River Science 2

The science behind the Swan-Canning Cleanup Program

Issue 2, September 2000

'Summer surprise'

The Swan River blue-green algal bloom

February 2000

The Microcystis *bloom in the Swan River in February 2000 (Photo courtesy Dennis Sarson).*

CONTENTS

Conditions that made the river green and potentially toxic

Unseasonable freshwater flow

The cause of the unusual and massive toxic blue-green algae bloom in the Swan and lower Canning rivers in February 2000, can be largely explained by two unseasonably large rain events that occurred in January 2000.

The rain that fell in early January gave much of the hinterland of the Swan-Avon River system a good soaking. This resulted in the catchment being unable to absorb much more rain.

A week later, rain-laden clouds left over from Cyclone Steve came down from the north and deposited over 12 000 million tonnes, i.e. 12 000 gigalitres (GL) of water on the Avon River catchment, an area the size of Tasmania. This resulted in over 270 GL entering the estuary (Figure 1).

This was enough water to fill the Swan-Canning rivers and estuary five and half times over. The soil was already saturated from the earlier January rain, so there was a rapid and huge runoff particularly from the normally dry Lockhart subcatchment and

Flooding at Beverley, Avon River.

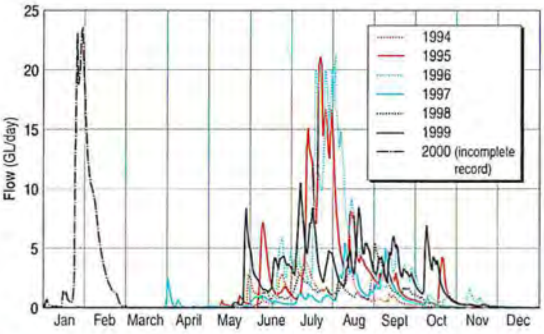
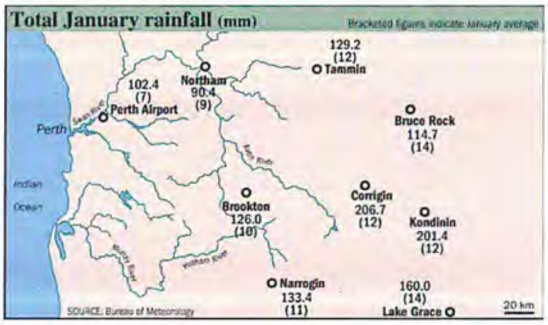


Figure 1. *Swan-Avon River flow (gigalitres per day) measured at Walyunga Canyon – start of the Swan-Canning Estuary, showing normal summer and winter flow and the unseasonal flow that occurred in January-February 2000.*



SOURCE: Bureau of Meteorology

Figure 2. *Rainfall (mm) in the Swan-Avon River catchment for January 2000 compared to the average rainfall in January in brackets.*

