Mannus Lake cyanobacteria study – monitoring of the bloom and effectiveness of mixer – Stage 2 report

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Background

Mannus Lake has recently undergone a series of severe cyanobacterial (blue-green algal) blooms. Dense blooms were first reported in late 2017 and have recurred in subsequent summers, affecting the water quality of the lake and downstream Mannus Creek. The potentially toxic *Chrysosporum ovalisporum* is the dominant species during these events, while *Microcystis* sp. and *Dolichospermum* sp. were also present in high numbers on occasions. UTS were engaged by Snowy Valleys Council to study the blooms to determine the causes and possible management solutions. After a 12-month study period, 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. The water column consistently re-stratifies throughout summer 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, as outlined in Stage 1 of the most recent study. 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 2020 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 2020 summer up to end December, cyanobacteria were present in small biovolumes and did not reach dangerous levels.

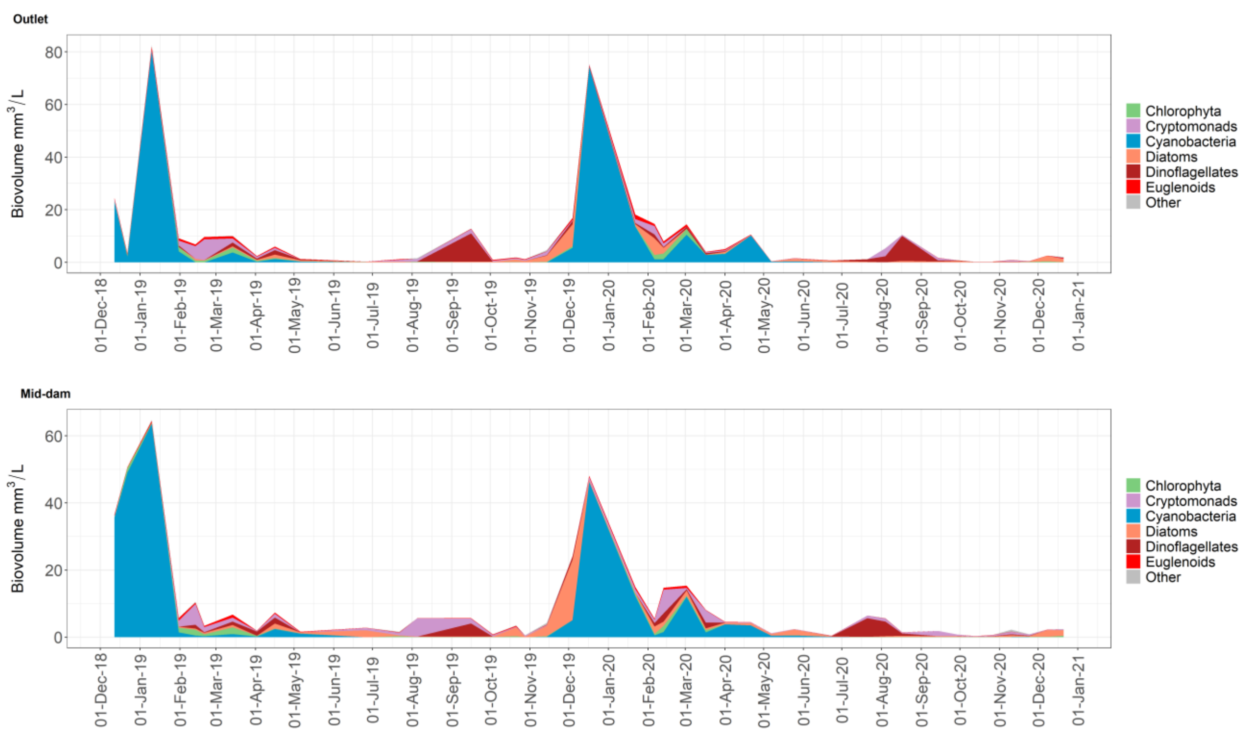

Figure 1. Biovolume of various phytoplankton groups throughout the sampling period. The blue colour represents cyanobacteria.

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 *Dolichospermum* can dominate. In the summer of 2020, *Chrysosporum* biovolume remained negligible. *Microcystis* was present at times but at significantly lower numbers than previous years (Figure 2).

