Blue green algal blooms: a preventable emergency?

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Reports of blue green algal blooms have increased over the last two decades. Whether this is due to an increase in public awareness and reporting, more favourable conditions for algal growth or a combination of the two is unclear. Coincident with the increased reports of blue green algal blooms has been the greater appreciation by communities of the hazards associated with these organisms. There is a genuine concern, particularly in communities that have been affected by blue green algal blooms, for an appropriate risk management framework to be implemented.

In the following discussion of these issues, I consider the question of whether blue green algal blooms are *ecological* emergencies, and suggest that theories of risk management in the emergency management context can provide a valuable tool for the conservation and management of Australia's threatened inland riverine ecosystems. For the present paper I take an anthropocentric view of an emergency, concentrating only on the impact of toxins on humans.

Algal toxins: the major hazard

The major hazard for communities in contact with high numbers of blue green algae is the capacity of this group of organisms to produce a suite of hepatotoxins, neurotoxins and endotoxins. These toxins have acute and chronic effects on humans and stock (*Table 1*). Toxins from blue green algae have been linked to severe human illness (Falconer *et al* 1983, Hawkins *et al.* 1985) and considerable stock losses (Baker and Humpage 1994, Codd *et al* 1994, ANZECC & ARMCANZ 1999). Managing the risk associated with blue green algal toxins is complicated by a number of factors. The amount and type of toxin produced by blue green algal bloom may vary over reasonably short time scales. While the notion that a bloom can be toxic one day but not the next is probably an exaggeration, over a scale of weeks the toxicity of the bloom may well vary (MDBC 1993). At present, tests available for toxin production are expensive, time consuming to perform and are only undertaken in a limited number of laboratories in Australia. Therefore, frequent routine monitoring of water bodies in remote parts of Australia for toxicity is not possible. The toxins produced are relatively stable in water, therefore, water bodies containing toxic blue green algae may remain toxic for up to several weeks before for toxins are degraded by naturally occurring bacteria (Jones 1994). Also of concern is the capacity for blue green algae, as with many other algae, to produce compounds which impart an unpleasant taste and odour to domestic water supplies.

Vulnerability

The vulnerability of a human community to blue green algal blooms is a function of the ability of the community to detect the presence of toxins in the water supply and their dependence on the impacted water. For example, the community living along the Darling River during the 1991 bloom was highly vulnerable because the only source of water for stock and domestic supplies was impacted and there was limited preparedness for the emergency. In an extensive survey of blooms in the Murray-Darling Basin, 42% of samples showed some degree of toxicity (Baker and Humpage 1994). This indicates that not all blue-green algal blooms are toxic. However, our present inability to forecast the eventual toxicity of developing blooms means that management of algal blooms has to assume the worst case scenario for toxin production. That is, it is assumed that all cells present are highly toxic, when in reality they may not be. This current gap in knowledge may greatly increase the cost of managing algal blooms.

The affected parties to a significant blue green algal bloom may extend well beyond those that rely on contaminated water for stock and domestic supplies. Tourism and recreation industries can be severely impacted. For example, a bloom of blue green algae on Lake Hume in March 1996 resulted in reductions in tourism bookings at lakeside resorts. A major concern for irrigators along the Lower Murray is the potential damage a blue green algal bloom would have on the environmentally sustainable (clean and green) image that the horticultural industry is promoting for the region. This image is a critical aspect of the promotion of premium grade produce for the international market. The potential for significant financial losses to agricultural and tourism sectors as well as impacts on human health have to be considered in risk evaluation of blue green algal blooms.

Options for treating risk

Since the Darling River bloom in 1991 there has been significant research effort aimed at identifying the range of options for managing risk associated with algal toxins and selecting intervention options for the control of blue-green algal blooms. This effort has focused on understanding the biology of blue green algal blooms and the toxins that they produce. While our knowledge is far from complete, there is now a considerable understanding of the role of eutrophication (nutrient pollution) and river regulation (including effects of water abstraction and of impounding water behind dams and weirs) in the development of blue green algal blooms. The application of this knowledge has led to the development of a number of tools with which to manage blooms. Risk

Toxin Group	Effects
Hepatotoxins	Peptides that can cause hepatoenteritis, liver damage and may promote tumour growth
Neurotoxins	Act as neuromuscular blocking agents leading to muscle tremors, staggering, paralysis and respiratory arrest
Endotoxins	Lipopolysacharides that can cause gastroenteritis, skin and eye irritations, skin rashes and allergic reactions

Table 1: Toxins produced by blue green algae (Adapted from MDBC 1993)

management for blue green algal blooms has evolved into a comprehensive emergency management strategy which incorporates the framework outlined by Salter (1998) of prevention, preparedness, response and recovery.

