Mannus Lake blue-green algal bloom management study – Interim Report

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Summary
A research program was implemented in December 2018 to better understand the causes of toxic cyanobacterial blooms at Mannus Lake and to indicate possible management approaches. Two major blooms occurred between December 2018 and May 2019. This interim report summarises the major findings so far into the potential causes of the blooms and possible management options.

Causes of blooms

Chrysosporum blooms appear to be related to the development of persistent thermal stratification. The bloom appeared several weeks after the establishment of strong persistent thermal stratification in the lake. There is likely a seed bank in the sediment and under these stable water column conditions the algae grow and dominate. Sediment released nutrients may help sustain or magnify these blooms, however surface waters appear to have enough nutrients to maintain high density growth. The bloom ended when the water column mixed in late January and several mixing events occurred in close succession through February. *Microcystis* and *Dolichospermum* blooms occurred in April 2019 under further periods of stronger thermal stratification. There were a few mixing events through this period but persistent stratification lasted for extended periods (greater than 12 days consecutively) at the time of this bloom. Stratification was weakened from late April and the water column mixed daily. From this period toxic cyanobacterial numbers decreased to below guideline levels.

Possible management actions

As *Chrysosporum* blooms occurred with the establishment of strong persistent thermal stratification in the lake, mechanical mixing of the lake to stop this occurring should prevent the blooms from forming. A mixer such as a fan/propeller that limits the formation of thermal stratification to just a few degrees or less on a daily cycle (full mixing of the water column at night) should reduce or stop these blooms from occurring. Reduced ability to utilise buoyancy should prevent *Chrysosporum* blooms due to reduced light availability and reduced competitive advantage over other algae. Mixing would have the added effect of maintaining oxygen through the water column and reducing the potential release of nutrients from the sediment. Blooms of *Dolichospermum* and *Microcytsis* occurred in April under a persistently stratified water column at the outlet, however, mixing events were more common at this time. The blooms decreased in biovolume as mixing events increased while water temperature, Secchi depth and available nutrients remained relatively stable. It is likely that artificial mixing of the water column will reduce the risk of these blooms from occurring as well, however, it should be considered that there is a possible risk that they may form under "less" stratified conditions.

Some longer term management approaches may also be to improve nutrient management in the catchment – in particular NOx from the Mannus Lake system. The Munderoo Creek system also had consistently low oxygen concentrations indicating high organic matter/reducing materials in the system. Macrophytes can be effective at helping to prevent cyanobacterial blooms from occurring. Reducing cyanobacterial blooms through mixing should increase water clarity and help the macrophytes re-establish. Planting macrophytes or protection of existing macrophytes and the riparian zone should help to prevent blooms and a system where the water is clearer tends to promote macrophytes and not algal blooms. This may be supported by improving water quality (sediments and nutrients) coming from the catchment through Mannus and Munderoo Creeks.

Background

Mannus Lake has recently experienced severe algal blooms of the potentially toxic cyanobacteria *Chrysosporum ovalisporum*. The bloom was for noticed between late 2017 and early 2018 after public complaints about downstream water quality. UTS were engaged to do a short study of this bloom in early 2018 and sampling and analysis were undertaken for 5 weeks with some samples supplied by Snowy Valleys Council for a further few weeks. Without data prior to and during the initiation of the bloom it was difficult to determine conclusively the causes of the bloom. However examination of the limited available data before the bloom formed and data collected after the bloom indicated several factors that may have led to the bloom forming. Firstly, thermal stratification occurs over summer in the dam, leading to anoxic conditions in the bottom water and release of sediment-bound nutrients, particularly ammonia. These nutrients were largely kept within the bottom waters, separated from the surface waters by a thermocline (rapid change in temperature). In December 2017 a high rainfall event occurred which led to a large influx of water into the dam which resulted in mixing of the water column. This mixed the water column and brought bottom water nutrients to the surface and may have also brought nutrients into the lake from the catchment. The inflow may have also brought in sediments that may have reduced the light penetration depth to a lower level. This combination of high nutrients and reduced light levels may have benefited buoyant cyanobacteria when the lake re-stratified approximately a week later. The stratified water column, low light penetration and high nutrients may have allowed the bloom to develop to the high densities measured.

Following this initial study a research program was implemented in December 2018 to better understand the causes of toxic cyanobacterial blooms and to indicate the best management approaches. A possible approach may be to include artificial mixing of the water column with a propeller. This stops stratification from forming and reduces the ability of cyanobacteria to float to the water surface and reduces sediment nutrients from being released (stopping the formation of anoxic bottom waters). This interim report examines the data collected to date from UTS sampling from December 2018 to early May 2019 and gives preliminary conclusions. Sampling started just after the formation of another *Chrysosporum* bloom in November/December and analysis includes the algal count data that council had collected prior to this and other data collected by council.

Results of the investigation so far

Cyanobacterial Growth

Algal samples were taken from the Outlet and Pontoon from November 2018. Cyanobacterial biovolume started to increase in mid-November and by early December bloom levels were reached (Figure 1). Extremely high biovolume was recorded for both the Outlet and Pontoon sites. There was a reduction in biovolume in late December that coincided with an inflow to the dam after higher rainfall on 15th -16th December. The bloom then increased in magnitude with biovolume reaching above 80 mm^3/L. The bloom reduced in biovolume through January and by early February had ended at both the outlet and pontoon sites. Biovolume of toxic cyanobacteria again increased in mid-April through to May after which toxic cyanobacterial biovolume decreased.

