



Office
of Water

The Murray River Algal Bloom

Evaluation and recommendations for
the future management of major outbreaks



Department of
Environment, Climate Change and Water NSW



Publisher

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The NSW Office of Water is a separate office within the Department of Environment, Climate Change and Water. The Office manages the policy and regulatory frameworks for the State's surface water and groundwater resources to provide a secure and sustainable water supply for all users. The Office also supports water utilities in the provision of water supply and sewerage services throughout New South Wales.

The Murray River Algal Bloom: evaluation and recommendations for the future management of major outbreaks

Acknowledgements

The New South Wales Office of Water would like to acknowledge the stakeholders within the Murray RACC that managed responses to the bloom and enabled a successful interstate multi-level whole of government and water management agency regional response.

This report may be cited as:

Ryan N.J., Dabovic J., Bowling L.D., Driver B. and Barnes B. (2009) ***The Murray River Algal Bloom: evaluation and recommendations for the future management of major outbreaks***. NSW Office of Water, December 2009

ISBN 978 0 7313 3934 1

December 2009

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Foreword

The NSW Office of Water (the Office), and its predecessors, have been instrumental over the years in managing a coordinated, whole of government response to the occurrence of blue-green algal blooms in the State's rivers and storages. The establishment of the NSW Algal Management Strategy in 1992 by the Blue-Green Algal Task Force, (which was later replaced by the State Algal Coordinating Committee), was a direct result of the blue-green algal bloom in the Darling River system in 1991. That five year strategy included such programs as the formulation of the nine inter-agency Regional Algal Coordinating Committees (RACCs), nutrient control works programs, education programs and the stock and domestic bore subsidy. Since that time the NSW Government, through the Office has continued to provide the framework for the coordinated regional risk management response of algal blooms through the nine regional algal coordinating committees.

In recent years, there has been a shift towards the implementation of water sharing plans across NSW, to better share our precious water resources, and meet requirements of Federal programs, such as the National Water Initiative. Nevertheless, water quality monitoring and management has always remained a critical function of the Office. The recent blue-green algal bloom in the Murray River over an eight week period in early 2009 highlighted the resilience of the NSW Algal Management Strategy and the commitment of the NSW Government through the Office in managing the risk posed to the community by blue-green algal blooms. As a consequence of this bloom the Office, in collaboration with the Sydney Catchment Authority (SCA) and Water Quality Research Australia (WQRA), organised a national workshop on blue-green algae to facilitate scientific research, information exchange and seek greater inter-jurisdiction discussion on blue-green algal management.

I have commissioned this report in order to document the process that was used to manage the Murray River Algal Bloom, but to also enable an evaluation of the response so that the Office, other NSW Government agencies, the RACCs and other states can better manage the resource and improve future responses to regional blue-green algal blooms. Since commissioning this report, the Office has also reviewed its implementation of the NSW Algal Management Strategy with its key stakeholders – the outcomes of both of these evaluations are being used to improve the management of future blooms.

I would also like to thank the Murray and Sunraysia RACCs in NSW and Victoria for their effective management of the bloom and acknowledge the dedication and commitment of the NSW Office of Water staff who responded by sampling, monitoring, analysing, reporting and managing the bloom during the period.



David Harris
Commissioner
NSW Office of Water

Purpose

This report has been developed to provide an overview of the management response initiated by the NSW Office of Water (the Office) in relation to a major blue-green algal bloom that extended some 1,000 km along the Murray River on the border of New South Wales and Victoria downstream from Hume Dam during a two month period from March to May 2009.

This report provides a critical evaluation of the management framework implemented in response to the blue-green blooms in the Murray River. The evaluation provides for adaptive environmental management, by recognising the importance of continual evaluation, risk assessment, reporting and improvement. The report will:

- document and review the management response at both the state and interstate level, in terms of what worked well, together with an evaluation of improvements required in order to manage future blooms more effectively
- provide a technical evaluation of current monitoring and testing methods including an overview of the scientific research that the Office initiated or is involved with, detailing pending scientific reports expected within the coming year.

Additionally, the Federal Minister for the Environment (Minister Wong) established the Blue-Green Algal Advisory Group (BGAAG), which is chaired by the Chief Executive Officer of the Murray-Darling Basin Authority (MDBA), to review the effectiveness of the management response to the 2009 Murray River bloom. The Office is a member of this group, together with the South Australian and Victorian environment agencies, the South Australian Water Quality Centre, and the federal Department of Environment, Water, Heritage and Arts. The findings of the group unanimously acknowledged that NSW, through its implementation of the NSW Algal Management Strategy, successfully managed responses to the bloom. The framework of effective communications established under the auspices of the Murray Regional Algal Coordinating Committee (MRACC), as managed and coordinated by the Office, was an effective means of ensuring a successful interstate multi-level whole-of-government and water management agency regional response.

1. Background

1.1 Murray River characteristics and water management

The Murray River rises in the Snowy Mountains and is 2,500 km in length, draining into the southern ocean in South Australia (Figure 2). The regulated section, which is subject to flows from Hume Dam, is approximately 1,700 kilometres (km) in length (DIPNR, 2004). The Lower Darling is the lower portion of the Barwon-Darling River, which runs for some 2,700 km and drains a catchment that includes the central and northern portions of inland NSW and much of south-western Queensland. The regulated portion of the Lower Darling, below Menindee Lakes, is some 500 km long.

The volume and pattern of flows in the Murray River have been greatly altered by the construction of Hume Dam on the Murray, Dartmouth Dam on the Mitta-Mitta River and numerous weirs and diversion structures. These works facilitate the supply of water to extractors and the diversion of water from the Snowy River through the Snowy Mountains Scheme into the Murray.

Hume Dam, with a capacity of 3,038 gegalitres (GL), which is located near Albury, stores and regulates flow of the Murray River. It is operated in tandem with Dartmouth Dam located in the Victorian Alpine Region. Hume Dam is jointly managed by Victorian and New South Wales authorities on behalf of the Murray-Darling Basin Authority. Goulburn-Murray Water manages water and land in Victoria, while the NSW State Water Corporation is responsible for day-to-day operation and maintenance, as well as the management of major remedial works.

Without the construction of these dams and the regulation of water releases from these dams, the flows in the Murray River would vary dramatically between seasons and between years.

New South Wales, Victoria and South Australia currently share the available water in the Murray and Lower Darling River valleys under the Murray-Darling Basin Agreement. A Basin Plan is presently being developed under the federal *Water Act 2007* which will facilitate future sharing arrangements.

New South Wales has established the Murray and Lower Darling Regulated Water Sharing Plan (2004) and the Upper Billabong Unregulated Water Sharing Plan (2004) that defines how water is shared between the environmental assets and a range of water users, including a range of rules and thresholds to restrict access to water. The regulated plan (the Plan) also establishes management responsibility between the state and the MDBA, depending upon volumes within key storages in the Murray-Darling (e.g. Menindee Lakes).

The provisions in the Plan provide water for the environmental needs and ecological processes of the Murray and Lower Darling Regulated Rivers Water Sources, and direct how the water available for extraction is to be shared. The Plan also sets rules that affect the management of access licenses, water allocation accounts, the trading of (or dealings) in access licenses and water allocations, the extraction of water, the operation of dams, and the management of water flows (including those to meet environmental water requirements). Many of these provisions are similar to those that were in place prior to the Plan.

The water in the Murray and Lower Darling is shared between New South Wales, Victoria and South Australia according to the Murray-Darling Basin Agreement and its consequent arrangements. The Plan only deals with sharing of the water in the NSW Murray and Lower Darling which is within the direct control of NSW. The water available to NSW in the Murray is, in part, dependent on the water available from Menindee Lakes on the Lower Darling. However; in most other respects, the sharing and allocation of water in the two water sources are independent.

The river is highly regulated and subsequently has a range of impediments creating weir pools. Additionally, when Hume Dam storage levels fall below six per cent, blooms in the Murray River have been shown to be more likely to occur. It is felt this is a consequence of lower velocity flow and/or algal blooms in the dam itself seeding the river (Baldwin et al. 2008, 2009).

The Murray River is the life blood of the regional towns that are located on and around it. Apart from regulation providing available water for stock, domestic, industrial and agricultural purposes, it provides an amenity for recreational pursuits. The many pressures on the river include regulation, land management issues, return agricultural and wastewater flows, and run-off. These pressures, combined with the requirement of the river to supply raw water for potable reticulated water supply, mean the establishment of a knowledge and management framework to respond to critical water shortages and or water quality problems is paramount in the protection of human health and livestock, and for the management of the future health of the river. The NSW Algal Management Strategy and implementation of the Murray Regional Algal Contingency Plan, are instrumental in ensuring the public health aspects are met.

1.2 NSW Algal Management Strategy

The State Algal Advisory Group (SAAG) has provided strategic direction for algal management in NSW since its inception as part of the NSW Algal Management Strategy. This strategy was established under the Blue-Green Algal Task Force (BGATF) following the 1991 Darling River blue-green algal blooms. Throughout the years of water reform and major structural changes within NSW Government, The NSW Office of Water (the Office), Department of Environment, Climate Change and Water (DECCW) and predecessors have continued to provide a coordination and 'knowledge broker' role for other agencies and water authorities within NSW.

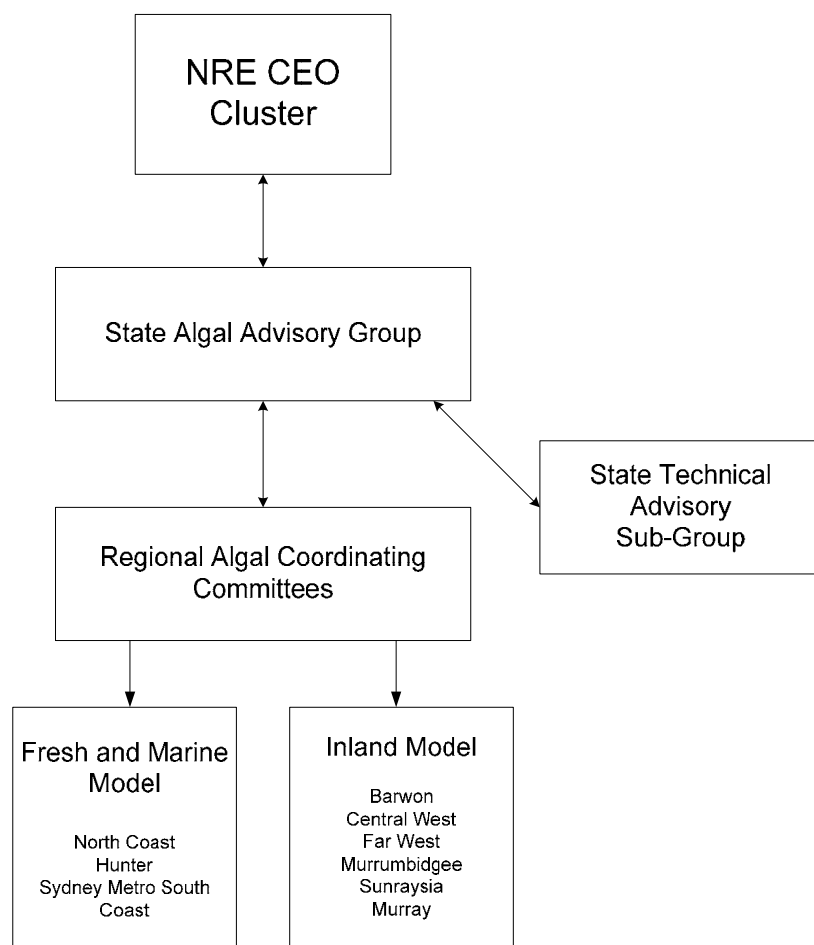
The Task Force was replaced by the NSW State Algal Coordinating Committee (SACC), whose responsibility it was to implement the NSW Algal Management Strategy. The Strategy involved a range of initiatives and was well resourced by the then Department of Water Resources. These initiatives included the development of algal guidelines, Regional Algal Coordinating Committees (RACCs), community education measures, blue-green algal stock and domestic bore subsidy program, and nutrient control strategies. A range of annual reports were developed by the BGATF and State Algal Coordinating Committee during the strategy.