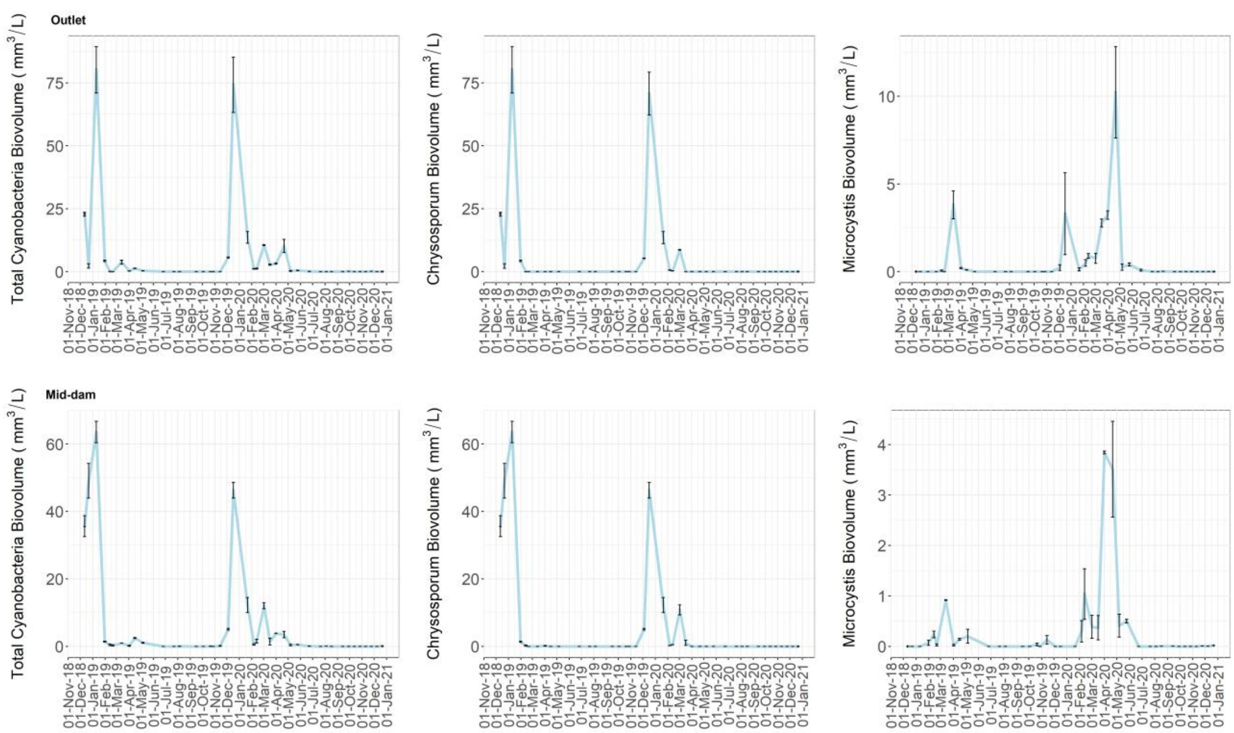

Figure 2: Growth of total cyanobacteria and individual species during the 2019-20 bloom at Mannus Lake.

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 2020 (Figures 3, 4, 5). However following mixing events the water column appeared to restratify for short periods. This is particularly evident in December. It is likely that these periods of restratification 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.