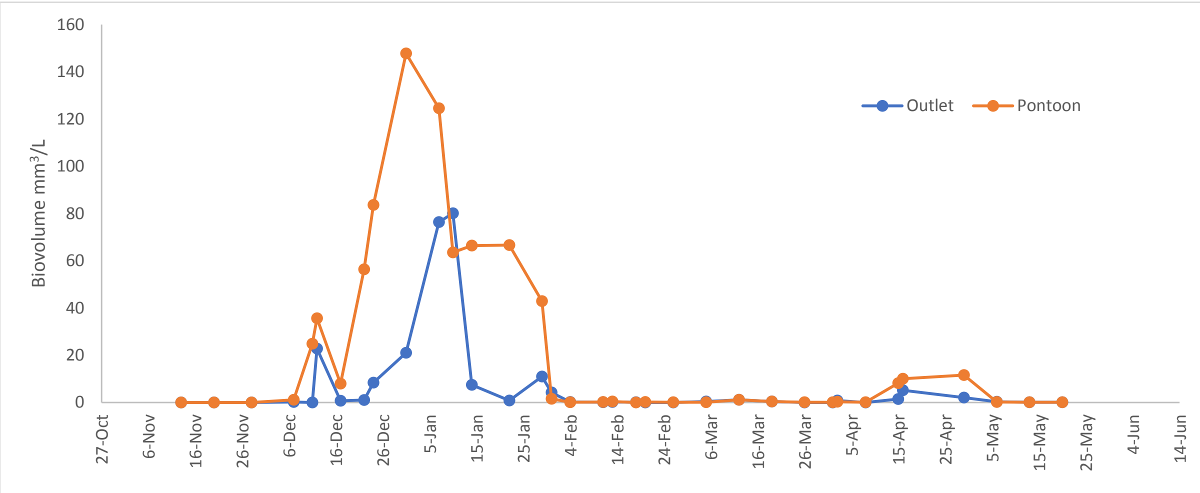

Figure 1. Toxic cyanobacterial biovolume at Mannus Lake from November 2018 to May 2019.

The first bloom through December, January and February was dominated by *Chrysosporum* (reaching red alert on the 11th December 18). This bloomed through till the end of January. Samples taken on the 31 January were still in Red alert while samples taken on the 4th Feb showed very reduced numbers. A second bloom by *Microcystis* or *Dolichospermum* or both (Figure 2) occurred during April 2019. *Chrysoporum* had the greatest biovolume of the three toxic species, however biovolume of *Dolichospermum* sp. (potential saxitoxin producer) and *Microcystis* sp. (potential microcystin producer) were above recreational guidelines in April.

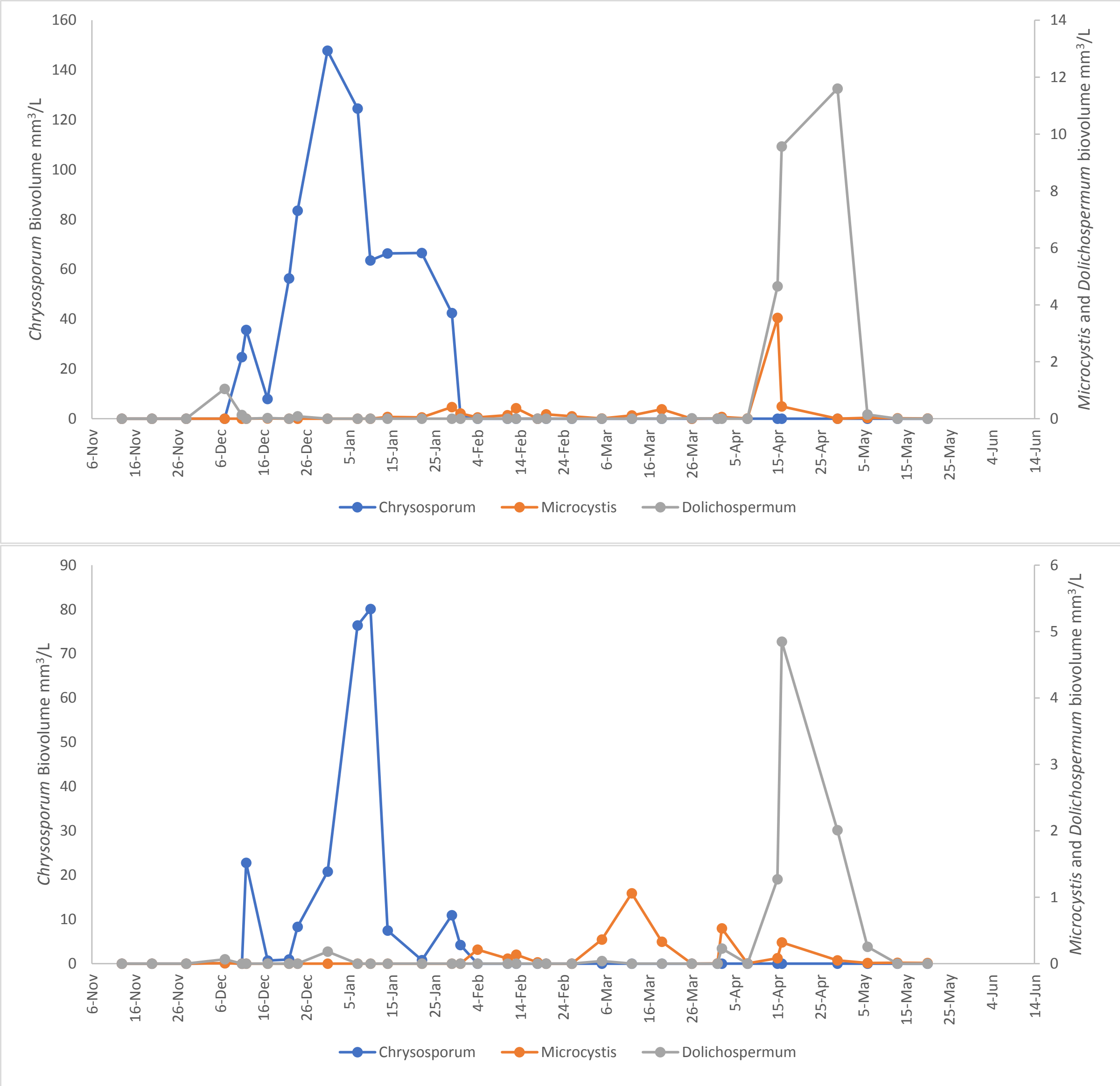

Figure 2. Algal biovolume of dominant toxic cyanobacterial species at Mannus Lake from November 2018 to May 2019. Top figure is the Pontoon site and Bottom is the Outlet site.