Since that time, the history of governance arrangements for algal management in NSW has varied, but the fundamental principles underlying NSW Algal Management have been the regional management of blue-green algae through an interagency committee of stakeholders (i.e. the RACC).

The Office and its predecessors have been responsible for the knowledge broker role or co-ordination role, while other agencies such as the NSW Industry and Investment (II), Regional Health authorities, NSW Food Authority (NSWFA) Catchment Management Authorities (CMA), Water Authorities and local government were part of the process, each agency responsible for its jurisdictional legislative responsibilities.

The RACCs report to a State Algal Advisory Group (SAAG) which is a strategic group reporting to the Natural Resource and Environment (NRE) CEO Cluster. At the state level a technical advisory group was formed to debate technical issues involved in algal management and to provide advice to the SAAG, this framework can be observed at Figure 1. Currently in NSW there are three coastal RACCs managing marine and blue-green algae and six inland RACCs managing blue-green algal blooms.

Figure 1: Governance model of NSW algal management



1.3 Regional Algal Coordinating Committee

Within the Murray and Lower Darling systems, the Murray RACC (MRACC) and Sunraysia RACC (SRACC) respectively are responsible for coordinating risk management responses to blue-green algae. Additionally, in the Murray and Lower Darling Water Sharing Plan, the triggers for use of the Lower Darling Environmental Contingency Allowance (LDECA)¹ are directed by the Sunraysia RACC.

The Murray and Sunraysia RACCs membership consist of representatives from the Office, State Water, regional councils, Murray Catchment Management Authority (MCMA), Lower Murray-Darling CMA, Victorian Mallee CMA, Industry and Investment NSW (I&I NSW), Murray-Darling Basin Authority (MDBA), Goulburn Murray Water (GMW), Lower Murray Water (LMW), Victorian Department of Sustainability & Environment (VDSE), NSW Food Authority (NSWFA), NSW Health, Department of Human Services (Victoria), Greater Southern Area Health Service, Murray Goulburn Coop (COBRAM), Far West Area Health Service, Anabran Water, Murray Irrigation Ltd and Western Murray Irrigation.

The MRACC has established a Murray Regional Algal Contingency Plan (Version 12) that forms the basis of the framework for decision making and managing risk from blue-green algal occurrence. The Office coordinates and produces this plan and its amendments. The plan details the responsibilities of the stakeholders in responding to algal blooms and incorporates information on the guideline triggers for responses. Continual review and improvement of the plans is required in order to incorporate new technological advancements and guideline implementation, based on best available scientific knowledge.

¹ The LDECA is volume of water set aside in Menindee Lakes that can be used under certain conditions to flush algal blooms.

1.3.1 RACC Locations

The Murray RACC area of responsibility encompasses the same catchment area as that of the Murray CMA, and includes the Murray River, its tributaries and lakes (on the NSW side) from the upper catchment in the highlands above Albury, downstream to where the Murray is joined by the Murrumbidgee. Major storages and waterways in the area include Lake Hume, Lake Mulwala, the Edward River, the Wakool River and Billabong Creek. Since both NSW and Victoria would be affected by algal blooms (e.g. for municipal supply to towns along the Murray River), the plan includes the Murray River floodplain and applies across the State border to Victoria.

The Sunraysia RACC region covers the River Murray, its tributaries and lakes between the confluence of the Murrumbidgee River and the South Australian border and the Darling River below Wilcannia including the Menindee Lakes and Broken Hill.

1.3.2 RACC response group

The RACC response group is formed when a high alert status is confirmed or imminent that covers a significant portion of the region (i.e. is not a locally confined bloom). The group is established by the Chair to manage responses to the bloom on behalf of the RACC. The group includes representatives of the relevant local water manager(s), government agencies, municipal councils and other appropriate water managers. The chairperson of the group will be the RACC Chairperson (or as nominated by the Chairperson) who will act as spokesperson for the group dealing with media interest about the bloom.

The algal response group is established by the RACC to manage responses to a specific algal incident. The group membership depends on areas of responsibilities of the stakeholders and varies with incident. The communications and management responsibilities of the Murray River Bloom algal response group are detailed in Table 1.

Table 1: Communication and management responsibilities of the Algal Response Group

Responsibility		Action
Communication	Public information	Media releases Household notices Notices to other users (e.g. farmers, private diversers, ski clubs, angling clubs) Public notices to be posted in public places, particularly; Holiday places Tourism centres Police stations Road signs – crown land
	Government agencies	Relevant emergency officers for both states (if a major outbreak) NSW Health DHS (Victoria) NSW Office of Water Municipal Councils Laboratory for cell counts Commonwealth and interstate authorities and agencies where applicable Waterways Authority of NSW Murray Catchment Management Authority Murray-Darling Basin Authority NSW Lands Department

Responsibility		Action
	Special consumers	Hospitals Doctors Nursing homes Childcare centres Schools and kindergartens Food processing premises Veterinary premises Hotels/motels Restaurants Camping grounds and caravan parks
Adequate monitoring, sampling and testing during the event		Selecting relevant sampling sites Selecting parameters to be monitored determining the frequency of sampling Selecting competent analytical laboratory(s) Cost allocation.

Make arrangements for implementing reduction/minimisation options (e.g. flow manipulation in rivers, withholding discharges from wastewater treatment plants), with approval from the relevant responsible agency.

Provide regular advice to the RACC on the situation on a weekly or even daily basis, depending on the severity of the bloom.

After the bloom has dissipated, the Response Group will hold a debrief meeting and prepare a report to the RACC on the causes (where known) and management of the bloom, including recommendations for improvements in future management arrangements. This will be used in the end of season RACC protocol evaluation and update.

Additionally, within the response group the roles and responsibilities of the major stakeholders are determined. These responsibilities are normally based on the agency roles and legislative responsibilities as defined within the Murray Regional Algal Contingency Plan. The roles were defined as follows in Table 2.

Table 2: Agency responsibilities for Murray Bloom

Agency	Responsibilities
NSW Office of Water	<ul style="list-style-type: none"> • Monitor algae (types, concentrations and extent) in rivers and other surface waters (excluding farm dams and private supply/drainage). • Liaise with laboratories. • Report results of monitoring to RACC and water users. • Retain a supply of information sheets for water users. • In consultation with agencies undertaking monitoring, distribute media releases. • Provide RACC Secretarial support and Media Coordinator, organise meetings, archive RACC documentation. • Provide advice to RACC, local government and other water users on: <ul style="list-style-type: none"> ○ treatment options ○ alternative supplies.

Agency	Responsibilities
Goulburn-Murray Water (G-MW)	<ul style="list-style-type: none"> • Report on algal data collected from the NE Victoria Agencies as part of the NE Region RACC. • With the Office, ensure parity between Victorian and NSW RACC processes. • Lead Response Group activities and provide media services for blooms developing within the area of the Yarrawonga weir management plan. • Inform the RACC chair of all media releases to be made affecting the NSW RACC area.
Department of Environment and Climate Change and Water (DECCW)	<ul style="list-style-type: none"> • Be alert to control incidents and investigate any reports. • Inform RACC secretariat of any algal bloom observed or reported by the community. • Advise government agencies on disposal of contaminated water treatment wastes and have input into disposal methods specified for disposal of dead stock in close consultation with other affected agencies. • Investigate, assess & provide timely advice on environmental impacts of any proposed control measures for algal blooms.
Industry and Investment NSW (I&I NSW)	<ul style="list-style-type: none"> • The Sampling Service can be accessed by contacting the I&I NSW Laboratory at Wollongbar on (02) 6626 1103. • I&I NSW Agriculture to provide stock watering advice (I&I Vet) and irrigation. • I&I NSW fisheries maybe able to provide advice on commercial.
NSW Health Department and Victoria's Department of Human Services (DHS)	<ul style="list-style-type: none"> • Liaise with and provide advice to doctors, hospitals, local government and water supply authorities. • Liaise with the NSW Office of Water, water supply authorities and local government regarding water. • Treatment, systems and related issues.
Local government and water authorities	<ul style="list-style-type: none"> • Monitor algae (types, concentrations and extent) at water supply intakes and recreational areas. • Maintain appropriate water treatment capabilities for potential algal blooms. • Liaise with laboratories. • Report results of monitoring to RACC and water users. • Hold stores of warning signs and erect when and where necessary. • Prepare and distribute warning letters to potentially affected water users. • Retain a supply of 'information sheets' for water users. • Develop local contingency plans for algal blooms in consultation with the RACC.
Murray-Darling Basin Authority (MDBA)	<ul style="list-style-type: none"> • May provide additional funds in the event of a significant algal bloom occurring in the River Murray system. • Take action upon consultation with the Office regarding options for variation in river flows/levels as part of the River Murray system control.
State Emergency Service (SES) and Police (NSW and Vic)	<ul style="list-style-type: none"> • Provide support when severe blooms occur which require assistance beyond local resources.

1.4 Fluorometry trial

Coincidentally during the Murray algal bloom the Office was trialling the use of fluorometry for real time measurement of cyanobacteria² to determine whether the technology can be used as an early warning for the potential for algal blooms in western rivers.

The traditional method of monitoring inland freshwaters for cyanobacterial presence and bloom formation is through the collection of water samples that are sent to a laboratory for analysis. Analysis includes the identification of any cyanobacterial taxa present to genus or species level, and an enumeration of the number of cells per taxa present in one millilitre of water (cells mL⁻¹). These data, either as cell counts or converted biovolume value (cubic millimetres per litre – mm³ L⁻¹) are then compared with guideline values for the various water uses, including for raw (untreated) drinking water, stock watering and recreation. If the recreational 'Red Alert' guidelines (NHMRC 2008) are exceeded, media releases are issued to warn the public not to use the water for any purpose. If only the drinking water or livestock watering guidelines are exceeded (NHMRC 2005, NSW Algal Advisory Group 2007), only the relevant water utilities, landholders and other stakeholders are advised.

One problem with this method of monitoring cyanobacteria is that there are often delays of several days or longer between sample collection and the analytical data becoming available for management use. One factor affecting this includes the time taken between the sample being collected and its arrival at the analytical laboratory. Because of the long distances from the laboratory and remoteness of many sampling locations in regional areas of NSW, especially in the Murray-Darling Basin, this transportation time may be considerable. Another factor is the ability of the laboratory to analyse the samples promptly, and there may be delays if the samples are queued behind others awaiting analysis because the laboratory is already operating at its full capacity. The longer the delays between sample collection and the data becoming available, the less relevant and useful these data are for management purposes.