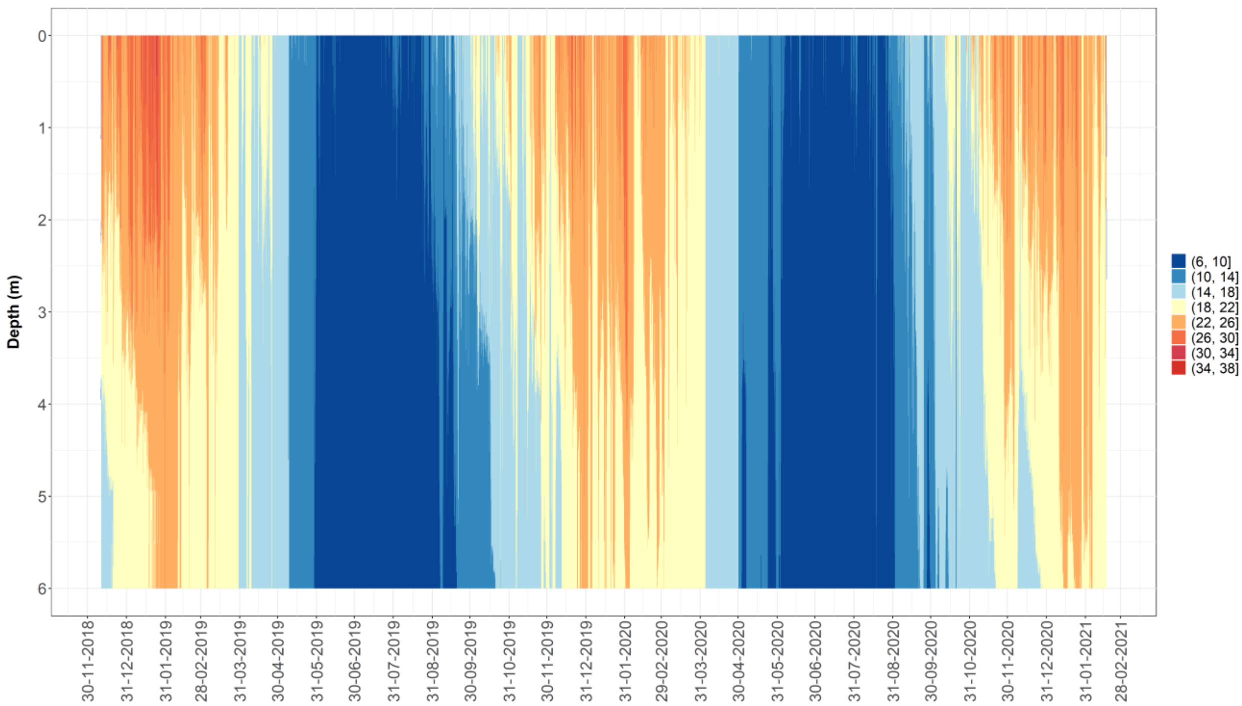

Figure 3: Temperature profile of Mannus Lake at the Outlet

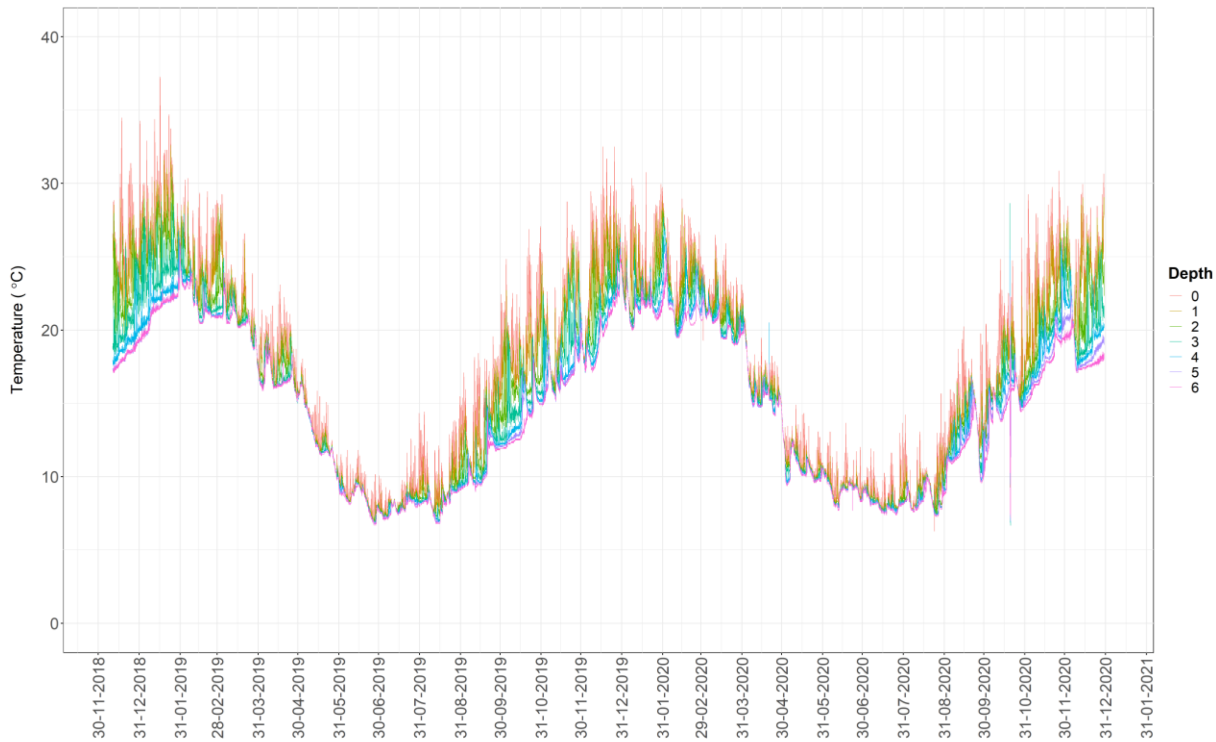

Figure 4: Detailed illustration of thermal stratification at Outlet during whole study period.

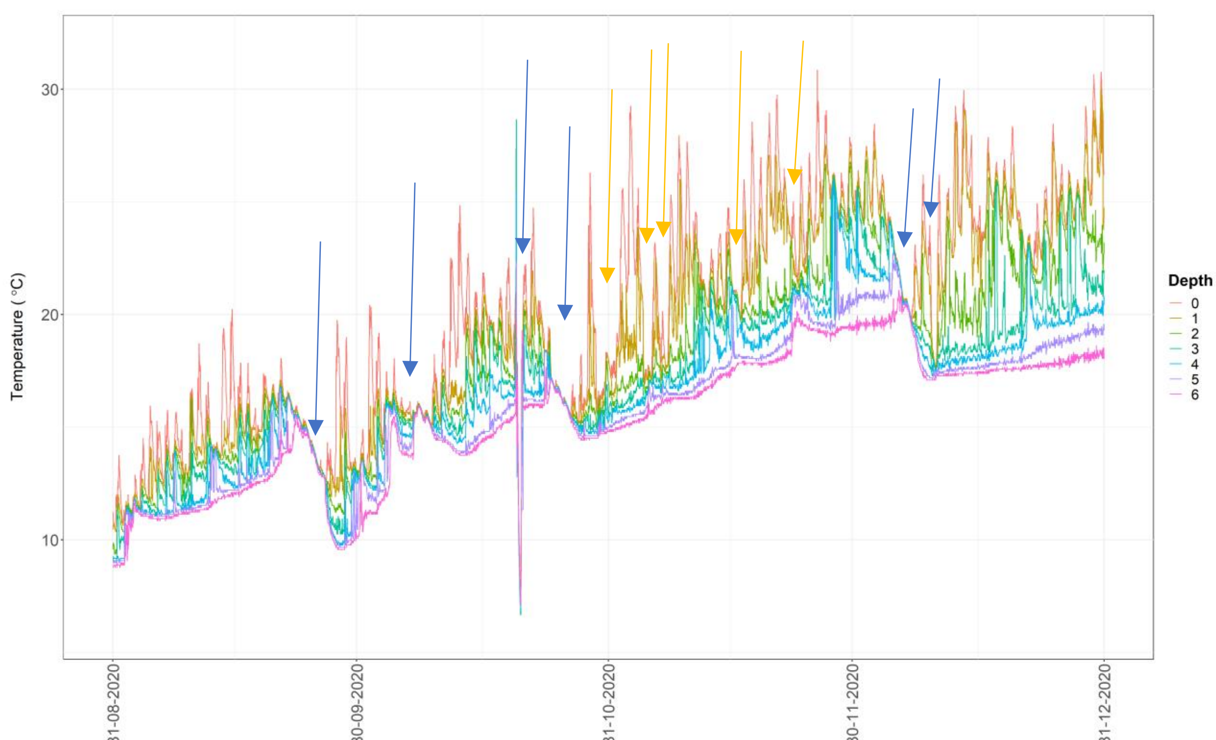

Figure 5: Detailed illustration of thermal stratification at Outlet in latest summer. Blue arrows indicate periods when the water column mixed fully and yellow with partial mixing.