Thermal stratification

UTS started collecting thermistor data (temperature readings through depth at 30 minute intervals) from the 12/12/19 at the Outlet site (Figure 3) and at the Pontoon site (Figure 4). These figures show that thermal stratification was already established at this time, shown by the different colours on the graph (warmer water at surface and cooler water as you move lower in the water column). To examine thermal stratification before the UTS thermistor chain was deployed, limited data (daily measurements at four depths) provided by Snowy Valleys Council showed that thermal stratification strengthened around mid-November (Figure 5). This data only allows an approximation of whether the water column mixed or not (you need at least hourly data for this), but it seems consistent with the later data (December/Jan) and the UTS data that mixing was limited from this time and two layers were formed (surface epilimnion and bottom hypolimnion). This is consistent with the appearance of low numbers of *Dolichospermum* on the 28th November and *Chrysosporum* appearing with *Dolichopsermum* on the 7th December 2018. These two cyanobacteria grow well under conditions of a more stable water column (stratified water column conditions). Samples on the 11/12/19 showed high numbers of *Chrysosporum*. This would give three weeks for the development of *Chrysosporum* blooms and this would be consistent with the numbers seen on the 11/12/19.

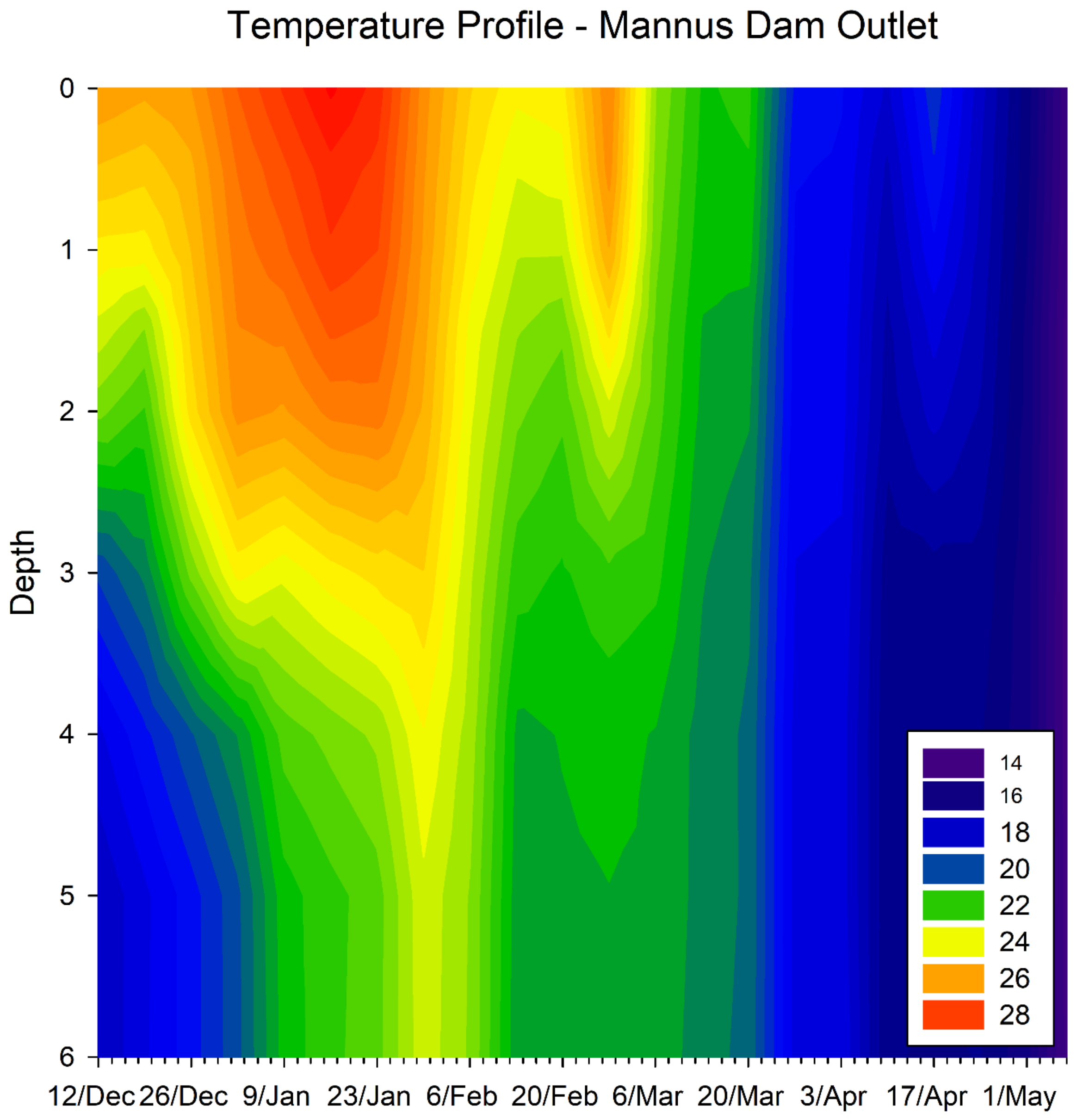

Figure 3. Thermal stratification in Mannus Lake at the outlet December 2018 to May 2019.