Prevention

There is a widely held perception in the community that blue green algal blooms are the result of human activities. From this perception it follows that appropriate management of human activities will prevent the occurrence of blue green algal blooms in the future. However, blue green algae are an indigenous part of the biota of Australian rivers. Blooms have been recorded from the Murray River system since the 1850's (Francis 1878, Codd *et al* 1994), well before significant river regulation or eutrophication took place. Therefore, elimination of blue green algae from Australia's inland rivers is both an unrealistic and ecologically unsatisfactory goal.

There is little doubt, however, that human activity has increased the frequency and intensity of algal blooms and that appropriately targeted management will decrease these. Consequently, prevention strategies focus on reducing the growth of blue green algae by reducing impacts of river regulation and nutrient pollution on the river system. As with all photosynthetic organisms, the two main ingredients for growth are an adequate supply of nutrient and light. In Australia's inland waters most of the 20 or so elements (nutrients) required for growth are in abundant supply. However, two nutrients, nitrogen and phosphorus are, at times, in low enough concentrations to limit the growth of blue green algae. Some blue green algae such as *Anabaena sp*. are able to utilise gaseous nitrogen (N_2) to supply the alga's nitrogen needs. The growth of these groups of blue green algae will not be limited by the availability of inorganic nitrogen since gaseous nitrogen is always abundant. Consequently, the most commonly adopted tool for the prevention of blue green algal blooms is the management of anthropogenic inputs of phosphorus to water bodies. This has been achieved by licensing and regulating point source discharges of phosphorus into rivers and lakes, for example, effluent from intensive animal industries and from sewage treatment plants. Community education programs aimed at decreasing the amounts of nutrient added to the waste stream frequently support this regulation. For example, the Albury City Council (Southern NSW) has implemented a public education program Phos-watch that has demonstrably reduced the levels of phosphorus entering the council operated sewage treatment plant.

Diffuse sources of nutrient, such as from broad acre agriculture, are considerably harder to identify, quantify and regulate than point sources. Across Australia managing diffuse sources of nutrient is increasingly being addressed at the catchment scale through collaborative programs between the local community and government. Local involvement is a critical factor in the adoption and ultimately the success of catchment management. A significant outcome of community involvement in catchment management is an awareness and knowledge of blue green algal blooms. This makes the community less vulnerable to them when they occur.

River regulation has increased the amount of favourable habitat for blue green algae. River regulation in inland Australia has resulted in the construction of tens of thousands of dams and weirpools and the abstraction of significant volumes of water. During summer, still or slow flowing waters regularly show temperature stratification, where warm layers of water form over the cooler bottom waters. The warm, shallow surface layer provides an ideal environment for blooms to develop (Webster *et al*. 1996). A number of techniques that reduce stratification are used to inhibit the development of blue green algal blooms. These include maintaining sufficient flow in rivers to reduce stratification, particularly during periods when blue green algae are likely to develop. Water mixing devices such as pumps, paddle wheels and aeration units have been deployed to reduce stratification with various levels of success (Sherman 1998).

Preparedness

The community and government were unprepared for the 1991 Darling River blue green algal bloom. The response by governments to the bloom was to declare a state of emergency and establish a task force to deal with the immediate problems of the bloom. After the bloom had dispersed, the task force concentrated on developing a longer-term strategy for managing blue green algal blooms. An outcome of this task force was the establishment of Regional Algal Coordinating Committees (RACCs) in NSW. The RACC's were to develop algal contingency plans. Algal contingency plans consider intervention options aimed at preparedness, response and recovery from algal blooms. The role of the RACC's includes:

- development, coordination and implementation of algal bloom contingency strategies;
- cooperation with neighbouring regions on algal management issues;
- coordination of public information programs including using the media;
- implementation of regional algal monitoring systems;
- monitoring of costs associated with algal blooms;
- coordination and implementation of training in algal identification, and monitoring and sampling in the region;
- identification of when algal warnings should be issued.