There were a number of major weather events (Figure 6) and high inflows (Figure 7) in 2020. High inflows from Mannus Creek consistently corresponded with mixing of Mannus Lake. Major mixing events occurred on several occasions in October and November during periods of high flow, for example, the 8th, 21th and 27th of October and the 7th, 15th and 23rd November. All of these mixing events coincided with inflows from Mannus Creek >150 ML. On the 6th of December a mixing event occurred with a small inflow ~50 ML and high wind action. Stratification then formed for a short period until a small mixing event on the 21st December following increased discharge.

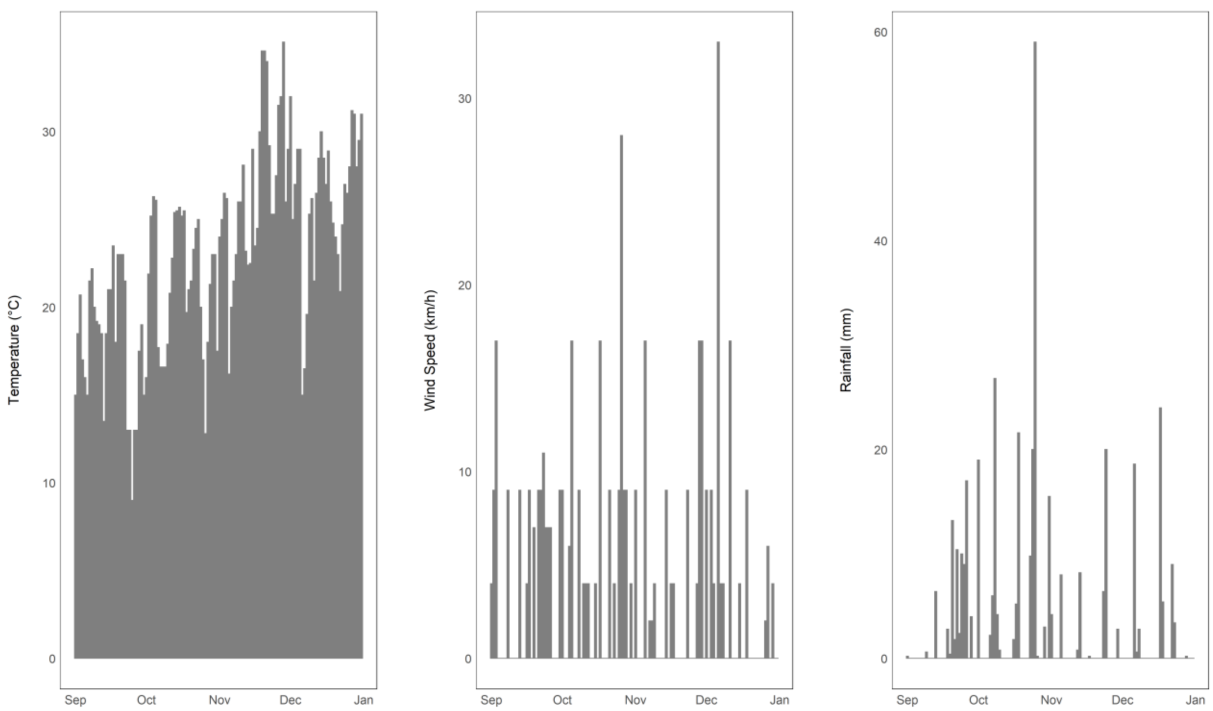

Figure 6: Summary of weather events in late 2020.