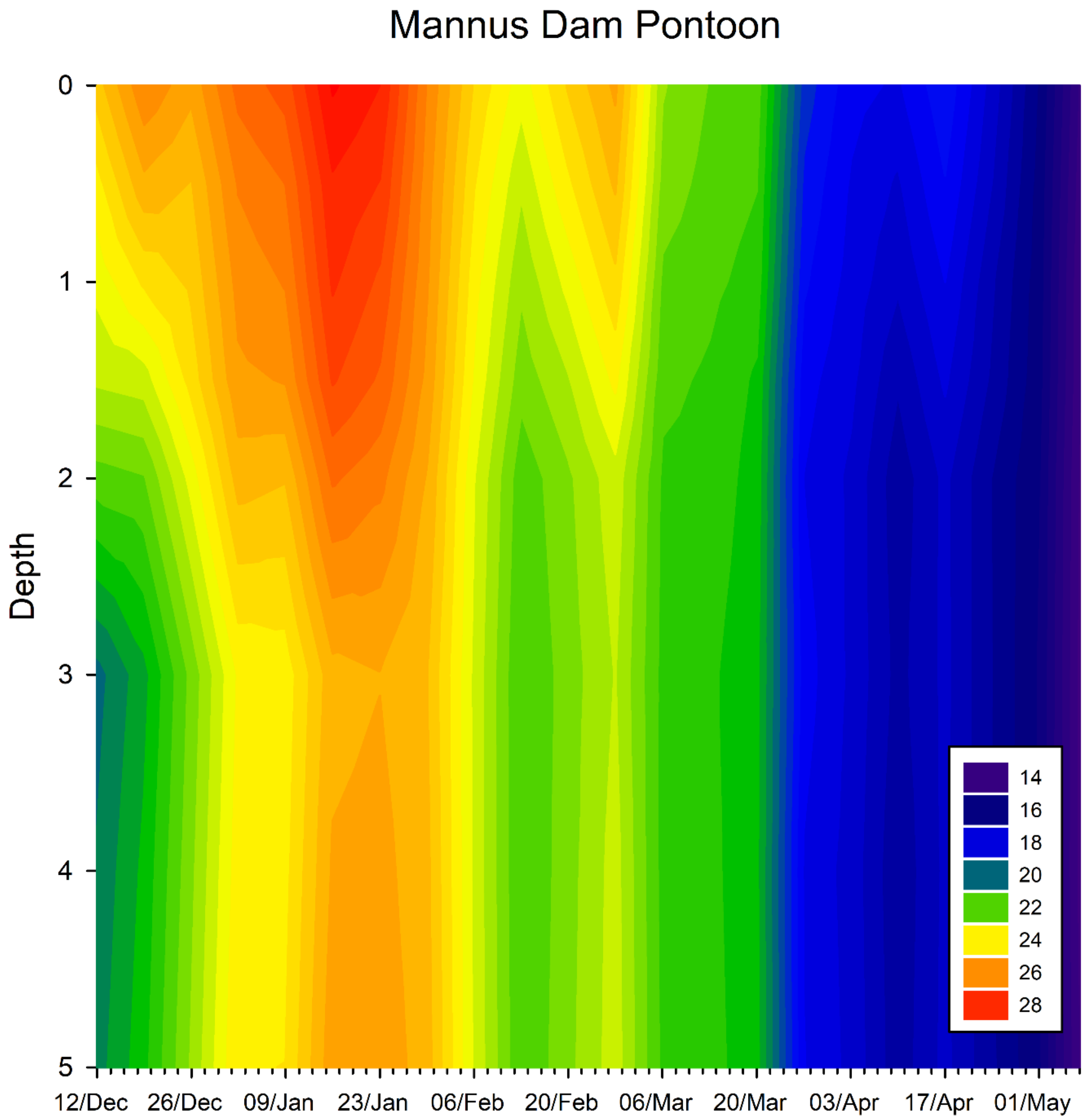

Figure 4. Thermal stratification in Mannus Lake at the Pontoon December 2018 to May 2019.

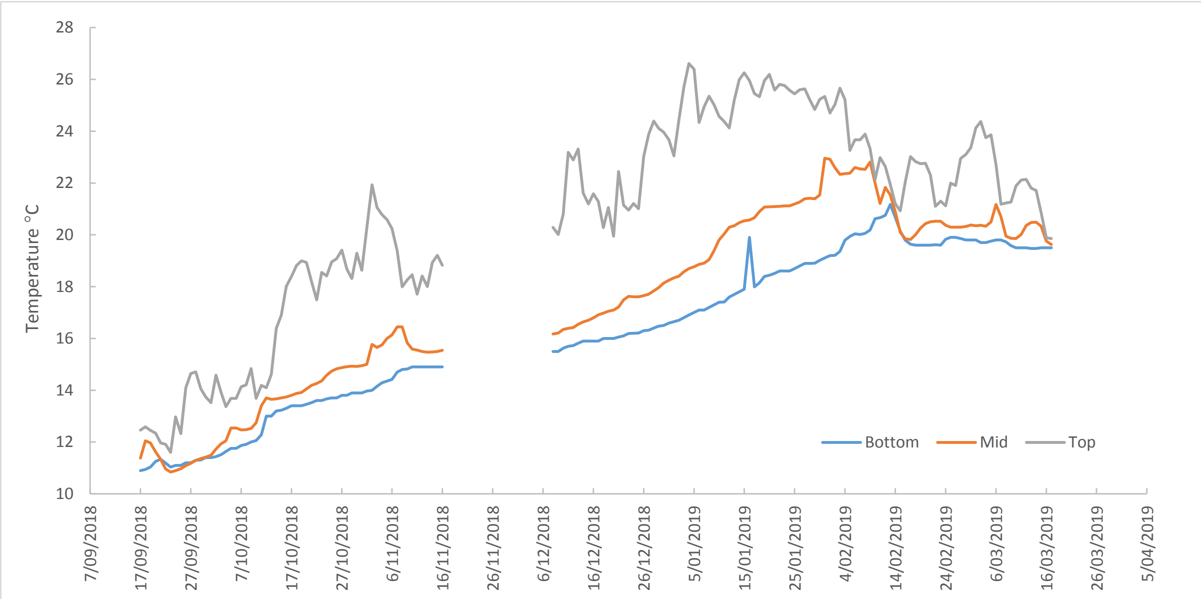

Figure 5. Thermal stratification in Mannus Lake at the Pontoon at three depths based on SVC data September 2018 to April 2019. Some data missing between 17 November 2018 and 7 December 2018.