The measurement of cyanobacterial occurrence using insitu fluorometry has been proposed as a means of providing immediate information on the amount of algae present to enable more rapid management responses. Briant *et al.* (2008) found a strong linear correlation between phycocyanin³ concentration measured with a TriOS microFlu-blue sensor and cyanobacterial presence measured as cells mL⁻¹, even when there was a very heterogeneous mix of taxa present. They found a slightly better correlation between phycocyanin content and estimated biovolume. Likewise, Leboulanger *et al.* (2002) found good correlation between fluorescence measured with a bbe-Moldaenke FluoroProbe with cell counts of the potentially toxic cyanobacterium *Planktothrix rubescens* in an almost mono-specific bloom situation in a French lake.

The following sections of this report include an explanation of the method for algae sampling in response to the bloom, as well as results of the fluorometry trial in the Murray River.

² cyanobacteria indicates blue-green algae

³ A cyanobacterial pigment used to detect the presence of cyanobacteria in water.

2. Introduction

2.1 The Murray River bloom

In March 2009 high concentrations of cyanobacteria were detected by routine monitoring in Lake Hume. This warranted issuing of a 'Red Alert' under the National Health and Medical Research Council (NHMRC)(2008) guidelines by the Murray RACC. Subsequent to the detection of the bloom in Lake Hume, additional downstream monitoring indicated that cyanobacteria was present in the Murray River for a distance of 1,000 km including associated tributaries of Gulpa Creek, Edward River and Wakool River during the period of March to May 2009. Lake Hume has been shown historically to seed cyanobacteria in the Murray River downstream of Lake Hume when the storage levels in the lake drop below six per cent (Baldwin et al 2009). This was the case during the March 2009 bloom. Plate 1 illustrates the extent of the bloom at key locations within the Murray Valley.

Management of the responses to the blooms was undertaken for the most part by the Murray Regional Algal Coordinating Committee (MRACC), with that for Robinvale/Euston being managed by the Sunraysia Regional Algal Coordinating Committee (SRACC). Stakeholders representing the major New South Wales and Victorian government agencies met by teleconference prior to issuing the initial regional Red Alert on 26 March 2009 to discuss appropriate management actions, including the issue of the alert and the enactment of the Regional Algal Management Plan. A teleconference inviting all members of MRACC was held on 27 March 2009 to fully brief all stakeholders on the situation. The Chairpersons of both the MRACC and SRACC were actively involved throughout the bloom period providing management advice to stakeholders and to the public via the media.

The presence of an algal bloom triggered increased sampling and investigations to ensure that bloom coverage was adequately ascertained and monitored. As such the river and other key locations were monitored biweekly for the duration of the bloom and algal alerts were issued at the following sites throughout the bloom period (Table 2). Key dates for alerts are also described in Table 2.

Table 3: Chronology of algal alerts

Date 2009	Action
5 March	Bloom was initially detected in Lake Hume in March with a Red Alert issued.
13 March	Red Alert issued for Lake Mulwala.
26 March	A regional Red Alert was issued for 400 km of the river from Lake Hume to Torrumbarry Weir. There was a high detection of potentially toxic cyanobacteria in the Murray River immediately downstream of Yarrawonga Weir, at Cobram, Barmah and Echuca. The storage levels in Lake Hume dropped below six per cent over the same period.
6 April	The regional alert was extended to cover 800 km of the Murray River due to the cyan bacterial bloom extending downstream of Torrumbarry Weir at Barham, Murray Downs and Tooleybuc.
9 April	The regional Red Alert was extended to include Gulpa Creek and the Edward River.
17 April	A Red Alert was issued for the Murray River at Robinvale/Euston (a further 200 km downstream of Tooleybuc) and Wakool River. Alert down graded to Amber at the mid sections of the Murray, between Torrumbarry Weir and Boundary Bend (downstream of Tooleybuc) due to the cyan bacterial bloom starting to decline.
4 May	Red Alert lifted in Lake Hume and for the Murray River as far downstream as Corowa due to the decline in the bloom due to the cooler autumn weather.
9 May	The Red Alerts for the section of the Murray River between Corowa and Moama/Echuca, including Lake Mulwala, and for the Edward River system were removed.
14 May	Finally the alert for Robinvale/Euston was removed.

Figure 2: Location of the Murray River

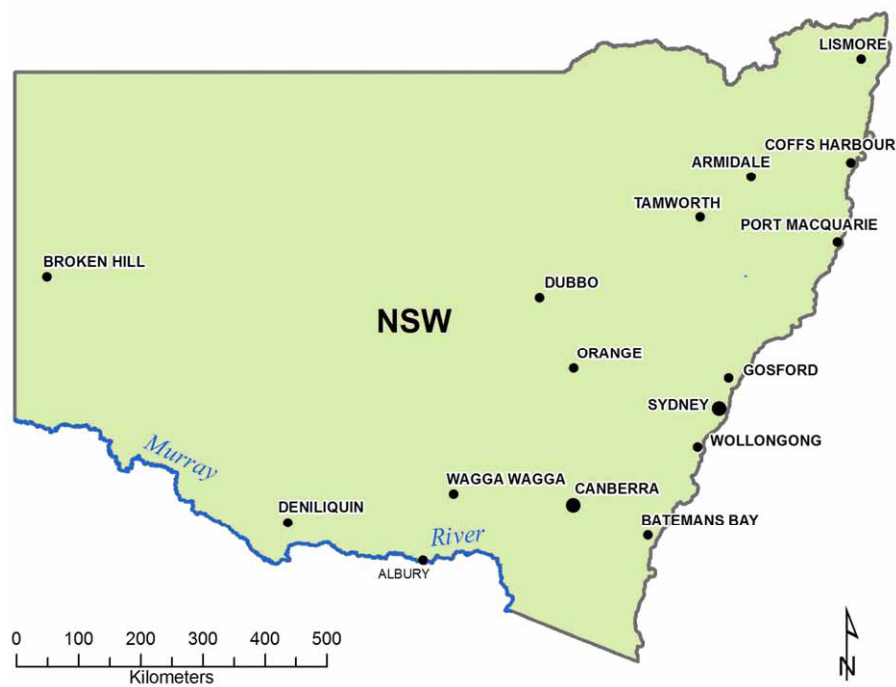


Plate 1: Aerial photographs of the extent of the algal bloom in a) Downstream of Hume Dam, b) Lake Mulwala, c) Torrumbarry Weir and d) Euston Weir – April 2009







3. Methods

3.1 Murray algal bloom methods

3.1.1 Sampling response

The MRACC stakeholders undertake routine monitoring as part of their water supply or water management operations. For example, the Office and State Water undertake routine algal and water quality monitoring in the Murray River and its tributaries as part of an MDBA-funded water quality monitoring data capture project and additionally as part of routine monitoring for the MRACC and SRACC. When algae is visually detected or found in samples, depending upon trigger levels, additional monitoring is undertaken to determine the extent of the bloom and the health implications.

Monitoring of the bloom was undertaken by the Office, with additional monitoring and data being made available by State Water Corporation (SWC), Wakool Council, Victorian Government agencies, Goulburn-Murray Water (GMW) and Lower Murray Water (LMW). Sampling sites listing the sampling agency are shown in Table 4 and locations are depicted by Figure 3.

Sampling took place at 19 locations along the Murray and Edward Rivers between Albury and Robinvale/Euston, and six sites downstream of Euston to the South Australian Border within the MRACC and SRACC regions. Additional site monitoring was conducted by SWC in Lake Hume and by local councils within the RACC area for their local lagoons and water supply channels. These data were also used for additional routine algal management purposes by the MRACC and SRACC.

During summer and autumn of 2009 the Office were also conducting additional monitoring at the sites used for routine algal monitoring for MRACC and SRACC on a weekly basis as part of the fluorometry evaluation program.

Table 4: Sampling site locations and sampling agency

Site	Sampling agency
Billabong Ck. Jerilderie	NSW Office of Water
Billabong Ck. Walbundrie	NSW Office of Water
Edward R Deniliquin	NSW Office of Water
Edward R. Moulamein	NSW Office of Water
Edward R. Old Morago	NSW Office of Water
Gulpa Ck. Mathoura	NSW Office of Water
Koraleigh Water Supply Channel	Wakool Council / NSW Office of Water
Lake Hume Dam @ Main Basin East Shore	State Water
Lake Hume, Dam Wall, Hume Shire Offtake	State Water
Lake Hume, Ebdon	State Water
Lake Hume, Heywoods	State Water
Lake Hume, Hume Dam Resort	State Water
Moonah Lagoon at Moonahcullah	Community/ NSW Office of Water
Mulwala Canal Offtake	NSW Office of Water
Murray R. @ below Yarrawonga	NSW Office of Water
Murray R. @ Howlong Bridge	NSW Office of Water
Murray R. Barham	NSW Office of Water
Murray R. Buronga	NSW Office of Water
Murray R. Cobram	NSW Office of Water

Site	Sampling agency
Murray R. Corowa	NSW Office of Water
Murray R. Curlwaa	NSW Office of Water
Murray R. Euston	NSW Office of Water
Murray R. Fort Courage	NSW Office of Water
Murray R. Lock 8	NSW Office of Water
Murray R. Merbein	NSW Office of Water
Murray R. Moama	NSW Office of Water
Murray R. Mount Dispersion	NSW Office of Water
Murray R. Murray Downs	NSW Office of Water during bloom (Wakool Council normal)
Murray R. Picnic Point	NSW Office of Water
Murray R. Tocumwal	NSW Office of Water
Murray R. Tooleybuc	NSW Office of Water during bloom (Wakool Council normal)
Murray R. Union Bridge	NSW Office of Water
Murray River @ Barmah	NSW Office of Water during bloom (Wakool Council normal)
Town lagoons, Deniliquin	Deniliquin Council
Wakool R. Kyalite	NSW Office of Water during bloom (Wakool Council normal)
Wakool R. Wakool-Barham Road	Wakool Council
Murray River @ Boundary Bend	LMW
Murray River U/S and D/S of Torrumbarry Weir	GMW
Lake Mulwala (several sites mostly on the Victorian side)	GMW

Figure 3: Murray River sample site locations



3.1.2 Frequency of sampling

Weekly sampling occurred along the Murray at all sites until 5 March 2009. There was a two week lapse in sampling due to the unavailability of the Office after this date. Once the bloom became evident in late March, additional contingent sampling took place from 25 March 2009. Twice weekly sampling commenced in the week beginning 20 March 2009 along the Murray River at all sites upstream of Tooleybuc. Sampling at sites along the river in Sunraysia RACC area continued on a weekly basis, as did sampling at sites along the Edward and Wakool Rivers.

Sampling in the mid section of the Murray River at Barham, Murray Downs, Koraleigh and Tooleybuc was also supplemented by samples collected by Wakool Council and by Lower Murray Water, and forwarded to the Office laboratory for analysis. This enabled these locations to be sampled twice a week throughout the duration of the bloom.

3.1.3 Sampling methods

Water quality and algal sampling

Surface and integrated samples were collected from the reservoirs using a boat, sampling pole and/or integrated sampler. Samples from the Murray River and tributaries were collected using a sampling pole.

Samples were collected in clean 250 mL polyethylene bottles which were inverted, immersed in the water to a depth of about 25 cm and turned upright and filled. The samples were preserved with Lugols for enumeration. Identification and counts were performed using a calibrated Lund cell and compound microscope at 200 X magnification after concentration by sedimentation (American Public Health Association, 1998: method 10200-F) with a counting precision to ± 20 per cent (Hötzel & Croome, 1999). Phytoplankton count data were converted to biovolume based on size measurements made by the laboratory following Hillebrand et al. (1999).

