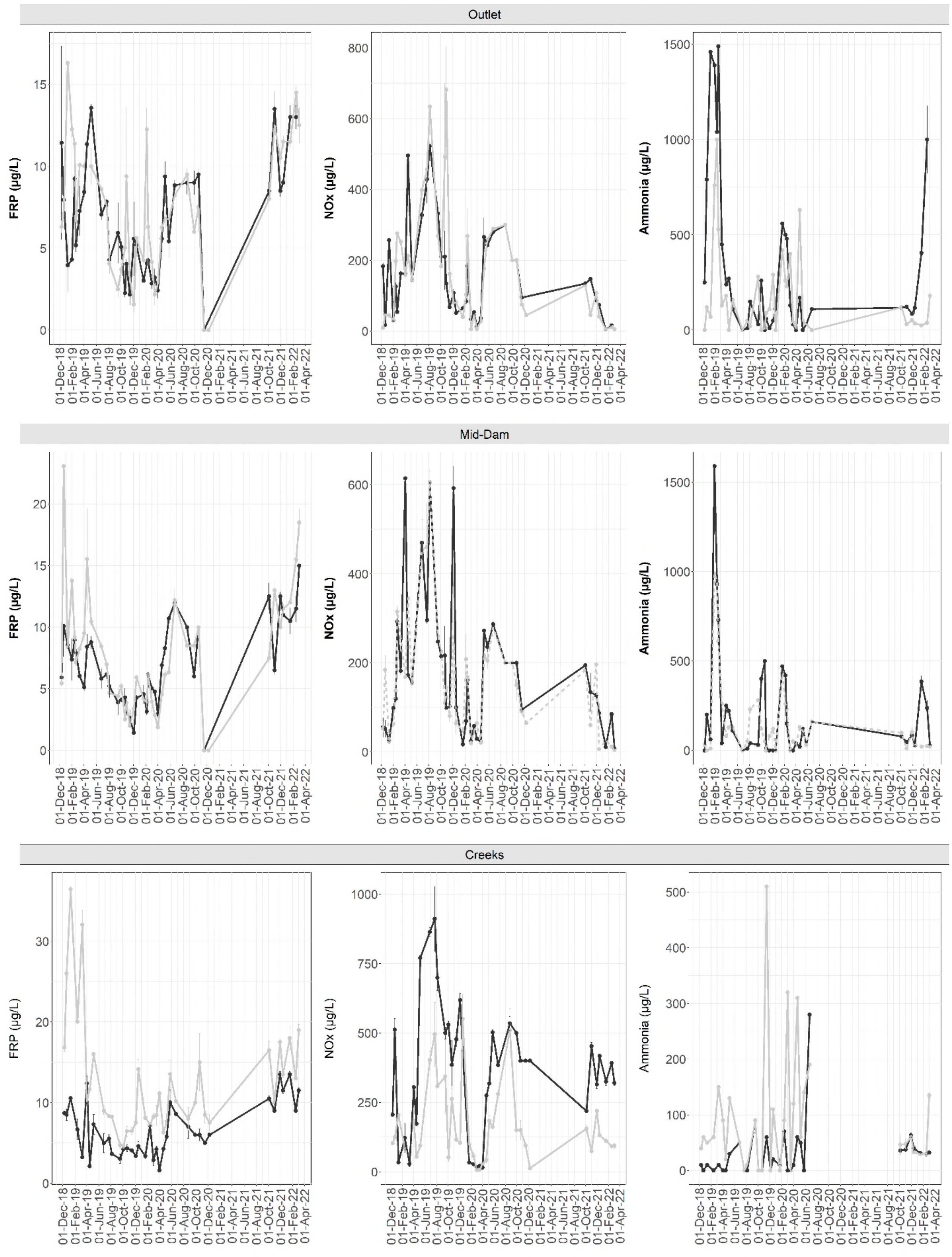

Figure 9: Nutrient concentrations in the surface (black line) and bottom (grey line). At the Creek sites the

black line corresponds to Mannus Creek and the grey line to Munderoo Creek.

Effectiveness of the Mixer

Cyanobacterial blooms were not observed during the summers of 2020-21 and 2021-22. This was likely due to decreased thermal stratification (length of periods and strength) compared to previous summers. However, during this period mixing events coincided with more frequent inflows from Mannus Creek. In between these inflows persistent stratification re-established consistently between December and February. We would expect that after a weather or inflow-driven mixing event the unit would have maintained the mixed conditions if its objective was to fully mix the water column. This does not appear to be occurring. This indicates that the breakdown of stratification and suppression of the cyanobacterial population was most likely due to high inflows as opposed to the mixer. The repositioning of the mixer to a new location in December 2020 has not appeared to improve performance, and stratification was observed nearby the mixer during sampling events and from the thermistor chain. Low nutrient concentrations may have also contributed to the low cyanobacterial biomass. Based on data collected after the unit was repositioned closer to the dam Outlet in December 2020, the effectiveness of the mixer in breaking down thermal stratification appears to be limited. However the mixer may have other benefits such as circulating cyanobacteria and other algae through depth in the water column or reducing surface water temperatures. The following three summers of monitoring will give a better understanding of the performance of the mixer at reducing toxic cyanobacterial blooms as a year with fewer inflows is required.