The water column remained stratified (separating the surface water from the bottom water) for most of the summer at both the outlet (Figure 3) and at the Pontoon sites (Figure 4). However, more detail is needed to better understand the mixing dynamics occurring in the lake. Figure 6 shows detailed profiles of temperature data from the thermistor chain at the outlet. It can be seen that a brief mixing event occurred (where the temperatures become the same forming a thin line) around the 1st of February (Figure 6 top) and several others occurred on the 6th, 9th and 13th of February (shown in more detail in figure 6 bottom). These coincided with the decrease in *Chrysosporum* counts and toxic cyanobacterial biovolume.

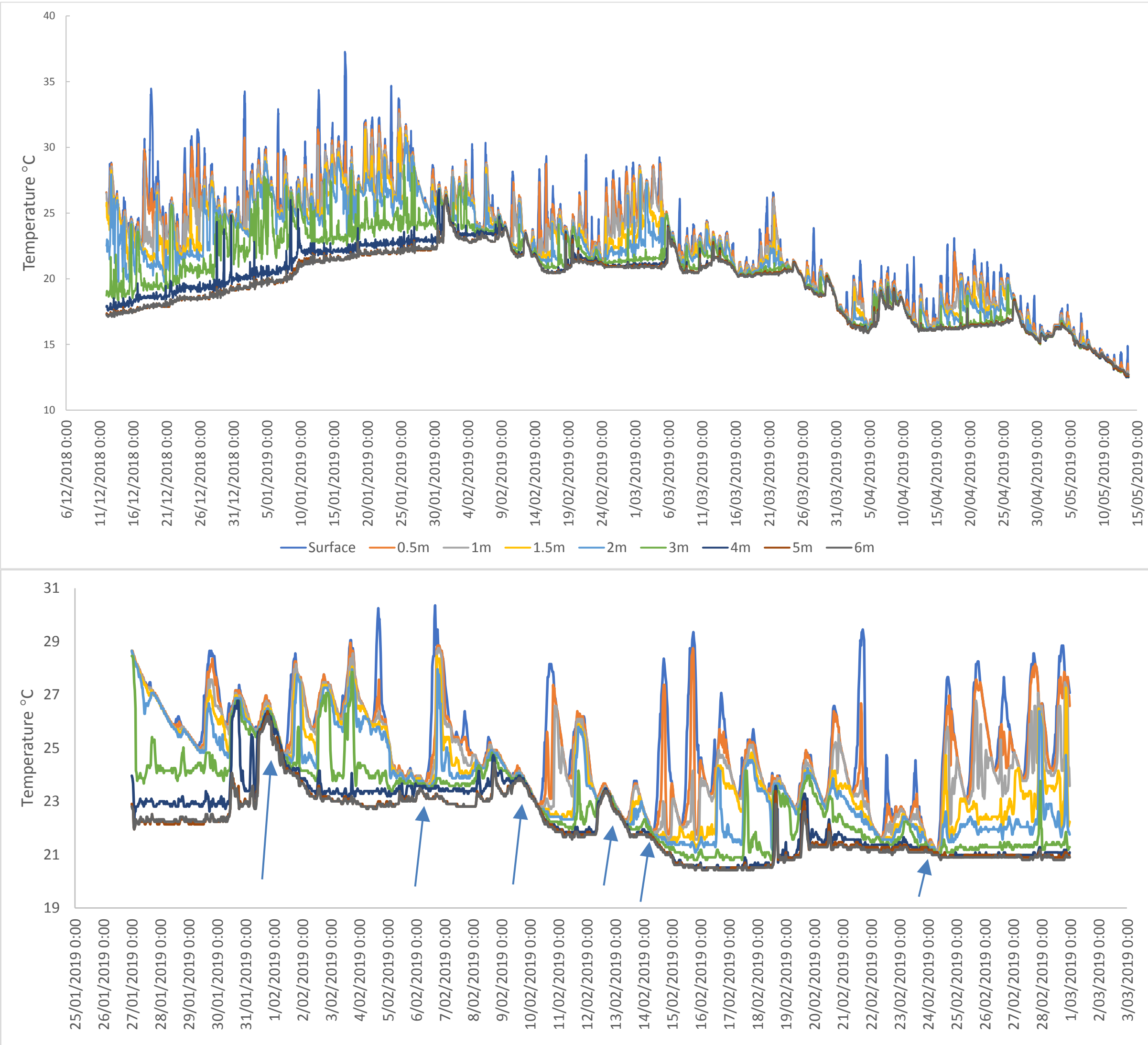

Figure 6. Top - Thermal stratification measured with a thermistor chain at the outlet site from 12 December 2018 to 15 May 2019. Different colours represent different depths. Bottom – focusing in on 27th January 2019 to 30th January 2019. Arrows indicate mixing events.

The second growth of cyanobacteria occurred during April 2019 dominated by *Dolichospermum* (peaked around 16th April) and *Microcystis* (peaked 29th April) and a smaller increase in *Microcystis* to 1.06 mm^3/L on the 12th March. Both of these growths occurred when persistent thermal stratification occurred for significant periods of time. The *Microcystis* growth during March had 10 days of persistent stratification prior to the increase to over 1 mm^3/L (less than recreational guidelines) being recorded (Figure 6 Bottom). The *Dolichospermum* and *Microcystis* bloom occurred during a period of a mixture of persistent thermal stratification with some mixing events (Figure 7). Mixing events occurred on the 2nd, 10th, 11th, 12th and 14th of April. Then there was a 12 day period from the 14th April to the 26th April which coincides with the highest *Dolichospermum* biovolume of 4.7 mm^3/L and 3.5 mm^3/L for *Microcystis* on the 15 April and then 11.6 mm^3/L of *Dolichospermum* on the 29th April. After May 1st stratification was much weaker and the water column was mixed on a daily basis. Toxic cyanobacterial biovolume then decreased to near zero.