Water temperature, pH and electrical conductivity (including temperature compensated) were measured insitu with a Yellow Springs Instrument (YSI) or Hydrolab Quanta G Transmitter QT 00819 Water Quality Monitoring System (Hydrolab Corporation, Austin Texas).

Toxicity sampling

Additional samples were collected from the river at sites between Moama-Echuca and Albury for toxicity testing using enzyme-linked immunosorbent assay (ELISA) at the Australian Water Quality Centre in South Australia on 6 April 2009. Further samples were collected at major sampling locations along both the Murray and Edward Rivers on a weekly basis for four weeks between 25 March and 22 April 2009 for toxicity testing using Polymerase Chain Reaction (PCR) (a molecular genetics technique) at the University of New South Wales (UNSW).

Samples collected for toxicity testing were placed into clean polyethylene bottles unpreserved and kept on ice and sent to the relevant laboratory for analysis. PCR sampling was undertaken to characterise whether the genotype of algae present was producing toxins, and to characterise further the risk for country town water operations.

Aerial imagery

Three aerial surveillance flights were undertaken. Two of the flights using high resolution and video digital imagery were funded by the MDBA and were flown by a commercial company from South Australia (IOJ Photography). The first flight was undertaken on 28 and 29 March 2009, and covered the area from Swan Hill to Lake Hume. The second flight on 9 April 2009 was from Mildura to Yarrawonga and on 13 April 2009 from Yarrawonga to Lake Hume. The Office also undertook a visual surveillance flight from Albury to Robinvale/Euston on 6 April 2009. Plate 1 demonstrates some aerial photographs of the bloom.

3.2 Fluorometry methods

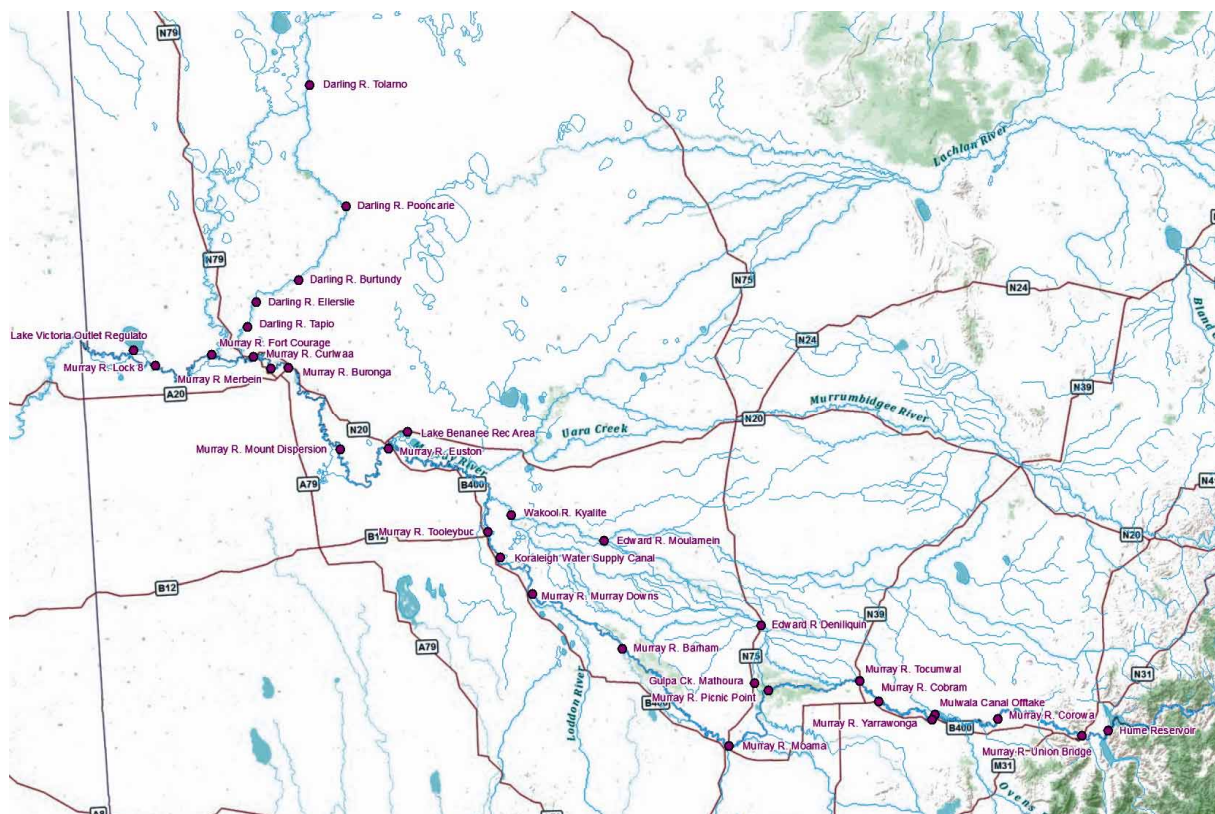
3.2.1 Sampling sites

Sampling occurred on an approximately weekly basis from mid November 2008 until late May 2009. A total of 20 sampling runs were made, with sampling undertaken at up to 26 sites each week (Table 5). The sites were located at major towns and other points along the Murray River from Albury downstream to Lock 8 (just upstream of the border with South Australia), on Gulpa Creek, the Edward River and the Wakool River between Mathoura and Kyalite, and on the lower Darling River between Menindee and Wentworth (Figure 4). Some sites on both the lower Murrumbidgee and lower Lachlan Rivers were also initially sampled, but later dropped because inclusion of these sites meant excessive time taken to complete the sampling runs each week.

Table 5: Sampling sites during the fluorometry trial

Site
Darling River @ Burtundy
Edward River @ Moulamein
Euston Weir Front of Lock
Gulpa Creek @ Mathoura
Koraleigh Town Water Supply Channel
Lachlan River @ Hillston Weir
Mulwala Main Canal @ Offtake
Murray River @ Curlwaa
Murray River @ Albury (Union Bridge)
Murray River @ Murray Downs
Murray River @ Picnic Point
Murray River @ Tooleybuc
Murray River U/S Euston Weir
Murray River @ Barham
Murray River @ Buronga
Murray River @ Cobram
Murray River @ Corowa
Murray River @ Curlwaa
Murray River @ Fort Courage
Murray River @ Lock 8
Murray River @ Merbein
Murray River @ Moama
Murray River @ Mt Dispersion
Murray River @ Tocumwal
Murray River D/S Yarrawonga Weir
Murray River at Howlong Bridge

Figure 4: Locations of fluorometry sampling sites



3.2.2 Sampling methods

A Yellow Springs Instruments (YSI) water quality sonde (with temperature, dissolved oxygen, specific conductivity, depth, pH, turbidity, chlorophyll-a and phycocyanin sensors) was used to measure water quality at each sampling site including chlorophyll-a and phycocyanin for the insitu algal measurements (plate 2).

Eight water samples (1L) were collected at each sampling site from different locations along the river bank and combined for a composite sample in a bucket. The in-field water quality measurements were then measured from the composite sample using the YSI sonde. This was done to reduce the amount of variability that would have otherwise occurred in the data had the sonde been placed directly into the river with the water flowing past.

Measurements from the YSI sonde were recorded every 10 seconds with measurements collected for a period of up to five minutes (sometimes longer). The in-field water quality data was later audited to remove any outliers and any initial unequilibrated data for each site. The mean value for each of the water quality attributes measured in the field was then calculated from the audited data.

A 250 mL algal sample of the composite water sample in the bucket was also collected for laboratory analysis, so that the field and laboratory data were directly comparable for statistical analysis. The algal sample was preserved in Lugol's iodine solution and forwarded to the Office laboratory in Wolli Creek (Sydney) for analysis.

Plate 2: NSW Office of Water quality field officer with YSI fluorometer



3.2.3 Laboratory analysis

Cyanobacterial taxa were identified and counted to genus or species level of taxonomy as appropriate. Those identified to species level were generally the potentially toxic taxa, and other representatives of the genera *Anabaena* (recently renamed *Dolichospermum*), *Microcystis*, *Cylindrospermopsis*, and *Cuspidothrix* (*Aphanizomenon*). Counting was undertaken to at least ± 20 per cent precision using a Lund cell and compound microscope (Hötzels and Croome 1999). Cell size measurements were also made on commonly occurring taxa using a compound microscope fitted with a high resolution digital camera and the images captured measured using image enhancement software, as described in Hawkins *et al* (2005). Cellular biovolumes were then calculated using the formula for the most appropriate geometric shape following Hillebrand *et al* (1999).

Total cyanobacterial biovolumes were calculated for each sample by multiplying the cell count for each taxon by the measured cellular biovolume for those taxa, and by summing these across all taxa. Published cellular biovolumes (see the Department of Human Services, Victoria 'Biovolume Calculator', 2007) were used for the less commonly occurring taxa where no sample-specific cell size measurements could be made.

4 Results

4.1 Murray bloom

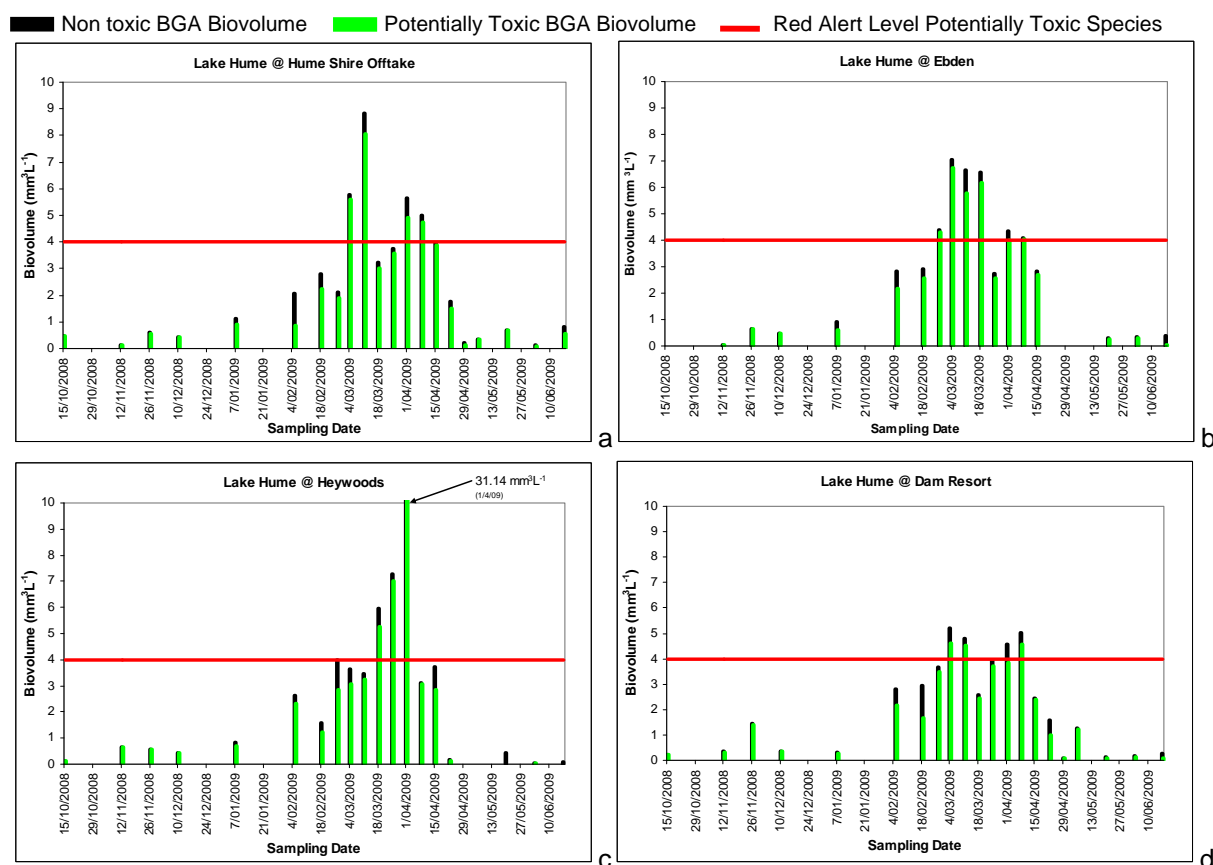
The results presented here are preliminary. A more comprehensive technical report, and/or peer review journal article will be produced upon more comprehensive statistical analysis and interpretation of algal data, flow and environmental gradients. One of the notable features of these blooms was the presence of *Cylindrospermopsis*, a tropical taxa inhabiting the warmer environments of Australia.

