Impact of river flows on algal bloom formation

Blue-green algae (cyanobacteria) are a type of bacteria capable of photosynthesis. They occur in all types of aquatic habitat and have critical ecological functions. However, increased nutrient loads, available light and warm temperatures may cause these species to reproduce rapidly and form algal 'blooms' (Anderson et al. 2002; Hudnell 2008).

Some types of blue-green algae can produce toxins and contact irritants which pose a serious risk to human, animal and ecosystem health (Chorus and Bartram 1999). In addition to toxin production, algal blooms can cause taste and odour problems in water supplies and blockages in irrigation systems.

Blue-green algal blooms are normally associated with lakes and reservoirs, but do occur in rivers when conditions suit.

Historically, the main toxin forming species that have caused blooms in the Darling and the Murray Rivers are *Dolichospermum circinale, Microcystis aeruginosa, Microcystis flos-aquae* and *Chrysosporum ovalisporum*.

Regional algal contingency plans outline how algal blooms will be managed to minimise the risk to the health and safety of the public in recreational areas and where water may be used for stock, irrigation or domestic purposes. This includes a traffic light system of alerts.

Red alerts are issued when contact with the water should be avoided. Monitoring and management actions are coordinated by the Regional Algal Coordinating Committees. Water treatment operators also must have drinking water management systems that include processes to reduce the risk to water quality from algal blooms.

Research has been undertaken to understand and model the links between river flows and algal bloom development in the Murray, Darling and Murrumbidgee rivers.

In addition to flow management, long term programs to reduce nutrients entering waterways are critically important in reducing the incidence of harmful algal blooms.

The key points are:

- Maintaining flow has been demonstrated to reduce algal bloom formation.
- Low or zero flow for more than five days, causing the formation of a cold layer at the bottom of a pool that does not mix with the water above (thermal stratification), has been linked to cyanobacterial growth.
- Flow velocities to prevent thermal stratification and reduce the risk of algal blooms have been calculated for a number of weir pools in the Darling River.
- Algal blooms in both the Murray River and the Darling River have also occurred under relatively high-flow conditions.
- The inflow of nutrients from flooding events can be a significant factor in algal growth.

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Frequency of blooms.

The NSW Blue-Green algal taskforce and Regional Algal Coordinating Committees were established because of extensive algal blooms in the Darling River in 1991.

The Menindee Lakes system is situated in flat terrain. In combination with the hot, dry climate and high nutrient inflows, the Lakes have become increasingly susceptible to recurrent harmful algal blooms. Red alert warnings (when contact with the water should be avoided) are often issued for Lake Wetherell around December and can persist through summer, autumn and into winter.

Algal blooms are also often present in the lower Darling during low flow years. Conditions in the lower Darling River during the summer of 2019/2020 provided ideal conditions for algal growth within isolated pools.

Persistent algal scums were observed in the lower Darling River in February 2021, although low cyanobacteria cell counts were found at routine monitoring stations. High numbers of non-toxic algae, known as *diatoms,* were detected in the river over spring and summer. Red alerts were issued for the Darling River and Menindee Lakes in February and March 2022 when the flow volume was high. The inflow of nutrients from flood events is likely to have promoted algal growth. Potentially toxic genera detected included *Plantothrix* and *Phorimidium*.

Blooms are also frequent in the Murray River. Blooms that extended for large distances along the River occurred in 2009, 2010 and 2016. The 2016 bloom persisted from mid-February to early June and was dominated by a nitrogen fixing species (*Chrysosporum ovalisporum*).

During April and May of 2016, the bloom extended from Lake Hume to Lock 8 and throughout the Edward, Wakool and Niemur River distributary system, a combined river length of about 2,360 km (Bowling 2018). The blooms may have started in Lakes Hume and Mulwala, which seeded the river downstream.

There have also been red alerts for extended periods in the lower Murray River in the 2019/20 and 2020/21 summers under relatively high-flow conditions. These were composed of several different potentially toxic species.

Research into links between flow and bloom formation

Blue-green algal growth has been observed to increase as flows decrease. Rivers in western NSW often have low flows, which are regulated for water supplies. Nutrients accumulate in river sediments and at dams and weirs following floods and high-flow events. These nutrients may be resuspended and become available to algae, when water at the bottom of the river becomes anoxic (without oxygen) (Croke 2002).