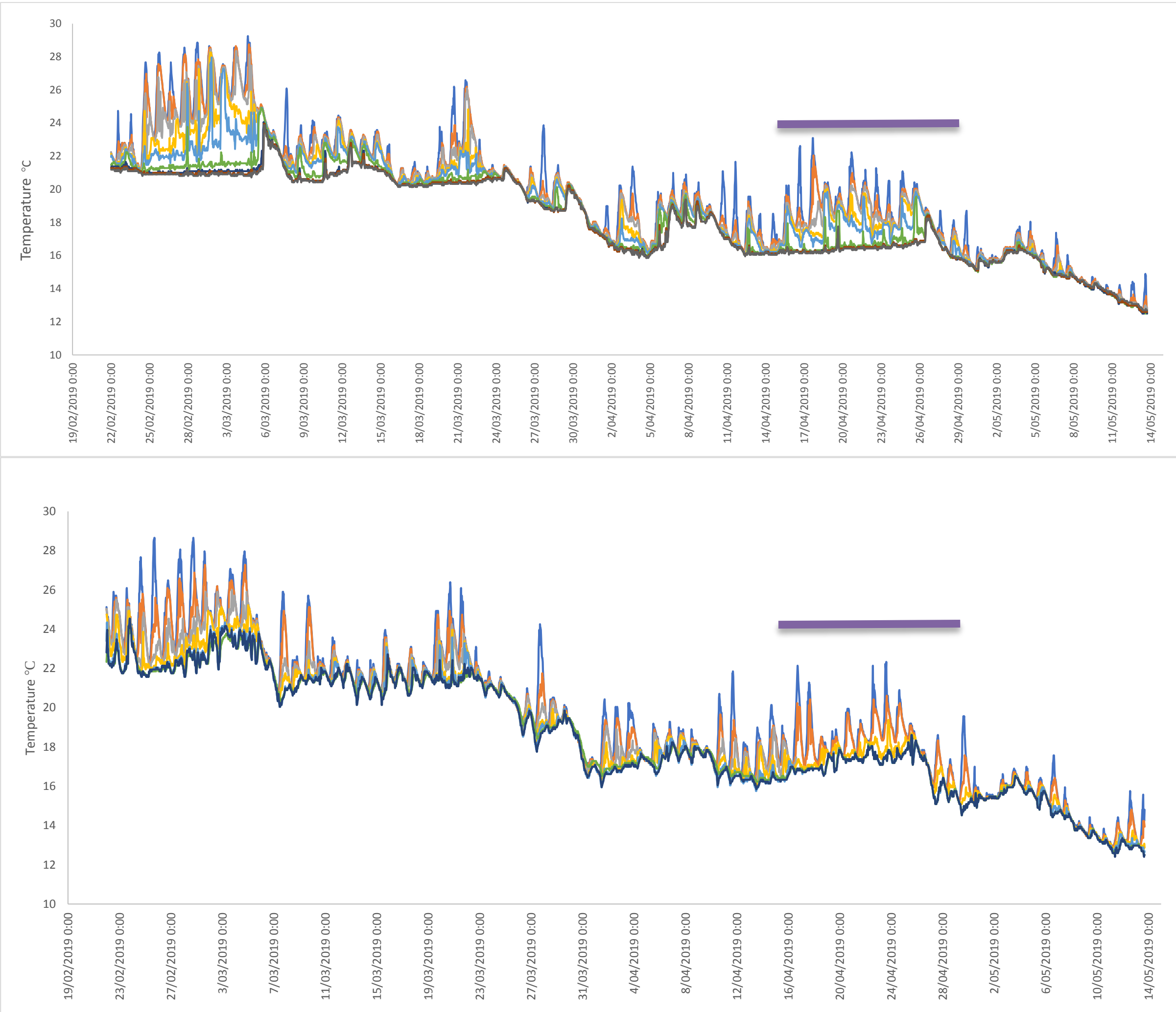

Figure 7. Thermal stratification measured with a thermistor chain at the Outlet site (top) and Pontoon site (bottom) from 1 March 2019 to 14 May 2019. Purple line indicates the period of *Dolichospermum* and *Microcystis* growth and bloom.

Inflows to Mannus Lake did not totally mix the lake in the summer of 2018-2019 (Figure 8). The largest inflow of 160 ML/d on the 16th December 2018 and combined weather associated with the event (i.e. increased wind speed and lowered temperature) did not fully mix the water column though a reduction in the strength of stratification was seen at the outlet (Figure 3). This inflow was smaller than the one that occurred in December 2017.