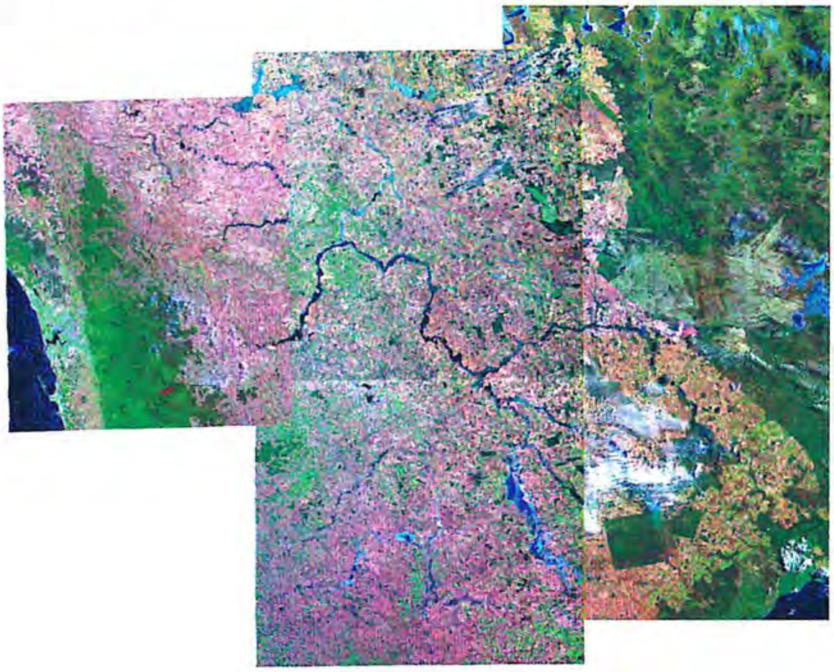


Figure 3. *Satellite image of the catchment of the Swan-Avon River in late January 2000, showing waterways in the Lockhart subcatchment and Yenyenning Lakes in blue, which are full and flowing. The Swan Estuary is to the upper left of the image.*

Yenyenning Lakes flooding.

Yenyenning Lake system, about 200 km south east of Perth, in the Avon catchment. It was the first time waterways in the Lockhart subcatchment had flowed significantly in the summer for forty years. Even during the winter, this area usually does not receive sufficient rain to contribute significant runoff to the Swan-Avon River system.

The source of nutrients for algal growth

The huge torrent of freshwater came down the Swan-Avon in two pulses, bringing with it high levels of nutrients, mainly nitrogen (N) and phosphorus (P). The nutrients came from an accumulation of animal manures, plant material, soil particles with nutrients attached and fertilisers washed into the creeks and rivers. Nitrogen and phosphorus are the two essential ingredients required for algal growth. Nutrient levels were as high as 7 mg/L for total nitrogen and between 0.2 to 0.3 mg/L for total phosphorus. The nitrogen levels were seven times the limit considered healthy for freshwater entering estuaries and two to three times the limit considered healthy for phosphorus.

This nutrient rich freshwater, which carried over 800 tonnes of nitrogen and 35 tonnes of phosphorus, flowed into the wide, shallow estuary of the Swan

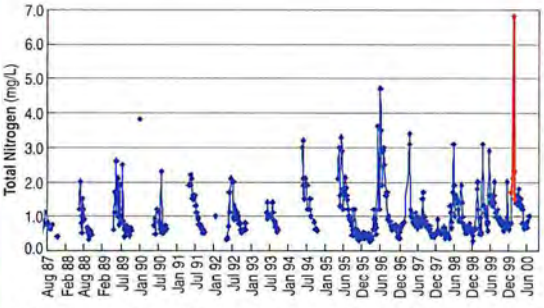


Figure 4. *Total Nitrogen concentrations measured where the Avon River enters the Swan-Canning Estuary at Walyunga Canyon in the Darling Range.*

River where the water was relatively clear, calm and warm. This combined with lots of sunlight, clear skies and long day length, provided ideal conditions for photosynthesis and algal growth. Normally the increased nutrient levels caused by freshwater runoff from the Avon catchment occur in winter, when conditions for algal growth are not favourable; water temperatures are low, day length is short and the river is more turbulent due to storms and strong flow.

In February 2000, dissolved inorganic nitrogen, which is instantly available nutrition for algal growth, reached 0.5 to 1.2 mg/L in the water between Success Hill and Blackwall Reach. This was five to 12 times higher than normal for summer conditions in the estuary.

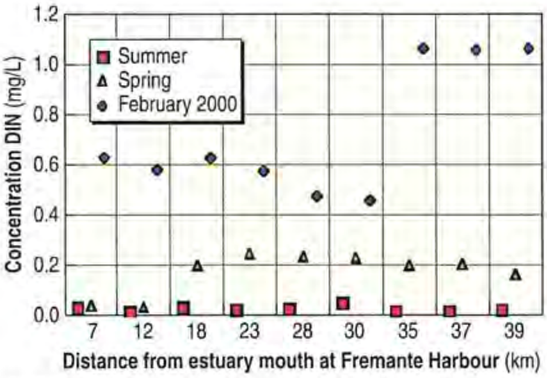


Figure 5. *Median dissolved inorganic nitrogen (DIN) concentrations during the* Microcystis *bloom. Median values are compared with the bloom values (February 2000) and other values usually observed in spring and summer.*