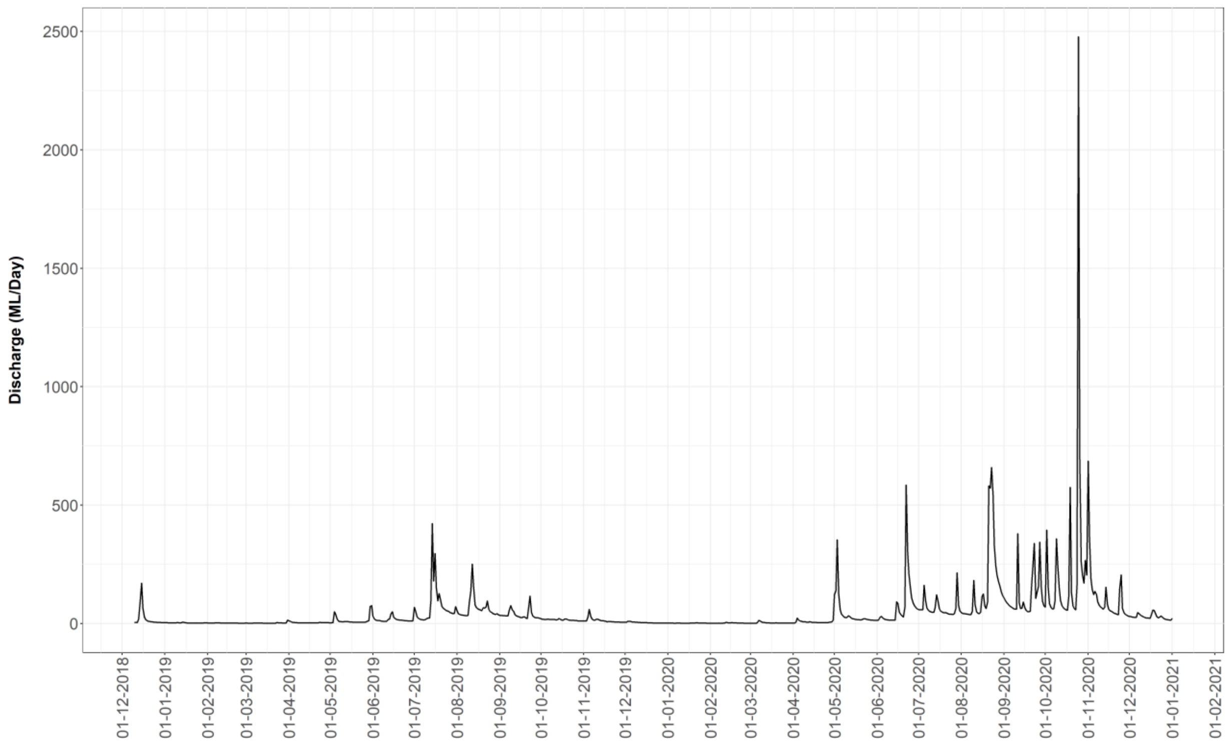

Figure 7: Discharge from upstream Mannus Creek at Yarramundi gauging station.

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. This can threaten fish species when anoxia spreads to the surface water following a mixing event, or overnight when algae respire (use oxygen). Anoxia was infrequent during 2020, likely due to regular mixing of the water column. Anoxia became evident in December when the water column stabilised.

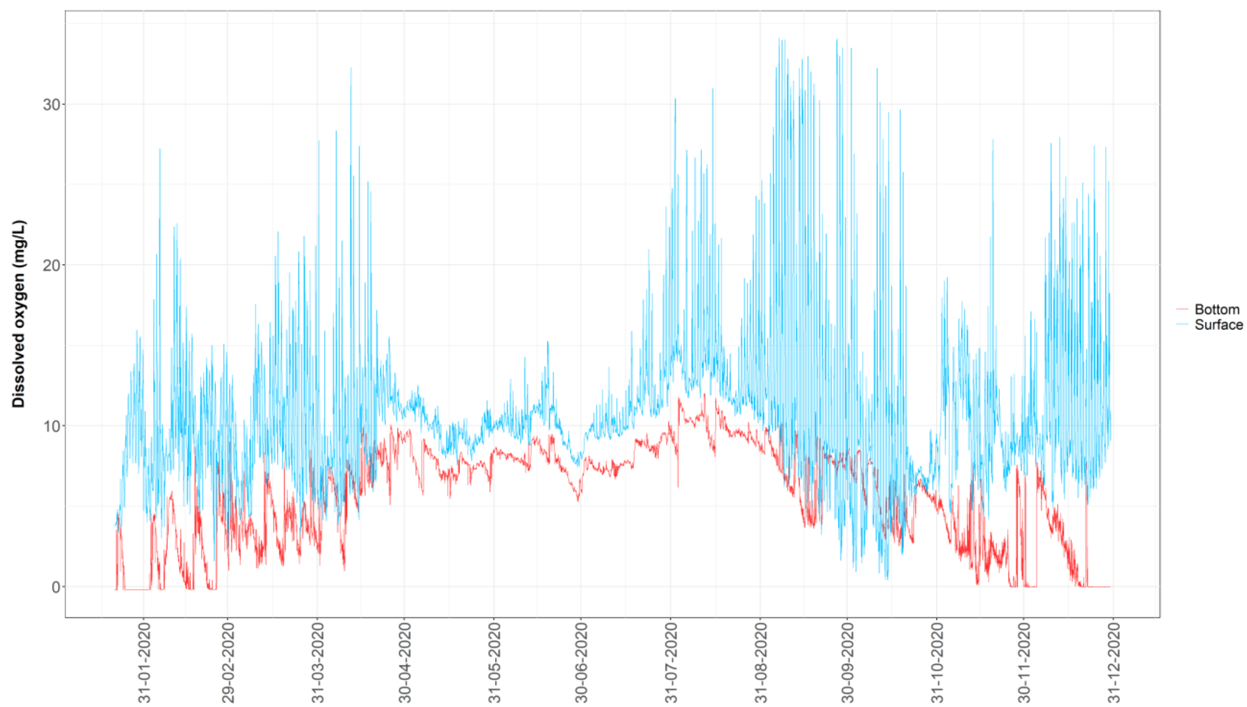

Figure 8: Dissolved oxygen concentrations at the Outlet site during January-March. Bottom water concentration is the red line, surface water concentration is the blue line.

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.

The concentration of nitrate at the Outlet site is presented in Figure 9, and phosphate in Figure 10. 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 mid-late 2020. This reflects fairly oxic sediments, particularly in the winter months. As observed in previous years, nitrate concentrations were higher in winter than summer, perhaps a result of less nitrate being incorporated into algal biomass or due to increased nutrient inputs from the catchment. The decreasing nutrients concentrations in October-November may have also been due to a dilution or flushing effect caused by the very high discharges.