This is most likely to occur when there is a cold layer at the bottom of a pool that does not mix with the water above (thermal stratification). This often occurs in weirs, reservoirs and lakes during summer. Low-flow and warmer conditions may also favour blue green algae, as they are more buoyant than other algal species and can float to the surface to receive more light.

Low or zero flows for more than five days enabling persistent thermal stratification has been linked to cyanobacterial growth (Mitrovic et al. 2003, Mitrovic et al. 2006, Webster et al. 1995, Sherman et al. 1998). Models have been developed to estimate the minimum flow required to prevent stratification and reduce the risk of bloom formation (Webster et al. 2000, Mitrovic et al. 2003, Mitrovic et al. 2006).

Flow releases from Menindee Lakes have been assessed for their ability to either suppress bloom development, or to mitigate pre-existing blooms in the Darling River. In Weir 32, a discharge of 300 megalitres (ML)/day (flow velocity of 0.03 m/s) was found to be sufficient to prevent prolonged periods of persistent thermal stratification, which also suppressed the development of *Dolichospermum circinale* blooms (Mitrovic et al. 2011).

Mitrovic et al. (2011) also found a flow release of 3,000 ML/day was effective at removing an established cyanobacterial bloom, with total cyanobacterial numbers declining from over 100,000 to 1,000 cells/mL within a week. This is likely to be partly due to increased flows flushing the bloom downstream and increased turbulence leading to higher turbidity, reducing the light availability required for algal growth.

Current research shows that the maximum velocities required to breakdown stratification varied between the eleven weir pools in the Barwon and Darling Rivers. For example, the larger weirs (e.g. Bourke) that are generally deeper, longer and wider need greater velocities of water flow to breakdown stratification than smaller weirs, such as the weir at Louth. Strong persistent stratification was not observed at any sites above 0.0506 m/s maximum daily velocity. Hence, maintaining flow velocity above 0.05 m/s in these weirs should be sufficient to prevent the formation of persistent thermal stratification that may result in algal blooms and potential fish deaths (Facey et al. 2021).

Webster et al. (2000) also suggested the use of flow management to reduce the incidence of cyanobacterial blooms in the Maude Weir pool in the Murrumbidgee River. The Maude Weir pool remained persistently stratified during periods when discharge was less than 1,000 ML/day. Flows of 1,000 to 3,000 ML/day generally allowed diurnal stratification, while flows greater than 4,000 ML/day kept Maude Weir pool well mixed at all times (Sherman et al. 1998).

An alternative strategy suggested was the use of a pulse every three days. This approach would reduce the total volume of water required for bloom suppression, but it has not been tested.

Blooms in the Murray River and its headwater reservoirs, Lakes Hume and Mulwala prior to 2016, have consisted primarily of *Dolichospermum circinale* or *Microcytis flos-aquae* (Baldwin et al. 2010, Al-Tebrineh et al. 2012, Bowling et al. 2013). Cyanobacterial blooms downstream of Lake Hume often only occurred when the lake fell below 10% capacity and there were low flows in the river (Bowling et al. 2013). The *Dolichospermum circinale* bloom in 2010, may be have resulted from low flows and high temperatures (Bowling et al. 2013).

The *Chrysosporum ovalisporum* bloom which occurred during 2016 happened under relatively high-flow conditions (Bowling et al. 2018) and when the lake was at 37% capacity. It has been suggested that cold water inflows into the lake may have brought nutrients to the surface, as well as mixing the lake, allowing the algae to be released downstream from outlets below the surface layer.

Nitrogen fixing algal species produce akinetes or dormant cells which may be present in the lake and germinate when nutrient supply, temperature and light become suitable for growth.

Flow velocities in the river were 0.6 m/s, well above the critical flow velocities determined for cyanobacterial bloom development in weir pools on rivers by Mitrovic et al. (2003, 2006). These flows were enough to spread the bloom downstream, but not enough to reduce the level of algae in the river.

In the Murray River, it has not been possible to flush out algal blooms using increased flows due to the size of the blooms, number of weirs and locks, and the lack of fresh water available to provide flushing flows (Bowling et al. 2018). Major blooms have eventually dissipated with the onset of cooler temperatures and increased flows from tributaries in proportion to the water being released from Lake Hume.

The formation of algal blooms is influenced by a range of factors, including the unique adaptive capacity of cyanobacteria species, nutrient loads, temperatures and flow dynamics. The prevention of low or no-flow conditions has been demonstrated to reduce bloom formation. However, blooms may also form under high-flow conditions in response to high nutrient concentrations and water temperatures.

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