Sources of algae are plentiful

The Swan River has hundreds of naturally occurring microscopic algae species (known collectively as phytoplankton) most of which are not harmful to humans or animals. Indeed many algae species are important sources of food for estuarine invertebrates, such as worms, prawns and mussels. The phytoplankton also supports the zooplankton (microscopic animals) which in turn are food for many fish species. In addition to the algae already in the river, reservoirs of all types of algae are present in the drains, ponds, lakes and wetlands connected to the Swan-Canning system. These can be flushed into the river by rain.

By considering the timing of detection and progress downstream it is believed that the strain of *Microcystis* that bloomed in February 2000 was most likely to have originated from stagnant pools in the Avon Catchment.

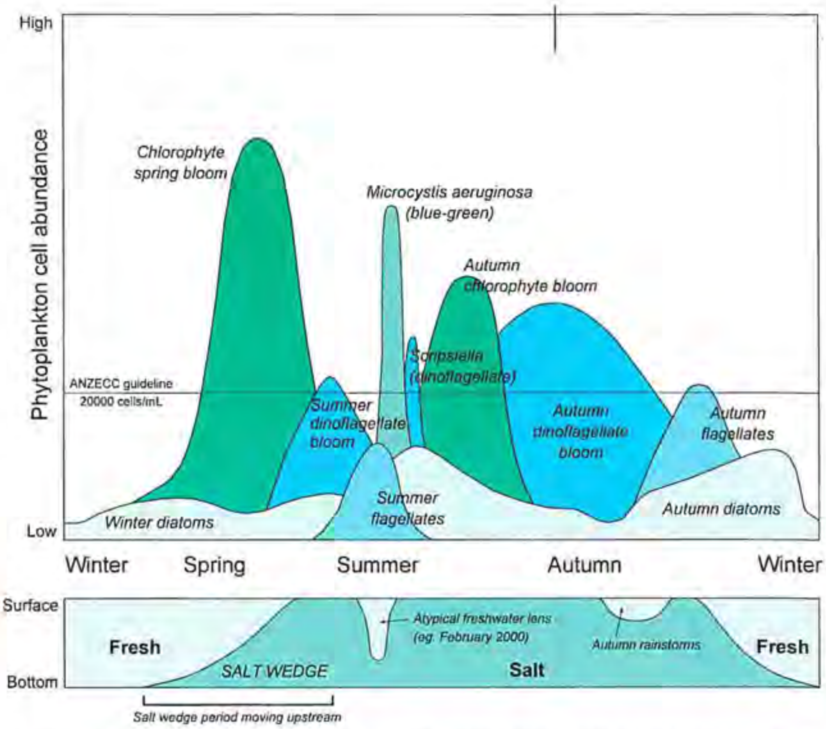


Figure 6. *The relative abundance of phytoplankton and the scale of the blooms in the upper Swan River by the seasons of the year and the timing of the salt wedge. The ANZECC guideline for blooms indicates the relative magnitude of cell numbers occurring in the upper Swan. The freshwater deluge that stimulated the toxic* Microcystis aeruginosa *bloom in February 2000 is clearly seen in the summer.*

The river's algae go through typical seasonal bloom cycles. Under normal summer river conditions various algae bloom and die. The extent of any particular blooms depends largely on the availability of the nutrients nitrogen (N) and phosphorus (P) and the salinity of the water. Different algae prefer different conditions so a number of factors will determine which algae will be the most successful and bloom at any particular time.

The *Microcystis* bloom was only a temporary aberration of the normal seasonal cycle shown in Figure 6. In a normal year beneficial spring blooms occur in response to nutrients washed in by the late winter and early spring rains.