A number of Blue Green Algal Contingency Plans have since been completed. A good example is the document prepared by the Central West Regional Algal Coordinating Committee (Central West RACC, 1997). This plan clearly outlines the responsibilities of agencies, establishes communication networks, identifies alternative water supplies and provides an inventory of available water treatment methods and where to obtain them rapidly.

Are blue green algal blooms 'ecological emergencies'?

Dovers and Norton (1999) define 'ecological emergencies' …*as sudden-onset events where the subject is non-human, such as an ecosystem, a species or a river system. In an ecological emergency, humans or human property may also be threatened, but the threat may be only to non-human entities.* The definition of Dovers and Norton (1999) indicates that the ecosystem has to be threatened for it to be considered an ecological emergency. In all but the most extreme cases, blue green algal blooms do not threaten the ecosystem. Blue green algae are a natural feature of Australia's inland river systems, with blooms occurring prior to European colonisation. The native biota have coevolved with blue green algae. There is no evidence that either native or introduced fish are harmed by ingestion of toxic blue green algae (Johnston *et al* 1994, Gehrke & Harris 1994). While there are conflicting reports about the toxicity of blue green algae to microinvertebrates (Matveev *et al* 1994; Boon *et al* 1994), healthy microinvertebrate populations were present in the Darling River at the height of the 1991 blue green algal bloom (Shiel & Green 1992, Boon *et al* 1994). Similarly, there were no reports of native animal or bird deaths associated with the Darling River bloom. This does not suggest that these organisms are necessarily immune to the toxins, but rather their behaviour is such that they do not ingest the toxins. Since, in all but the most extreme cases, there is no evidence that native flora and fauna or ecosystem processes are threatened by the presence of blue green algal blooms it is reasonable to argue that blooms do not represent an ecological emergency. However, there is little doubt that the health and integrity of Australia's inland waterways are seriously threatened by the factors that contribute to blue green algal blooms— river regulation and eutrophication. These processes have impacted many of Australia's river systems, threatening many plant and animal species (Harris and Gehrke 1997). Blue green algal blooms are just one manifestation of increased eutrophication and river regulation. Others include the dramatic decline in native fisheries, considerable reductions in the area of wetlands, enhanced growth of all aquatic plants (and the associated rapid and large alterations in oxygen content of the water which can result in fish death) and erosion of river banks. While blue green algal blooms may represent a major hazard to humans, river regulation and eutrophication are the major hazard for the ecosystem.

The concept of a *sudden onset event* is an integral part of the Dovers and Norton (1999) definition of an ecological emergency. Can river regulation and eutrophication, processes that have been increasing for the best part of a century, be classified as *sudden-onset* events? We argue that in the temporal context of ecosystem evolution, anthropogenic increases in eutrophication and river regulation are sudden-onset events. Society is generally cognisant of the need to monitor and detect hazards that threaten human life or property and has generally developed appropriate equipment and monitoring programs to detect these. On the other hand, methods for detecting ecological emergencies resulting from river regulation and eutrophication, are poorly developed and often poorly funded. For example, we are still developing adequate tools for quantifying 'river health' for lowland rivers. In the absence of these tools, how will we know that an ecological emergency is taking place?

At the river basin scale, eutrophication and river regulation threaten whole populations of organisms and ecological processes (Harris *et al* 1987, ANZECC & ARMCANZ 1999). An appreciation and acceptance that these anthropogenic alterations to the riverine ecosystem constitute an ecological emergency, and therefore require emergency management, would be a significant step in halting and perhaps reversing the decline that is currently taking place.

Conclusions

Since the 1991 Darling River bloom there has been a shifting emphasis in blue green algal management from one of hazard management to one of risk management. There has been a significant emphasis on identifying the range of options for treating risk associated with blue green algal blooms, which includes prevention, preparedness, response and recovery.

Except in the most extreme cases (and the 1991 Darling River bloom was not one of those) blue green algal blooms do not constitute an 'ecological emergency'. However, anthropogenic alterations to the riverine ecosystem of eutrophication and river regulation do threaten the riverine ecosystem. The temporal nature of this not withstanding, these factors do constitute an ecological emergency. Theories of risk management in the emergency management context can provide a valuable tool for the conservation and management of Australia's threatened inland riverine ecosystems.

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