4.1.1 Cyanobacterial alert biovolumes and species

Lake Hume

On March 4 2009, the potentially toxic taxa of cyanobacteria *Anabaena circinalis*, *Aphanizomenon ovalisporum*, *Cylindrospermopsis raciborskii* and *Microcystis flos-aquae* were detected at all sampling sites in Lake Hume. The total biovolume of potentially toxic species on this sampling date exceeded $4 \text{ mm}^3 \text{L}^{-1}$ at all sites except for Heywoods which had a total biovolume of approximately $3 \text{ mm}^3 \text{L}^{-1}$. The Heywoods site subsequently had the largest bloom with a biovolume of $31 \text{ mm}^3 \text{L}^{-1}$ on April 1. The total biovolumes mostly remained above $4 \text{ mm}^3 \text{L}^{-1}$ until mid April at all sites in Lake Hume (Figure 5).

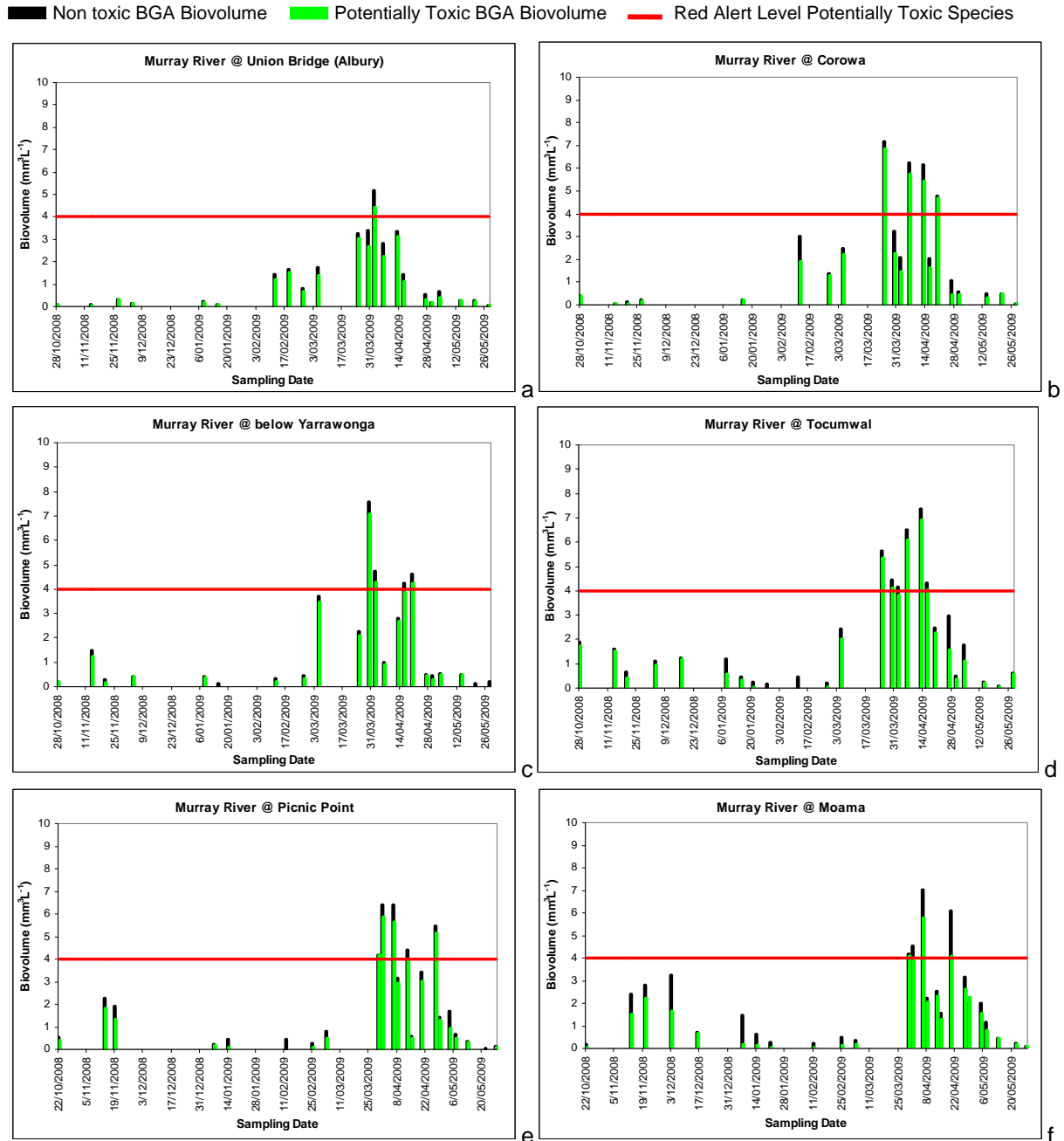
Figure 5: Biovolumes of cyanobacteria in Lake Hume a) Hume Shire Offtake, b) Edben, c) Heywoods and d) Dam Resort

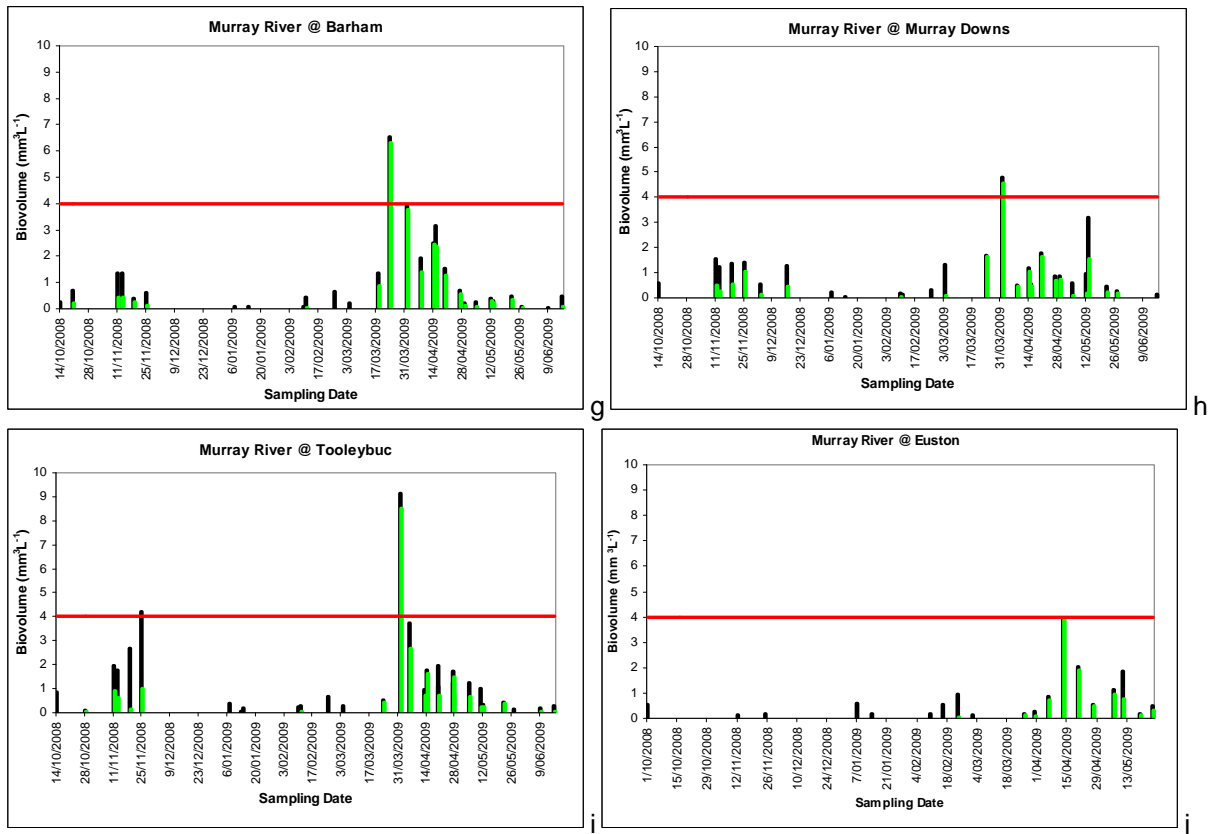


Murray River

In the Murray River the potentially toxic taxa *Anabaena circinalis*, *Cylindrospermopsis raciborskii* and *Microcystis flos-aquae* were detected at the majority of the sampling sites during March and April 2009. The biovolumes of potentially toxic cyanobacteria exceeded $4 \text{ mm}^3 \text{ L}^{-1}$ in late March at all sites with a biovolume ranging from 5 to $9 \text{ mm}^3 \text{ L}^{-1}$. Biovolumes decreased to below $4 \text{ mm}^3 \text{ L}^{-1}$ in late April/early May 2009 (Figure 6). The main features of this data are the ‘flash in the pan’ nature of the bloom in the Murray River at all sites downstream of Torrumbarry Weir.