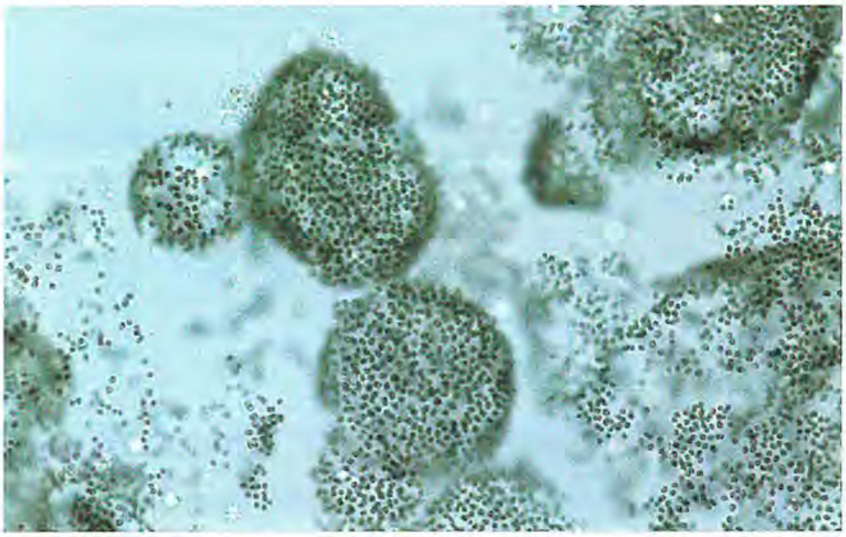
When the spring bloom collapses due to exhaustion of nitrogen supply the algae die and fall to the river bottom. Summer blooms of mainly dinoflagellates use N and P derived from the sediment and urban drains.

With the onset of autumn rains nutrients are once more washed into the river system and more algal blooms occur. In winter, low water temperature and short days (less sunlight for photosynthesis) significantly reduce algal growth.

Factors favouring growth of the toxic blue-green algae *Microcystis*

Salinity and the normal river situation

During winter, the Swan River upstream of the Causeway is flushed with freshwater. Downstream of the Causeway, the water becomes stratified with fresh to brackish water over deeper saline waters. During the spring and summer, the freshwater flow slows and almost stops. This allows seawater (salinity 35 parts per thousand) from the Indian Ocean and lower estuary to move into the upper estuary in what is known as a 'salt wedge'. Seawater is denser than freshwater, so initially the wedge moves upstream underneath the freshwater. As the summer progresses, tidal exchange with seawater works to extend wedge conditions and then mixing occurs throughout the water column. This produces salinities from 25 parts per thousand in the extreme upper regions to 35 parts per thousand in the lower regions of the Swan Estuary, typical summer conditions for the Swan.



Microscope photograph of Microcystis aeruginosa.

Salinity and the unusual summer rain conditions

The unusual freshwater flush that occurred in February lowered the salinity level in the Swan to 5 to 10 parts per thousand – it was fresh in the upper reaches and only slightly saline in the middle and lower estuary. Water in the middle and lower estuary was highly stratified with near freshwater on the surface and more salty water on the bottom. This level of salinity (fresh to low) and the huge input of nutrients (N and P) in runoff (mainly from the Lockhart River subcatchment, see Figure 3) favoured a number of algae already present in the system but in relatively low abundance.

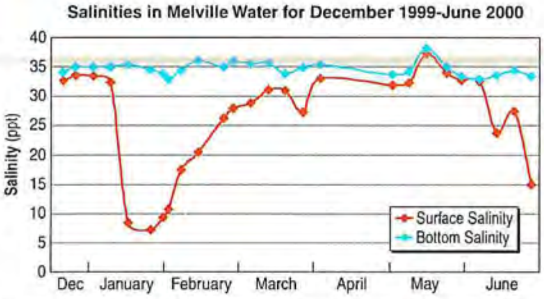


Figure 7. *Surface and bottom salinity at Melville Water in the middle region of the Swan River during the bloom and afterwards.*

Why *Microcystis*?