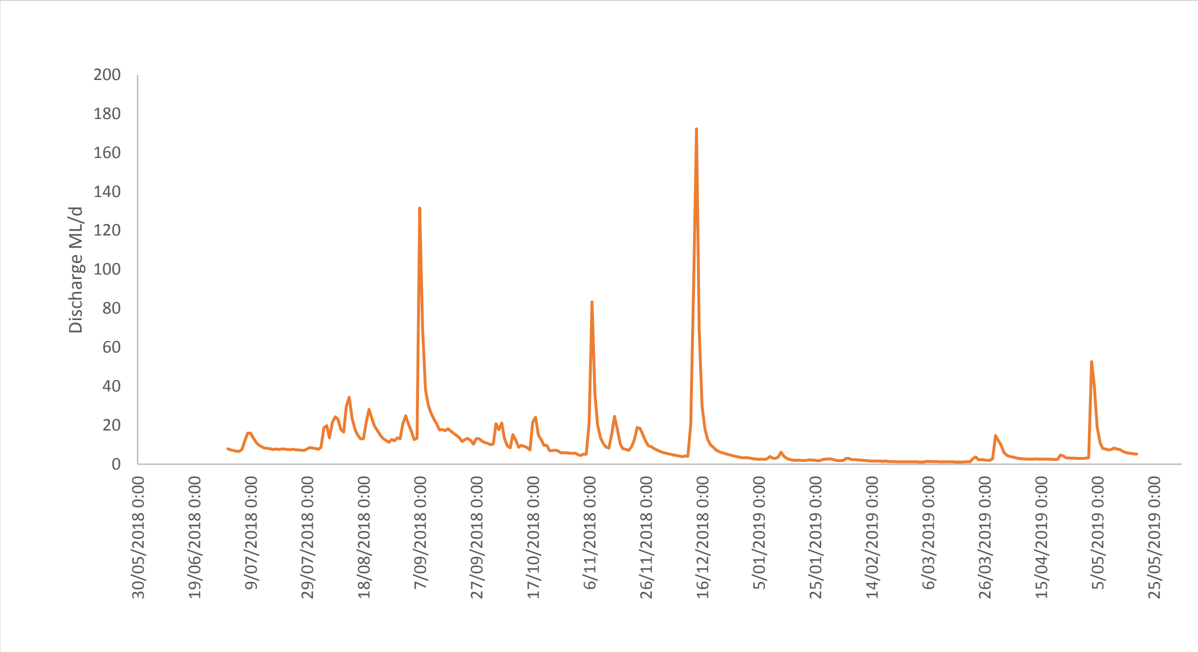

Figure 8. Inflows to Mannus Lake measured at the gauging station at Yarramundi.

Other factors

Light availability

Light availability can have important consequences for algal growth, and can either limit growth or can benefit cyanobacteria with buoyancy regulation ability. Secchi depths for the lake were quite low and varied between 0.15 and 1.5 m. During the major *Chrysosporum* bloom in December Secchi depth was reduced to 0.15 to 0.2 m. After the bloom ended the Secchi depth was approximately 1 m. During the *Chrysosporum* bloom at the outlet site (6 m deep) the average light available through the water column would not support growth in a fully mixed water column or moderate growth in the surface epilimnion. This suggests as seen in the 2017-2018 bloom that buoyancy regulation by *Chrysosporum* allowed it to maintain position in the surface waters and attain a competitive advantage.
Buoyancy regulation occurs when the water column is relatively stable such as during the strongly stratified conditions in November, December and January.

During the second bloom (*Microcystis* and *Dolichospermum*) the light climate was better with Secchi depth being about 1 m deep. This suggests that phytoplankton in the deepest part of the lake would receive light for 30-50% of the time, and for >50% of the time in the shallower waters. If cyanobacteria can utilise buoyancy it may give them an advantage over other algae under these conditions.

Nutrients

Phosphorus levels were quite low at Mannus Lake and varied between 10 and 50 ug/L. Low levels were also recorded for Mannus Creek and Munderoo Creek inflows. Little difference between surface and bottom waters was evident.

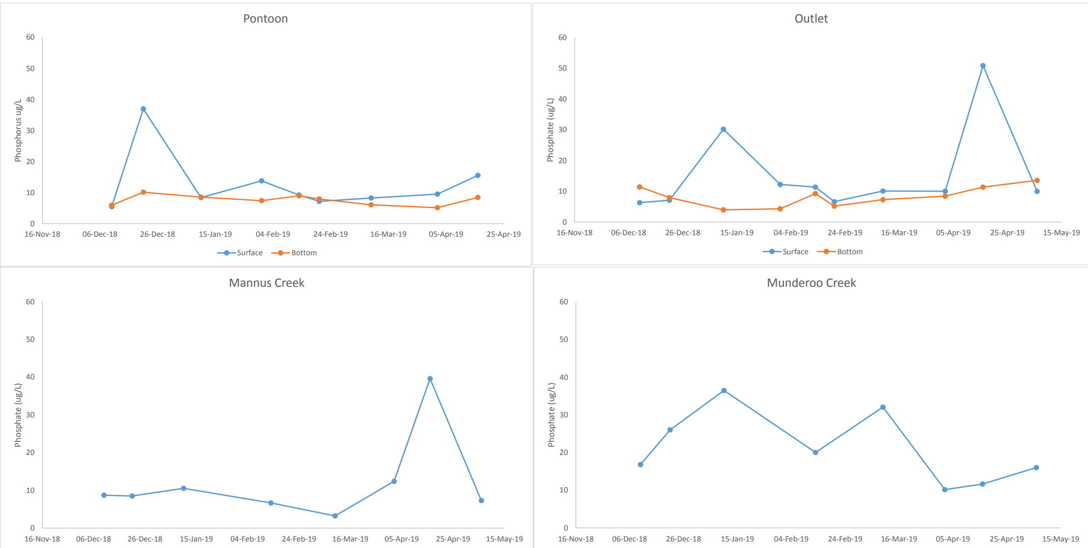

Figure 9. Phosphorus concentrations at Mannus Lake and the inflowing creeks.

Nitrogen levels as NOx (nitrate and nitrite combined) were higher and between 10 and 800 ug/L in the lake. At times NOx concentrations were higher in the bottom waters than surface waters suggesting possible release of nitrogen. Ammonia samples have not been analysed yet. These will give a better indication of whether nitrogen is released from the sediment as ammonia. After the 2017 -2018 summer bloom very high ammonia levels were recorded for Mannus Lake bottom samples. Mannus Creek was found to have higher concentrations of NOx than Munderoo Creek. Munderoo Creek had low oxygen levels most of the time and this may indicate the potential for higher ammonia concentrations. When these samples are analysed for ammonia we will have a better indication of this potential source of nutrients.