Figure 6: Biovolumes of cyanobacteria in Murray River a) Union Bridge (Albury), b) Corowa, c) Below Yarrowonga, d) Tocumwal, e) Picnic Point and f) Moama

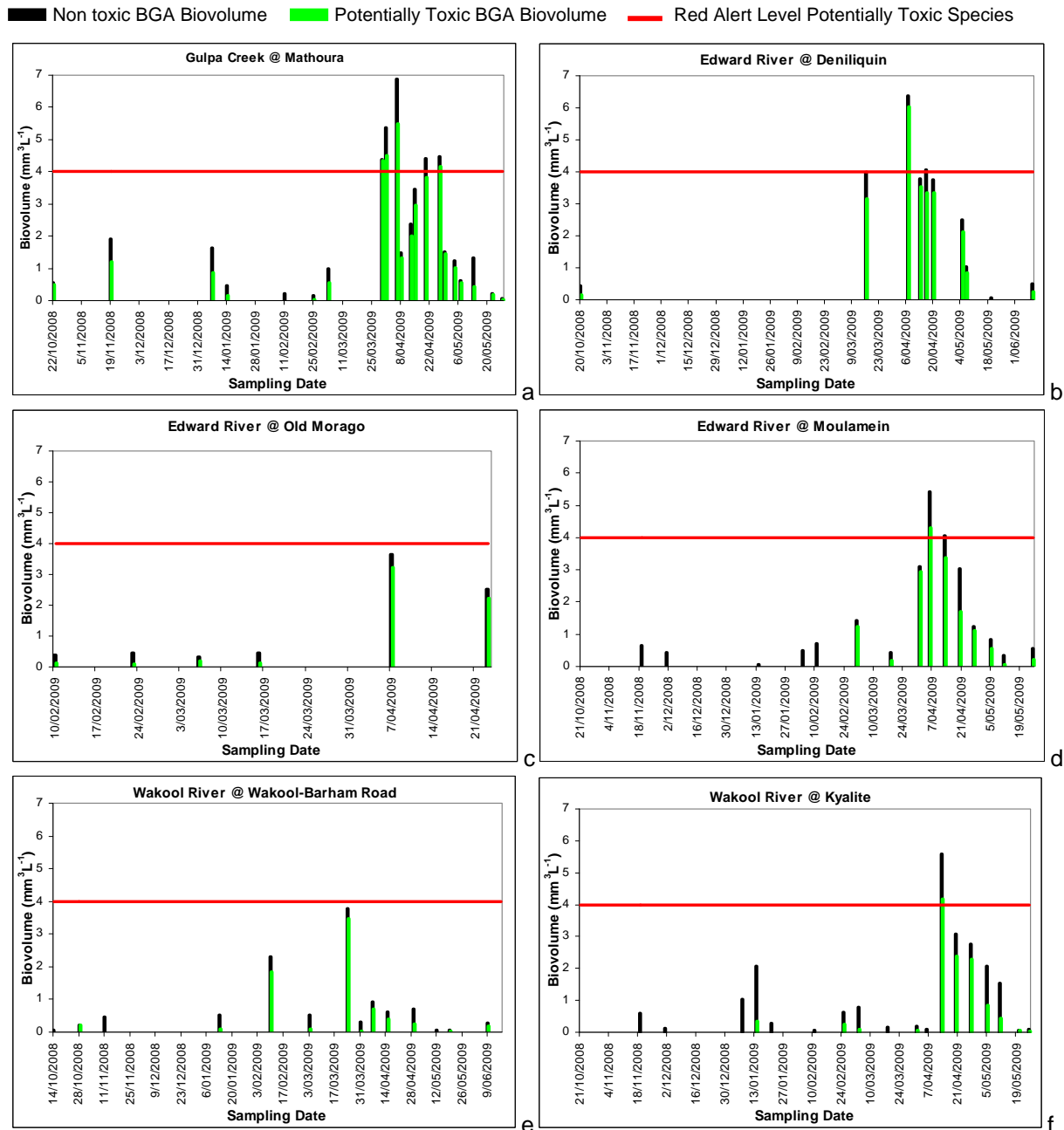




Tributaries

The potentially toxic species of *Anabaena circinalis*, *Cylindrospermopsis raciborskii* and *Microcystis flos-aquae* were detected in Gulpa Creek at Mathoura in the Edward River at Deniliquin and Moulamein, and in the Wakool River at Kyalite. Biovolumes in the Murray River tributaries exceed 4 mm³ L⁻¹ in April with the highest biovolumes detected in Gulpa Creek. The cyanobacterial biovolumes at the tributary sites of Edward River at Old Morgo and Wakool River at Wakool-Barham Road did not exceed 4 mm³ L⁻¹ (Figure 7) on any sampling occasion.

Figure 7: Biovolumes of cyanobacteria in Murray River tributaries a) Gulpa Creek @ Mathoura, b) Edward River @ Deniliquin, c) Edward River @ Old Morago, d) Edward River @ Moulamein, e) Wakool River @ Wakool-Barham road and f) Wakool River @ Kyalite



4.1.2 Cyanobacterial community composition

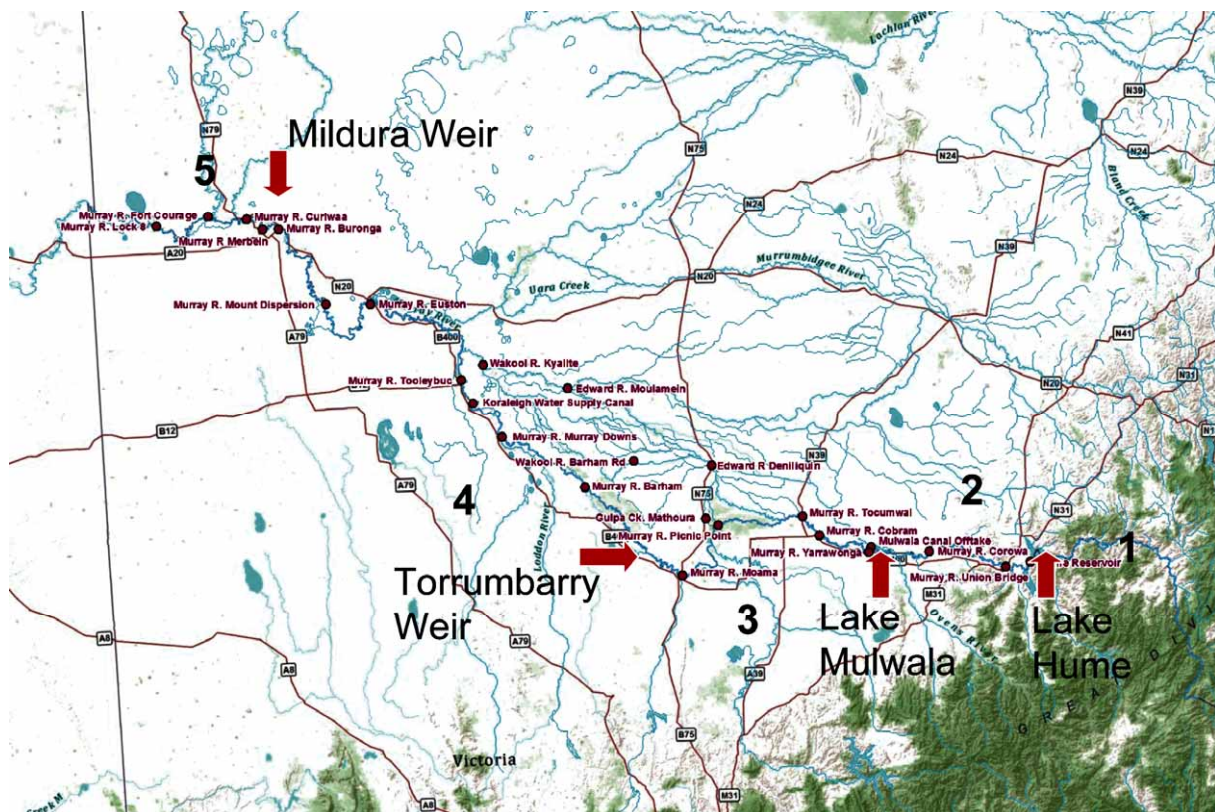
The dominance of specific cyanobacterial taxa changed at several of the sites shown in the section above which indicated that the cyanobacteria community may have changed in a downstream pattern from Lake Hume. Sites were grouped according to both these dominance changes and their location on the river. The differences in cyanobacteria community composition between these groups were tested using a multivariate statistical procedure called PERMANOVA (for Permutational Multivariate Analysis Of Variance).

The PERMANOVA results strongly confirmed the presence of five site-groups as shown on Figure 8 and listed from upstream to downstream as follows: Site-group (1) within Lake Hume, Site-group (2) downstream of Lake Hume, Site-group (3) downstream of Lake Mulwala, Site-group (4) downstream of Torrumbarry Weir, and Site-group (5) downstream of Mildura Weir. The cyanobacteria community

composition of these site-groups were all significantly different from each other, while the sites within these site-groups were not significantly different from each other. There was a downstream gradient of change with each site-group being more similar to the upstream site-group than the downstream site group. This gradient was not continuous but was 'stepped' with the boundaries of the site-groups coinciding with the weirs and their associated water bodies.

These results show that the 2009 Murray River cyanobacteria bloom did not have a uniform community composition throughout its extent and that the composition was influenced by the presence of weirs. This data will be incorporated in a peer reviewed journal publication upon completion of further statistical analysis.

Figure 8: Location of site-groups on the Murray River



4.1.3 Toxic species and toxin levels

ELISA Testing of Murray River samples from NSW

Samples were collected for ELISA testing on April 6, 2009 and sent to Dr Andrew Humpage at the Australian Water Quality Centre in South Australia (Table 5). Results of the testing showed that microcystin, a type of hepatotoxin, was not detectable at any of the sampling locations on this sampling date. *Cylindrospermopsis* was detected in quite high concentrations in comparison to the actual amount of *Cylindrospermopsis* that was present. Some of the concentrations were almost half of the unofficial *cylindrospermopsis* guideline used as a long term drinking water threshold in Queensland ($1 \mu\text{g L}^{-1}$) (Orr & Schneider, 2006).

When *Anabaena* was dominant in the upstream section of Lake Mulwala, saxitoxin (a neurotoxin) was present; however, when *Microcystis* was dominant in the downstream section there was no saxitoxin present.

Table 6: Toxin Levels at sampling sites from upstream to downstream

Sample	Location	Station no.	Microcystin (µg/L)	Cylindrospermopsin (µg/L)	Saxitoxin (µg/L)
1	Murray River at Moama	40910087	n.d.	0.34	n.d.
2	Murray River at Picnic Point	40910089	n.d.	0.47	n.d.
3	Murray River at Tocumwal	409202	n.d.	0.48	n.d.
4	Murray River at Cobram		n.d.	0.32	n.d.
5	Murray River at Yarrawonga	409025	n.d.	0.56	0.015
6	Murray River at Corowa	409002	n.d.	0.33	0.021
7	Murray River at Howlong	409037	n.d.	0.19	0.020
8	Murray River at Albury	409001	n.d.	0.37	0.023

Note: n.d. = not detected

ELISA limits of detection - Microcystin-LR 0.1 µg/L; Cylindrospermopsin 0.04 µg/L; Saxitoxin 0.015 µg/L

PCR determination

The toxicity assessment of the bloom is being undertaken by a PhD student in the School of Biotechnology and Biomolecular Sciences at the University of New South Wales, Mr Jamal Al Tebrineh, working under the supervision of Professor Brett Neilan. His assessment of the toxicity of the bloom in the Murray River, including the ELISA data provided by the Australian Water Quality Centre in Adelaide, is due to be completed later in 2009. These results will be combined with an assessment of the bloom monitoring results and physico-chemical results obtained by the Office into a single joint publication in the external peer reviewed literature in 2010.

Table 6 shows the presence (+) or absence (-) of the appropriate toxin producing genes for the three major potentially toxic cyanobacteria taxa at three sites in Lake Hume on 22 April, 2009. At the Heywood site all genes were present while at the Resort site all genes were absent. The potential toxicity of the populations of these taxa differed at these three sites on this one day.

Table 7: Lake Hume PCR results

PCR results showing presence (+) or absence (-) of toxin producing genes			
Potentially toxic taxa	Lake Hume sites – 22 April 2009		
Potentially toxic taxa	Heywoods	Resort	Dam wall
<i>Microcystis flos-aquae</i>	+	-	+
<i>Anabaena circinalis</i>	+	-	-
<i>Cylindrospermopsis raciborskii</i>	+	-	+

Table 7 shows the PCR results for Cobram on the Murray River over four sampling dates. All genes were absent on 25 March 2009, while they were all present on 13 April 2009. The potential toxicity of the populations sampled at this one site may change over a short time period.