One of these algae – a blue-green – *Microcystis aeruginosa*, scientifically known as a cyanobacteria and referred to as *Microcystis* for short, does especially well in freshwater and low salinity conditions. These were the very conditions that occurred in the Swan River in February 2000.

Microcystis has several characteristics that give it an advantage over its algal competitors who also like low salinity conditions (algal species are always competing for nutrients, sunlight and space). The most important of these are:

- It has an extremely buoyant nature. *Microcystis* has a very effective gas vacuole system that helps it to float to the very top of the water and receive strong sunlight.
- This buoyancy, which allows it to photosynthesise efficiently, results in the production of large amounts of sugar. After a few hours of photosynthesis in the sun, *Microcystis* cells get so heavy with sugar they sink below the surface where they consume the sugar they have produced. Once they exhaust their sugar supply they float to the surface again, ready to use the next day's first sunlight. If conditions are calm, this floating characteristic gives *Microcystis* an instant advantage over other algae.

A combination of *Microcystis'* natural characteristics, the unseasonable flood of freshwater and nutrients that entered the system and the warm, sunny summer conditions allowed it to grow spectacularly and produce large colonies of bright blue green cells and extensive scums.

A *Microcystis* population explosion

For over five years the Swan River Trust has regularly measured the concentration of various algae, i.e. numbers per millilitre (mL), at nine sites around the river.

Soon after the freshwater flowed into the estuarine system in February 2000, water samples showed concentrations of *Microcystis* beginning to rise rapidly. Under favourable conditions their growth is exponential, with the number of cells doubling at least every day. Health warnings were posted as soon as the concentration of *Microcystis* reached 20 000 cells per mL, the health limit considered safe for the recreational use of the river. In some beach and sheltered locations *Microcystis* concentrations on the surface reached 130 million cells per mL, producing bright green scums. However, in most of the open more turbulent areas of the river, cell counts were below the health alert level where whole water column samples produced counts varying between 5000 and 14 000 cells per mL.

At the peak of the bloom, the public was warned not to have contact with the water and both the rivers and estuary were closed for 12 days. The Swan River was closed between Success Hill and Fremantle Port and the Canning River between the Canning and Mt Henry Bridges. Scums and accumulations of algae were worst on the northern shores of the estuary, especially Claisebrook Cove, Crawley-Matilda Bay and Freshwater Bay. Scums were also present but occurred less frequently on some south shore beaches, such as Deepwater Bay. Fortunately they did not last long.

Hazard versus risk of the toxic bloom

The levels of microcystin, the major toxin produced by *Microcystis*, varied considerably during the bloom and exceeded the World Health Organisation's recommended level (0.5 µg/L) during one period, when concentrations reached 8 µg/L. Bio-assay tests indicated that as little as 20 to 25 mg/kg of mammal weight of the algae was fatal for mice. Mice are often used as an indicator mammal species to warn health authorities that a substance may be toxic to humans. As a comparison DDT can kill mice at 80 mg/kg.

While the toxicity of this strain of *Microcystis* was high and therefore the hazard it represented was high, the risk to humans was actually low. This is because the chance of contact or ingestion of a toxic quantity of *Microcystis* or tainted water was considered low. Only if recreational activities were undertaken in the sheltered bays where toxic scums were located would the risk increase. Given the number of recreational activities for this time of year, authorities felt they could not chance anyone in the public becoming seriously ill.