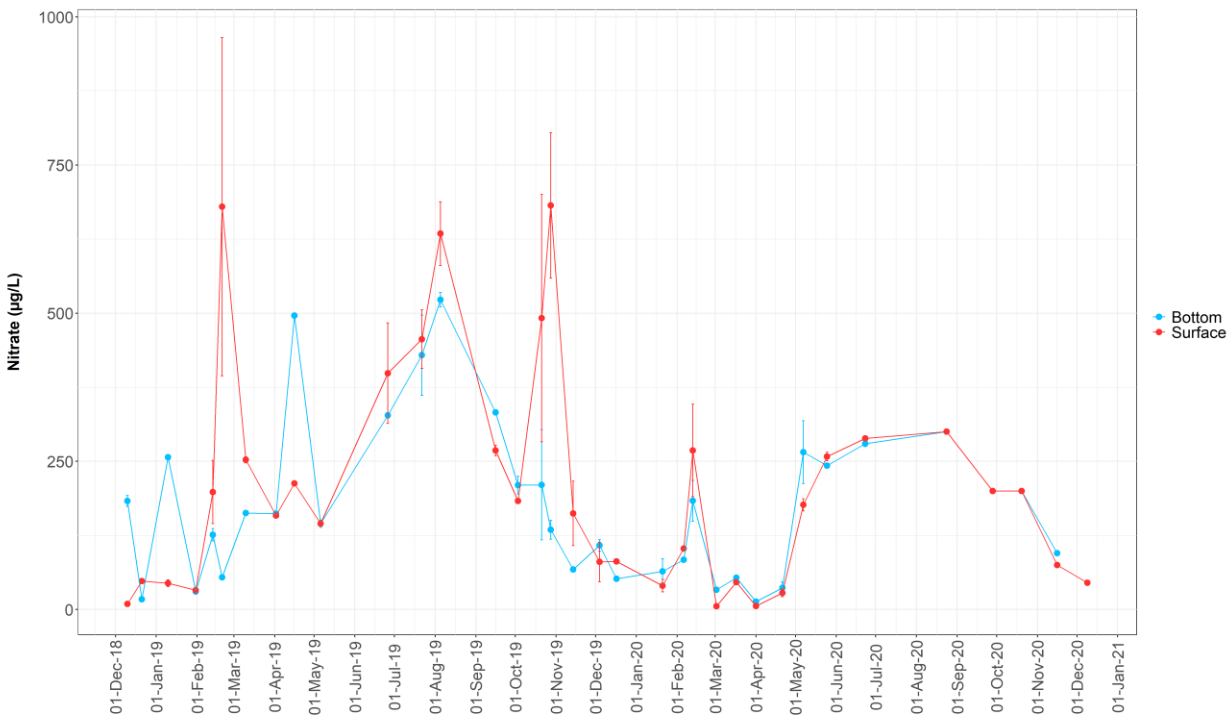

Figure 9: Nitrate concentrations in the surface (red line) and bottom (blue line) at the Outlet site.

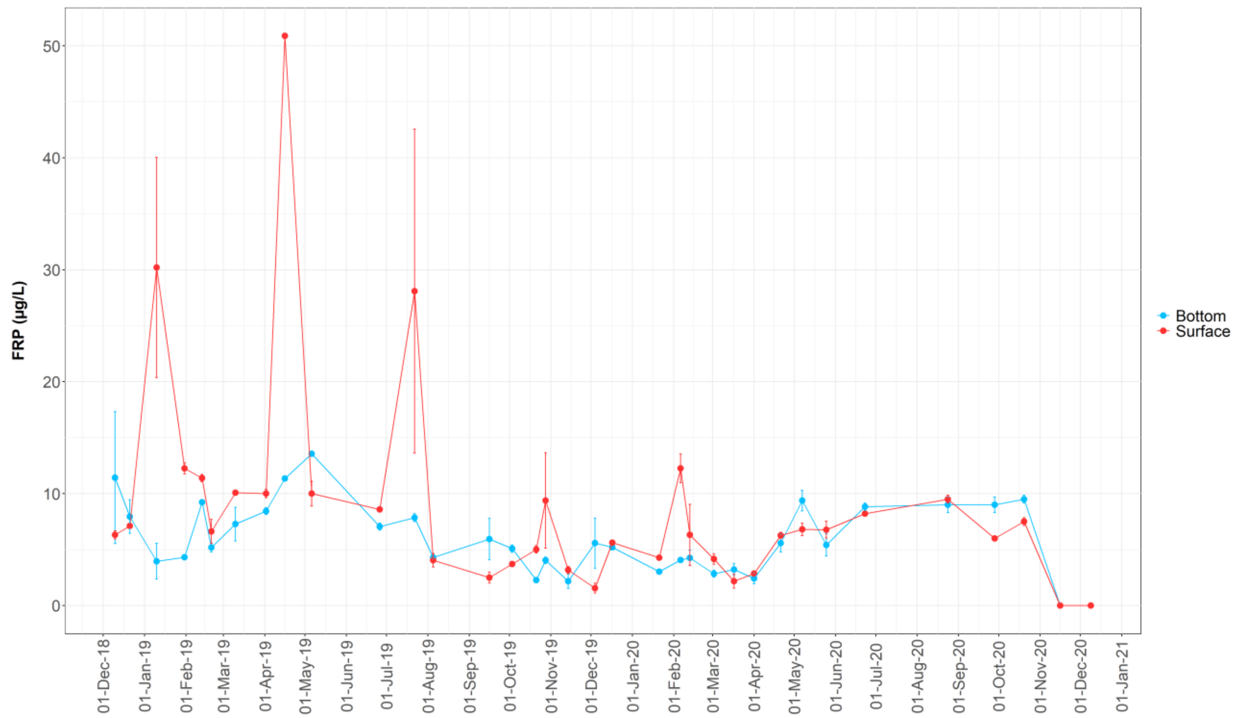

Figure 10: Phosphate concentrations in the surface (red line) and bottom (blue line) at the Outlet site.