Table 8: Murray River at Cobram PCR Results

PCR results showing presence (+) or absence (-) of toxin producing genes				
Potentially toxic taxa	Murray River at Cobram			
Potentially toxic taxa	25 March 2009	2 April 2009	13 April 2009	20 April 2009
<i>Microcystis flos-aquae</i>	-	-	+	+
<i>Anabaena circinalis</i>	-	-	+	-
<i>Cylindrospermopsis raciborskii</i>	-	+	+	+

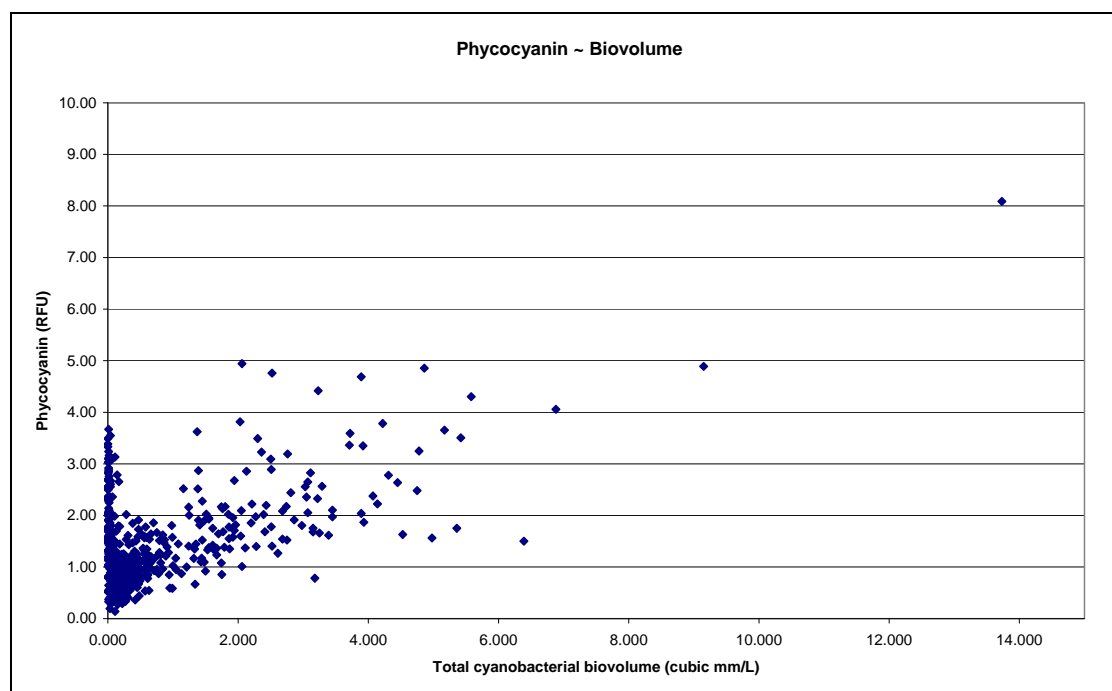
The variability of these toxicity results both within a water body and over time illustrate the difficulty of incorporating this test into the Public Health algal alerts, which are currently based on biovolumes in water samples. There is more PCR data to be incorporated in a final paper.

4.2 Fluorometry

The results presented in this section are a preliminary assessment using calculated biovolume and phycocyanin. A full data analysis including full methodology, water quality influences and full statistical analysis will be presented as a separate technical report/and or peer reviewed journal articles.

A scatter graph of the raw mean field phycocyanin presence as Relative Fluorescence Units (RFU) against total cyanobacterial biovolume is shown in Figure 9. Due to the delays in obtaining actual laboratory cell size measurements to calculate total cyanobacterial biovolume, total biovolumes were calculated using the Department of Human Services (DHS), Victoria (2007) 'Biovolume Calculator'. These data are used to illustrate the full range of the data that will become available. The laboratory measured biovolumes will be used in preference, once available.

Figure 9: Raw data of field measured phycocyanin plotted against total cyanobacterial biovolume calculated using the 'Biovolume Calculator' (DHS, Victoria, 2007)



The raw data demonstrates:

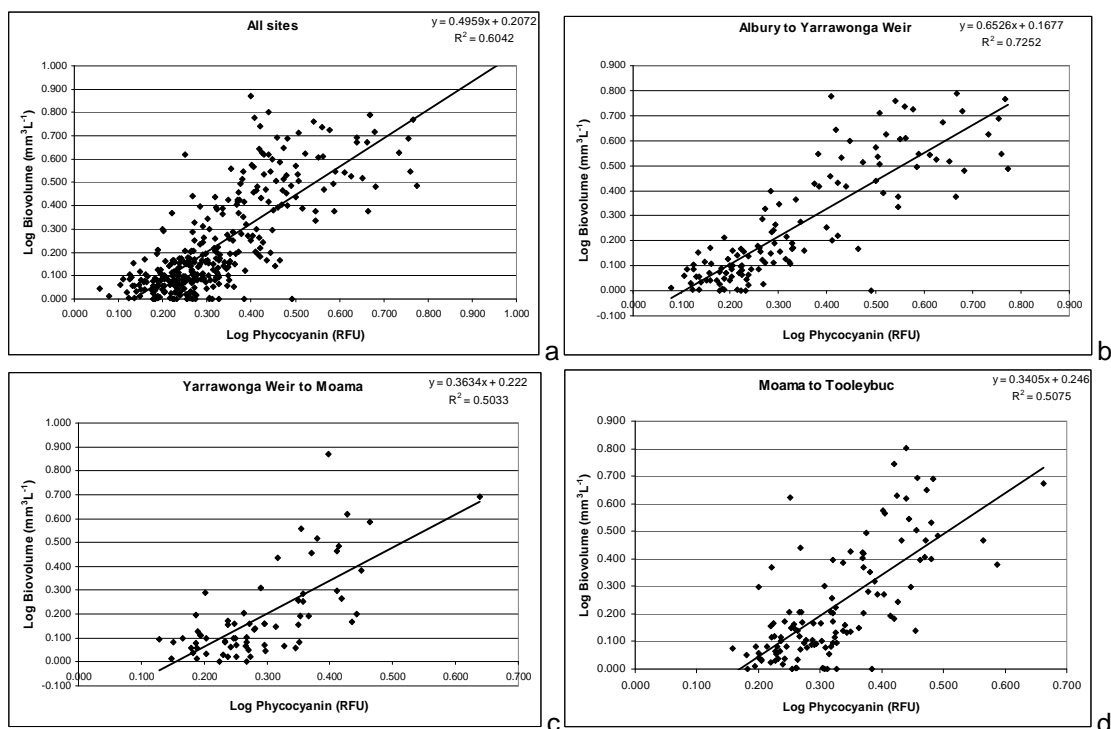
- The skewed nature of the data distribution, with the majority of the data points falling below a total cyanobacterial biovolume of $1 \text{ mm}^3 \text{ L}^{-1}$ and a phycocyanin value of 1.5 RFU. There are fewer data in the total cyanobacterial biovolume range of 2 to $6 \text{ mm}^3 \text{ L}^{-1}$, although the bloom in the Murray River during autumn 2009 provided more information in this range.
- Interference from suspended particulate matter at the more turbid sites caused false positives of up to almost four Relative fluorescence units (RFU) for phycocyanin, despite total cyanobacterial biovolume being negligible.
- Considerable variation is shown within the data. Nevertheless, a general trend of increasing phycocyanin fluorescence with increasing total cyanobacterial biovolume is indicated.

By arbitrarily excluding all sites with a turbidity of 20 Nephelometric turbidity units (NTU) or greater, the false positives due to suspended particulate matter are no longer present. This, however, removes all data from all sites on the Darling River (Burtundy, Ellerslie, Pooncarie, Tapio, Tolarno, and Weir 32), and also Lake Victoria, the Edward River at Moulamein, the Wakool River at Kyalite and the Lachlan River at Booligal. Turbidity in the Murray River at Murray Downs, Tooleybuc, Fort Courage and Lock 8 exceeded 20 NTU on approximately half the sampling occasions as it also did in the Koraleigh Water Supply Channel. The remainder of sites along the Murray River from Albury to Curlwaa have turbidities of less than 20 NTU on almost all sampling occasions. The biovolume and phycocyanin data was then log transformed as the data were skewed towards the lower concentrations.

Preliminary linear regression analysis was performed on the transformed data for calculated biovolumes and phycocyanin for all sites combined and grouped sites along the Murray River. The sites were grouped going downstream from Albury to Yarrawonga Weir, Yarrawonga Weir to Moama and Moama to Tooleybuc.

The initial data analysis (Figure 10) shows that the concentration of phycocyanin tends to increase with increasing cyanobacterial biovolume and indicates that fluorometry measurements taken in field are probably indicative of cyanobacterial biovolumes present within the Murray River.

Figure 10: Linear regressions for calculated biovolume and phycocyanin data within the Murray River



5 Risk management

5.1 Alert levels

Alert Levels used by the Murray RACC to issue public advisories are based on the recreational guidelines in *Guidelines for Managing Risks in Recreational Waters (NHMRC) (2005)*.

An alert level framework for raw water used for potable supply (*The Cooperative Research Centre for Water Quality and Treatment (CRCWQT, 2006)*) has also been adopted by the Murray RACC rather than the drinking water guidelines described in the *NHMRC (2004) Australian Drinking Water Guidelines* because the Alert Level Framework (ALFs) give more specific details on guidelines and management actions. The CRCWQT, 2006 document represents the latest in Best Management Practice for managing cyanobacterial blooms in raw waters used for potable supply (either with or without subsequent treatment) and is widely accepted and used in much of Australia. The RACC deals with environmental algal bloom problems that may impact on public health. The management of drinking water is not a responsibility of the RACC, but of the water utilities supplying this to the public. The RACC can only advise the utilities when cyanobacterial concentrations exceed the alert levels framework, although the utilities should also be undertaking their own monitoring of their raw water source.

Both the NHMRC (2005) and CRCWQT documents have been recommended for use for cyanobacterial bloom management in Victoria.

The Murray RACC, being made up of NSW and Victorian water managers concluded that this alert level framework provided the most consistent approach for both States to measure their respective data against.

A Red Alert level for recreational use under the (NHMRC) framework provide triggers that means if the water is unsuitable for recreational use it is also unsafe for stock watering and human consumption.

5.2 Communication strategy

5.2.1 Public notification

The public were kept advised through a number of means, but primarily by electronic and print media and internet. The free call 1800 number was also extensively used to provide current information that was accessible to a wide variety of stakeholders. The number (1800 999457) provides up to date information for NSW on the location and status of algal blooms.

Information on the bloom was regularly updated on the 1800 number Algal Information Hotline managed by the Office, and the algal warning page on the Office web site (www.water.nsw.gov.au) and that of other agencies, especially Goulburn Murray Water (GMW) in Victoria, NSW Health and the Department of Human Services (DHS) (Victoria) were updated two to three times per week as more current information became available. Hits on the Office algal web page increased considerably during the period of the bloom.

Media releases were made by the Office Community Relations and Media staff regularly and interviews provided to television, radio and newspapers by the RACC Chairpersons and the Commissioner of the NSW Office of Water provided further advice.

All media releases were drafted in accordance with the Murray RACC protocols and noted the location of the bloom, alert level, uses for the water and provided advice on management of the affected water.

In accordance with the Murray RACC protocols, each media release was approved by the Chair of the Murray RACC and the nominated Victorian RACC member before issue.

Media releases were sent to the NSW Minister for Water's media advisor and the full RACC 30 minutes before issue.

Additionally, a courtesy phone call was made to the Minister's media advisor and the Commissioner of the NSW Office of Water prior to the issuing of the media releases.

It was determined at the first response meeting that it was not feasible to erect warning signs due to the extent of the bloom, this meant that signage was not used at any time during this bloom on the NSW side of the river. Some signage was, however, erected on the Victorian side of the river by Victorian agencies.