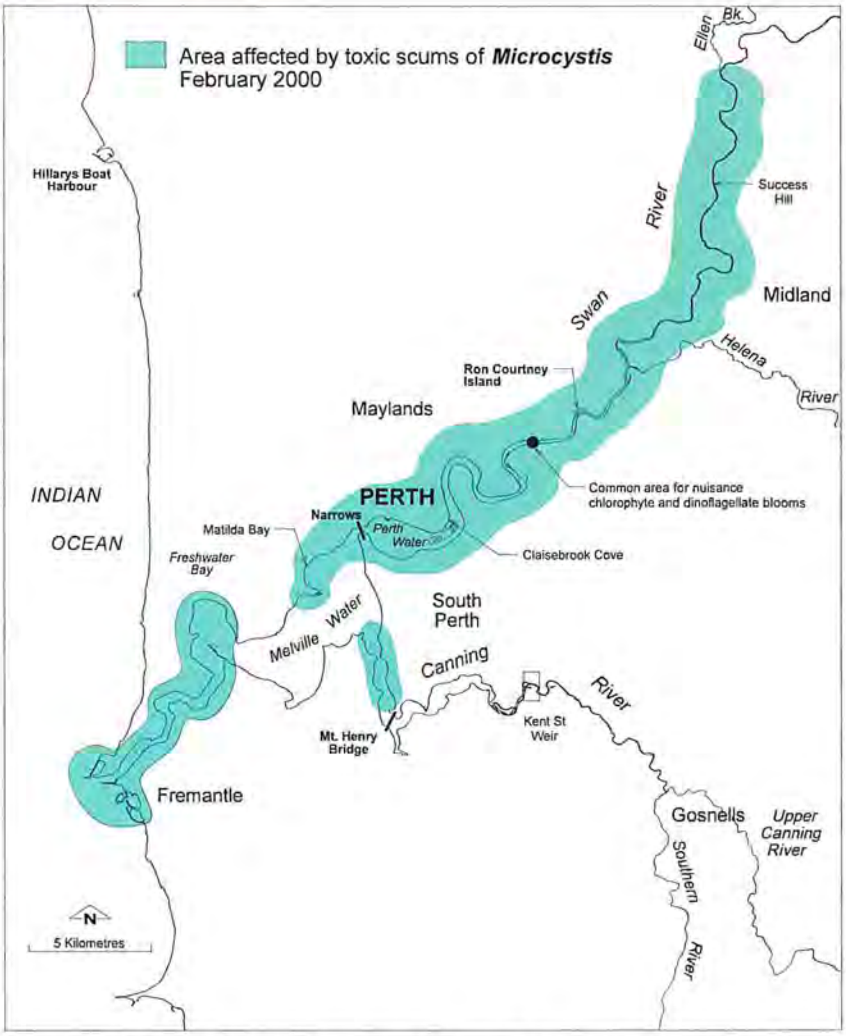


Figure 8. *The area of the river and estuary where the* Microcystis aeruginosa *scums were most prevalent during the bloom in February 2000. A toxic blue-green* Anabaena *bloom in the Canning River above the Kent Street Weir had just collapsed.*

Toxic algae sign with City of Perth in the background

Efforts to control the *Microcystis* bloom

Skimming successfully removed concentrated Microcystis *scums from the Swan River during the bloom in February 2000.*

Controlling the bloom

The Swan River Trust and Water and Rivers Commission tried a number of methods to reduce the *Microcystis* bloom. They included attempts to increase the salinity of the surface layer of water beyond the tolerance of the algae, using a slurry of clay particles mixed with a flocculating material applied in a fine spray on the water to try and sink the algae, and, skimming off high concentrations of *Microcystis* using oil spill equipment. Major public health risk was in areas of scum formation so the Swan River Trust and Water and Rivers Commission focussed control efforts on removing accumulations of scum that had aggregated in various sheltered parts of the river. This helped prevent extensive scums of *Microcystis* forming on nearby shorelines and popular recreational beaches where it could have remained a health hazard for weeks as the algal cells broke down releasing their toxins. It is estimated that over 900 tonnes of *Microcystis* was removed from the river and safely disposed of using sewage treatment. Treatment of broad reaches of the river was not successful by any method. However, trials using fine clays mixed with the flocculating material looked promising and if blooms occur again, it may be used at an earlier stage.