The Pontoon site followed similar trends to the Outlet in terms of nitrate (Figure 11) and phosphate (Figure 12) concentration in 2020. Concentrations were higher in the colder months from May-September, before decreasing steadily when inflows increased. There were not notable differences between the surface and bottom water concentrations of either nitrate or phosphate in the latest study period. At both sites, the concentrations of phosphorus (the key limiting nutrient for algal growth) was less than 13 ug/L on all sampling occasions in 2020. These levels are not excessively high. In November-December, phosphate concentrations at both sites were very low (<5 ug/L), which may have also contributed to the low cyanobacterial biovolume.

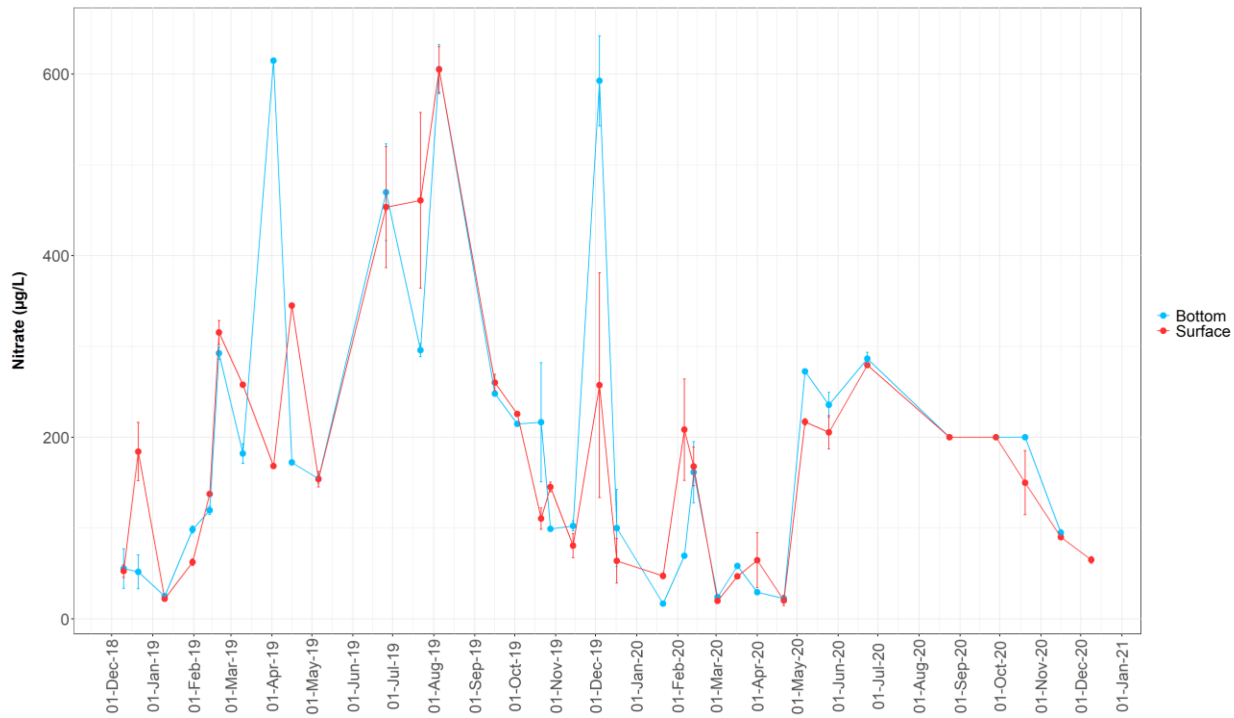

Figure 11: Nitrate concentrations in the surface (grey line) and bottom (black line) at the Pontoon site.