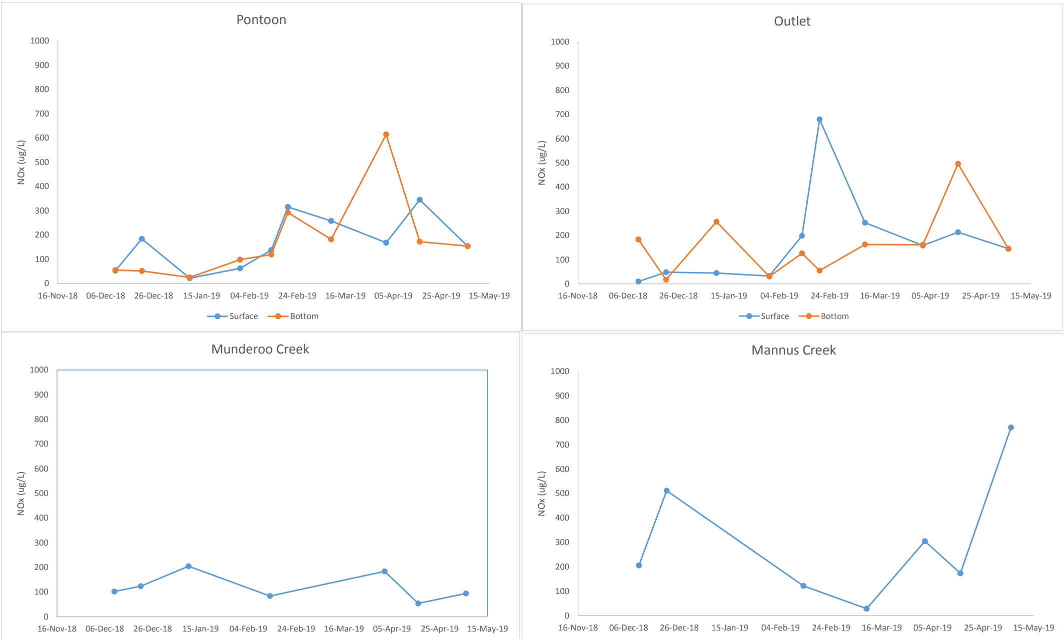

Figure 10. NOx (nitrate and nitrite) concentrations at Mannus Lake and the inflowing creeks.

Dissolved oxygen concentration can be an indicator of when nutrients may be released from sediments. In some lakes this can lead to high concentrations of nutrients within the sediments being released into the water column as the chemistry changes under anoxia. The released nutrients are generally held within the bottom water (hypolimnion) that is separated from the surface water (epilimnion) by the thermocline (rapid zone of temperature change). There can be leakage into surface waters or when brief mixing events occur this may make nutrients more available to the surface waters where cyanobacteria are growing. Dissolved oxygen levels in bottom waters were anoxic (or close to anoxic) for all sampling visits from the 11th December 2018 to the 31 January 2019. On the 13th of February oxygen levels had increased in bottom waters, probably as a consequence of mixing events on the 1st, 6th, 9th and 13th of February 2019. Profiles on the 20th February and on the 13th March again showed low oxygen concentrations in bottom waters. This coincided with the *Microcystis* bloom in March. Profiles on the 2nd April showed good oxygen through the water column (following a stronger period of mixing) and on the 16th April showed a gradual reduction in oxygen through depth coinciding with increased stratification and the *Dolichospermum* bloom.

Two nutrient limitation experiments have been run so far. The first run on 13th February showed no limitation of algal growth. This was after mixing events in late January and early February. A second experiment was run during the *Dolichospermum* bloom in April, however samples have not been analysed yet.

Causes of blooms –preliminary findings

Chrysosporum blooms appear to be related to the development of persistent thermal stratification. The bloom appeared several weeks after the establishment of strong persistent thermal stratification in the lake. There is likely a seed bank in the sediment and under these conditions the algae grow and dominate. Sediment released nutrients may help sustain or magnify these blooms, however surface waters appear to have enough nutrients to maintain high density growth. The bloom ended when the water column mixed in late January and several mixing events occurred in close succession through February.

Microcystis and *Dolichospermum* blooms occurred in April 2019 under periods of stronger thermal stratification conditions. There were a few mixing events through this period however persistent stratification lasted for extended periods (greater than 12 days consecutively) and may have allowed these algae to utilise buoyancy. Stratification was weakened from late April and the water column mixed daily. From this period toxic cyanobacterial numbers decreased to below guideline levels. Mean water column temperature also reduced.

Suggestions for potential management of Mannus Lake

Mixing of the reservoir to prevent thermal and oxygen stratification

As *Chrysosporum* blooms occurred with the establishment of persistent thermal stratification in the lake, artificial mixing of the lake to stop this occurring should prevent the blooms from forming. A mixer such as a propeller that limits the formation of stratification to just a few degrees or less on a daily cycle (full mixing of the water column at night) should reduce or stop these blooms from occurring. Reduced ability to utilise buoyancy should prevent *Chrysosporum* blooms due to reduced light availability and reduced competitive advantage over other algae without ability to utilise buoyancy. Mixing would have the added effect of maintaining oxygen through the water column and reducing the release of nutrients from the sediment.

There is a risk however given the occurrence of *Dolichospermum* and *Microcytsis* blooms which occurred in April, albeit at a lower biovolume. These blooms did occur under a more mixed water column, although persistent stratification occurred for extended periods and mixing was not strong enough to maintain high dissolved oxygen levels through the water column. This indicates potential for nutrient release and importantly increased water column stability allowing the algae to utilise buoyancy. It is likely that mixing will reduce these blooms from occurring as well, however, it should be considered that there is a risk that they may form under “less” stratified conditions. Samples taken examining their their limiting nutrients, should shed more light on these potential risks. These samples are still being analysed and results will be available in a few weeks.

Catchment management of nutrient sources

Improve nutrient management in the catchment – in particular NOx from the Mannus Lake system. The Munderoo Creek system also had consistently low oxygen concentrations indicating high organic matter/reducing materials in the system.

Improve water plant growth

Macrophytes can be effective at helping to prevent cyanobacterial blooms from occurring. They can compete for nutrients, produce chemicals that reduce algal growth known as allelopathic chemicals and can also shade algae. It is possible that the cyanobacterial blooms have reduced macrophyte growth due to shading through reduced Secchi depth. Reducing cyanobacterial blooms will increase water clarity and help the macrophytes re-establish. Plantings of macrophytes or protection of existing macrophytes and the riparian zone should help to prevent blooms. A system where the water is clearer, tends to promote macrophytes and not algal blooms. If Secchi depth can be increased to 2-3 m it is unlikely cyanobacterial blooms will occur. This may be supported by improving water quality (sediments and nutrients) coming from the catchment through Mannus and Munderoo Creeks. Bank stabilisation and promotion of macrophytes and riparian vegetation along the creek will aid this process. This a longer term solution.