Management of the bloom

The response to the bloom was coordinated by the Water and Rivers Commission and the Swan River Trust. In the first few days when water samples indicated rapidly growing colonies of toxic

Spraying concentrated brine solution on Microcystis *concentrations to disperse accumulations was unsuccessful during the bloom in February 2000.*

Pumping saltwater from depth and spraying it on Microcystis *concentrations to disperse accumulations was also unsuccessful during the bloom in February 2000.*

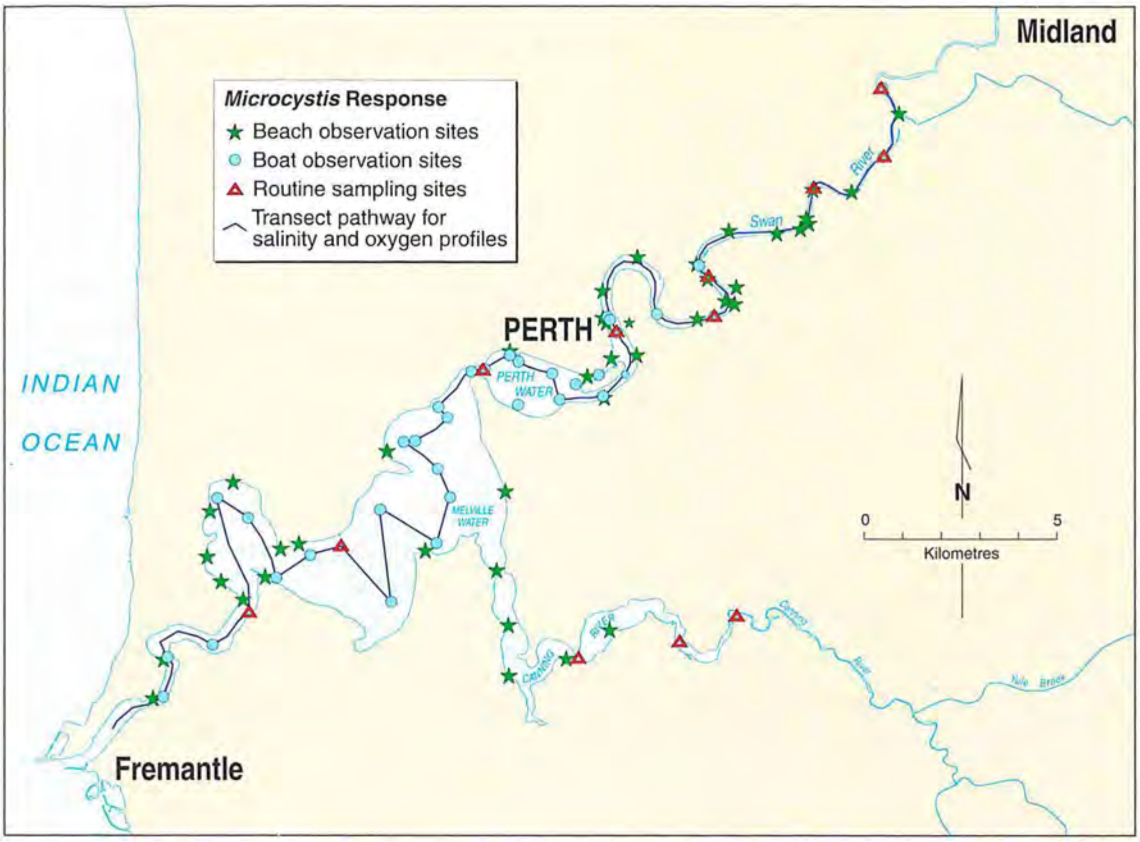


Figure 9. *Sample sites, transect routes and beach observation sites used to monitor progress and decline of the* Microcystis *bloom, February 2000.*

Microcystis, an intensive sampling program was immediately established throughout the Swan-Canning rivers and estuary to monitor the algae's growth, location and toxicity. For example, 20 lower estuary and 35 to 41 beach sites were monitored several times a week during the bloom. A crisis management team with active communication with other agencies held daily meetings to organise control efforts, water sampling and testing and beach clean up efforts. The team also provided information to the media, river users and the general community on the current status of the bloom and its public health implications.