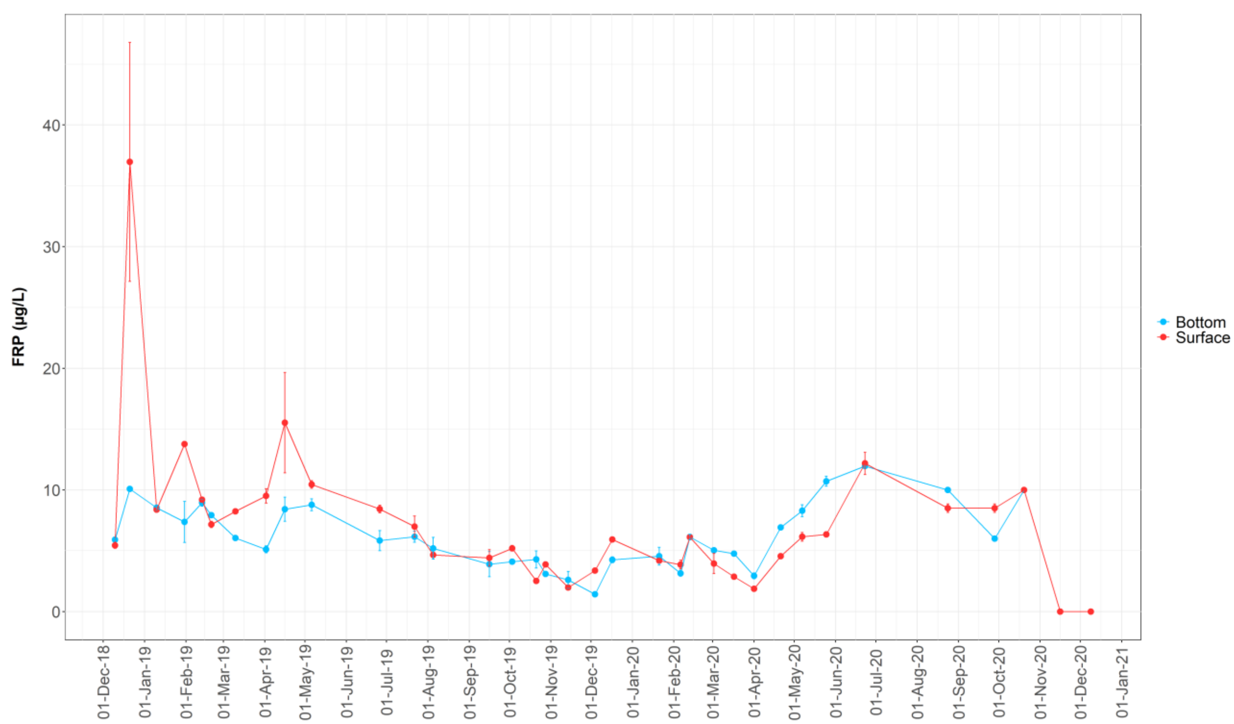

Figure 12: Phosphate concentrations in the surface (red line) and bottom (blue line) at the Pontoon site.

The nitrate concentrations measured in Mannus Creek and Munderoo Creek are displayed in Figure 13, and phosphate in Figure 14. 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. Phosphate concentrations were higher in both creeks than in Mannus Lake in late 2020. However, the higher nutrient loads coming from the creeks did not translate into a meaningful increase in phosphate concentrations in the lake, likely due to dilution or rapid incorporation into algal or macrophyte biomass.

Figure 13: Nitrate concentrations in Mannus Creek and Munderoo Creek

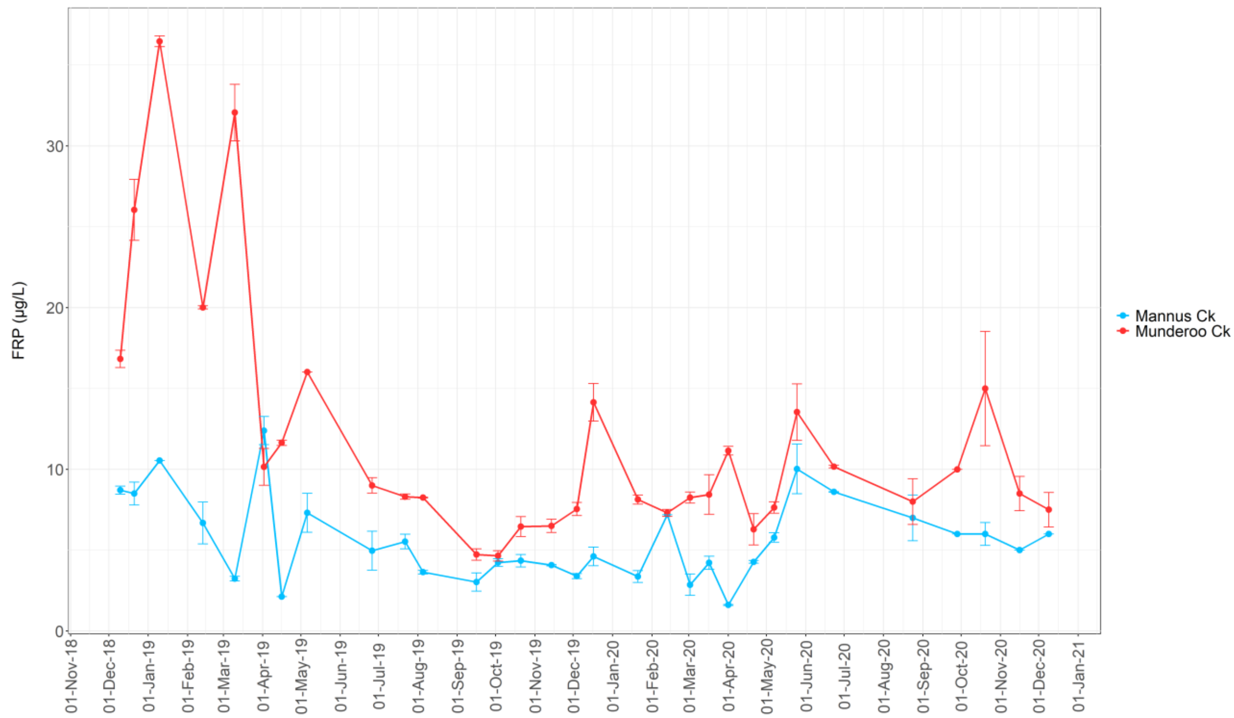

Figure 14: Phosphate concentrations in Mannus Creek and Munderoo Creek

Effectiveness of the Mixer

While thermal stratification was significantly reduced in 2020 compared to previous summers, mixing events coincided with inflows from Mannus Creek. In between inflows, and particularly during December when inflows were reduced, persistent stratification re-established rapidly. We would expect that after a weather or inflow-driven mixing event the unit would have maintained the mixed conditions. 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 discharge as opposed to the mixer. 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. Given that the mixer was only repositioned in December, near the time when stratification was beginning to establish, this may not have allowed enough time for the mixer to turn over the water column. The next few summers of data collection will reveal the broader effectiveness of the mixer on both stratification as well as algal blooms.