The collapse of the bloom

Natural salinity increases in the estuary caused the *Microcystis* bloom to collapse. When the freshwater flow began to subside towards the middle of February the normal summer seawater intrusion from the Indian Ocean into the Swan Estuary began to re-establish itself. As the seawater progressed up the estuary it raised the salinity above the critical 10 parts per thousand level which was considered to be the upper tolerance limit for this strain of *Microcystis*. The die off was first noticeable in the lower estuary and quickly spread to the middle and upper estuary as the seawater mixed with freshwater. By the end of February the few remaining isolated pockets of *Microcystis* in the upper reaches of the Swan River had also collapsed.

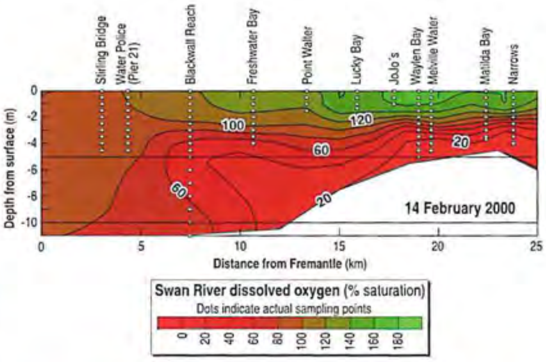


Figure 10. *Dissolved oxygen profiles (water depth by site up the river to the Narrows) during the* Microcystis *bloom.*

Using oil spill booms in Matilda Bay to concentrate and skim scums of Microcystis.

An action plan for the rivers' future

Restoring our natural treasure

The Western Australian Government, Local Governments and the Commonwealth Government are committed to implementing a program to reduce the amount of nutrients that find their way into the Swan-Canning system. By lowering nutrient levels in the river, algal growth will be significantly reduced. This will be accomplished through integrated catchment management and restoration, improved planning and land-use management, modifying river conditions to reduce algal blooms fed by nutrients from the sediments, monitoring the health of the river and filling in critical gaps in our knowledge that could help us better manage and prevent blooms.

There are two major parts to the integrated catchment management program. The first is the Swan-Canning Cleanup Program (SCCP) *Action Plan*. The plan aims to reduce nutrient inputs entering the Swan and Canning Rivers from urban development (domestic and industrial) and rural and semi-rural land uses. The plan focuses on the Swan-Canning coastal catchment (approximately 2 100 km^2) which is bound to the east by the Darling Range. The introduction of water sensitive design requirements in regional and town planning and development schemes, improving land use activities, reducing diffuse nutrient pollution and fostering community led catchment restoration will be important aspects of this plan.

The SCCP *Action Plan* is not designed to address the nutrient problems associated with inland catchments east of the Darling Range. These areas contributed the nutrients which caused the toxic algal bloom in the Swan-Canning Rivers in February 2000. This was a one in twenty year summer rain event and a one in forty year summer flood event. It is difficult to reduce nutrient losses from the land under these unusual natural conditions. Long term efforts though, would reduce nutrient accumulations or the potential for nutrients to be so easily washed into the waterways. The *Action Plan* also does not deal with the normal annual winter runoff that brings a flush of nutrients into the river system from the Avon catchments east of the Darling Range. These inland catchments come under another program, the Swan-Avon Integrated Catchment Management Program.

Clay and a flocculating compound being sprayed to clump and sink Microcystis *cells was partially successful but needed to be done earlier in the bloom.*

This second part of the Integrated Catchment Management Program involves the much larger Avon catchment further upstream and east of the Darling Range (approximately 121 000 km^2). Efforts to reduce nutrient inputs from this larger area are being addressed through initiatives that focus on catchment restoration, revegetation, erosion, better land use and reductions in, and more efficient use of, fertilisers. The West Australian Salinity Action Plan is highly relevant to this program and directly affects this work.

The nutrient reduction programs that have been set in place are long term. Significant results may not be seen for 10 to 20 years, but they are essential if we are to continue to improve the health of one of our greatest natural assets – the Swan-Canning river system. By reducing nutrient inputs the chances of our beautiful river being closed again because of a toxic bloom will be much less likely in the future.

Acknowledgments

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