The 1800 number was actively promoted and updated by the Office of Water media officer following new results – likewise the websites of the MRACC members were used extensively to provide information with each site ensuring that the bloom information was noted on the home page.

Summary of media activity:

- Nine media releases were issued from 5 March to 14 May 2009. This is an average of one media release per week.
- Forty-seven media interviews were given from 52 media enquiries. Media interviews were provided to ABC Goulburn Murray (Wodonga), ABC Riverina (Wagga), ABC Shepparton, 2AY Albury, *Border Mail* (Albury, Tabloid Newspaper), ABC Radio National also picked up by Triple J, *Riverina Herald* (Echuca Tabloid newspaper), Star FM Albury, Prime News, WIN News and 5NU Power FM at Murray Bridge South Australia and the *Deniliquin Pastoral Times* and the *Murray Pioneer Renmark*.
- The NSW Water Commissioner also responded to state and interstate media requests including ABC World Today, Victorian Country Hour, Stateline Victoria and *The Melbourne Age*.
- Approximately 700 enquiries from the public were handled by staff at the NSW Office of Water, GMW, NSW regional health authorities and Victorian DHS during the bloom.

5.2.2 RACC

All stakeholders in both the MRACC and SRAAC were kept informed as data appropriate to their part of the river system was received from the laboratory. This was usually done by the RACC technical Coordinator based in Albury via an email distribution list on the same day as the data were received, or as soon as possible thereafter. This report could occur on any of the working days during the week. If the RACC Coordinator was unavailable, this role was performed by the State Algal Coordinator in Parramatta as a contingent.

5.2.3 State agencies

The total cyanobacterial biovolume data and appropriate alert level were entered onto an Excel™ spreadsheet by the State Algal Coordinator in Parramatta as these were received. The spreadsheet provided a chronological and geographical account of bloom conditions throughout the river system, and formed the basis of bi-weekly reporting to key stakeholders in agencies in New South Wales, Victoria, South Australia and in the Commonwealth government.

The spreadsheet formed the basis of a briefing provided to these key stakeholders by the Office. The briefing notes were generally provided to the stakeholders each Tuesday and Friday, and contained the following information:

- A description of the current condition in the river.
- Current and previous management actions.

- A copy of the Excel™ spreadsheet summarising the analytical data provided by the NSW Office of Water Laboratory with a short analysis of the total BGA bio-volume.
- An alert level for stock water and recreational use as prescribed in the RACC Plan.

5.2.4 Ministerial advice

The NSW Minister for Water also received both bi-weekly reports from the Office, before they were distributed to the key stakeholders.

The Minister for Water also received a weekly briefing note on cyanobacterial blooms across the whole of NSW that included a summary of the bloom in the Murray River. These reports were prepared by the Office using data collected from Monday to Friday each week, and submitted to the Minister's Office each Monday. These briefings listed the location of blooms across NSW, the alert level for each bloom, whether the most recent data indicated that the bloom was increasing or decreasing in severity (or remaining the same), and the management actions taking place for each bloom. The aim of these briefings was to keep the Minister regularly updated on the cyanobacterial bloom situation in the Murray River.

A number of cyanobacterial species produce potent toxins, and all species can produce contact irritants. Major blooms can have major environmental, water use, socio-economic and other impacts that require considerable effort to manage. With a bloom in the Murray River, there are also issues between agencies and jurisdictions, especially at an interstate and Commonwealth level. The Minister needed to be kept informed of the bloom and progress with its monitoring and management so he could deal with any issues that arose at State Government level.

5.2.5 Interstate notification

A number of Victorian State government agencies are members of the Murray RACC. These agencies mirror the NSW equivalent authorities that manage town water supply, population health, resource assessment and availability and tourism. A full list of member agencies is available in the Murray RACC plan.

The over arching aim in the management of the blue-green algae issues in the Murray River region is to provide local advice to the local community by combining resources and expertise and making decisions by agreement.

While the NSW Government led the day-to-day management of the bloom, monitoring results were shared amongst stakeholders and were assessed against agreed guidelines.

Media releases and other communication material, including Rapid Response Notes (RRNs), were developed by the Office and were approved by NSW RACC Chair and Vic Deputy chair before issue.

Frequently Asked Questions (FAQs) developed by Department of Human Services were approved by the Office and made available to all RACC members for customer information and web information and speaking points.

Weekly teleconferences during the bloom, that focused on providing immediate updates on the bloom, coordinating monitoring and identifying areas where gaps in monitoring needed to be addressed, were also held.

5.3 Town water supplies

5.3.1 Response

Within the 1,000 km of affected waterway a number of water treatment works (WTW) were identified as 'high risk' due to concerns over capabilities to treat affected water and sustain the provision of safe drinking water. These were the local government areas of and country town water supplies of:

- Albury, Corowa (Howlong, Corowa, Mulwala), Deniliquin, Murray (Moama, Mathoura), Wakool (Barham, Tooleybuc, Wakool, Moulamein), Hay and Balranald.

The water utilities section of the Office provided water authorities with sample bottles, treated with Lugols, and requested sampling of raw waters entering the works, and filtered (final) waters. These were sent to the departments' laboratory and analysed for cyanobacterial counts and biovolumes. The water authorities were also asked to provide information on pH, turbidity, colour and comments on odour (after boiling) on the raw and filtered water. All results were coordinated and analysed by the Senior Water Inspector at Cootamundra. All water authorities complied with the response, albeit one needing some encouragement. Only two water supply authorities works were sampling and identifying algae themselves.

5.3.2 Treatment

The water authority works utilised Powdered Activated Carbon (PAC) and only one 'breakthrough' of algae was evident, but this was due to a coagulation fault at the works. As such, all WTW proved capable of treating the water to the required standard with no evidence of taste and odour.

5.3.3 Evaluation of issues affecting town water supply response

The main issues that hampered effective response of town water suppliers and water utility officers within the Office were mainly communication issues between departmental officers within the Office and the regional health authorities. This was mainly over the long weekend in Easter due to the lack of arrangements and contingencies with officers on leave. Additionally, the lack of correctly prepared sample bottles at the WTWs also delayed responses, and the lack of address labels and analyst sheets hampered a streamlined response. The results were also not communicated effectively in a timely matter to the WTW inspectors. These communication issues can be easily rectified to ensure a more timely and streamlined response and should include:

- an effective store of sample bottles and Lugols at the WTW or in key locations, easily accessible
- address labels and delivery instructions
- an improved stakeholder communications strategy
- a more detailed and comprehensive framework of procedures to streamline process and ensure clarity in responsibilities and actions
- training of WTW operators in algal identification and treatment techniques
- more effectively managed coordination at the local level.

5.4 Coordination of management response

Coordination of the management response took place at two levels. Local coordination was undertaken by the MRACC Regional Algal Technical Coordinator based in Albury, and the Community Relations and Media Officer (CR&M) based in Deniliquin. The Regional Algal Technical Coordinator received cyanobacterial cell count and identification data for samples collected during the bloom directly from the Office laboratory in Sydney, and passed this information on to regional stakeholders and to the Chair of the MRACC. These data were also the basis for the media presentations prepared by the CR&M Officer for the Chair of the MRACC. The Regional Algal Coordinator also arranged the aerial surveillance flight undertaken by the Office and GMW staff on 6 April 2009.

Coordination of the broader response to both NSW, interstate and Commonwealth government agencies was undertaken by the Office's Environmental Evaluation and Performance Branch (EEP Branch) based in Parramatta. The State Algal Coordinator also received the cyanobacterial identification and count data direct from the laboratory, and used these data to prepare briefings to these agencies. The State Algal Co-ordinator (also the Project Manager for the fluorometer evaluation project), coordinated the sampling program undertaken by field staff based at offices within the region, to ensure that the twice weekly sampling routine was maintained throughout the duration of the bloom, as well as the collection of the fluorometric data. The project manager also coordinated the collection to the toxicity samples that were sent to both South Australia and the UNSW for analysis.

The Director of EEP Branch (the Office) was also in contact with the Murray-Darling Basin Authority (MDBA), and upon his request the MDBA arranged for two aerial photographic surveillance flights to be made of the River Murray. The State Algal Coordinator then worked in conjunction with MDBA staff to assess the aerial photography and to forward the information arising from this on to other relevant stakeholders.

Coordination of the assessment of the performance of the town water supply treatment plants was undertaken by the Office Water Utilities Branch staff.

Overall, the two levels of coordination worked well, with local management being undertaken at a local level, while the broader scale management was undertaken from Parramatta. It is recommended that a similar two tiered bloom response co-ordination effort be used in the event of future blooms, although possibly local coordination of the sampling effort may be more appropriate.

5.5 Blue-Green Algal Advisory Group

On 16 April 2009 the Federal Minister for Climate Change and Water, Minister Wong, established the Blue-Green Algal Advisory Group. This group was established for a period of up to six months with the written instrument appointing members to cease on 15 October 2009. The group is chaired by the Chief Executive Officer (CEO) of the MDBA with Director level membership from the jurisdictions with the NSW Office of Water representing NSW, DSE representing Victoria and the Department of Water, Land and Biodiversity Conservation representing South Australia, the Department of Environment, Water, Heritage and Arts (DEWHA) representing the federal Minister and staff from the MDBA also involved. Three expert panel members of Professor Terry Hillman, Dr David Cunliffe and Dr Chris Bourke were appointed to represent expertise in river ecology and water quality, public health and water quality, and animal toxicology respectively. Additionally, Queensland was invited to attend, but declined and the Australian Capital Territory (ACT) government were also invited as an observer.

The group was established for six months to oversee and review the NSW's implementation of management responses. During that time three meetings were held with a range of issues discussed with respect to consistency in warnings, signage, the application of guidelines in the Murray-Darling Basin by the jurisdictions with the group being updated regularly by the Office with respect to any issues.

At the third meeting BGAAG 16 October 2009, the Chair of the BGAAG acknowledged that the terms of reference (TORs) of the group had been met and that NSW effectively coordinated through the Murray RACC. A copy of the minutes of this last meeting was not available at the time of this report compilation.

6 Discussion and outcomes

6.1 What factors contributed to the bloom

Detailed data analysis including phytoplankton, water quality and flow is still to be undertaken; however, considering the previous research that has been undertaken and the knowledge and understanding of the conditions conducive to algal blooms, interpolation of factors that may have contributed to the development of the blue-green algal bloom in the Murray River is plausible.

A number of factors are likely to have contributed to the bloom. Firstly; the ongoing drought conditions in southern NSW and north-eastern Victoria would have been a major factor. This has led to reduced inflows of water into the major headwater storages, including Lake Hume, and a decrease in the volumes of stored water there to less than 10 per cent of full capacity. Previous; studies by Baldwin *et al.* (2008) have illustrated the impacts of low water levels in Lake Hume, including the mobilisation of nutrients and the onset of cyanobacterial blooms within the lake. Cyanobacterial infested water is then passed downstream with releases from the reservoir and can impact sites along the river as far downstream as Corowa (Baldwin *et al* 2009), although there is no evidence that it is limited to this location.

Although analysis of the available data has yet to be completed, it is likely that a similar situation occurred downstream of Lake Mulwala. A bloom also occurred in this lake and water infested with cyanobacteria was released downstream from both Yarrawonga Weir and the Mulwala Main Canal. It is possible this impacted the Murray River at least as far as Moama/Echuca, and also Gulpa Creek and the Edward River system as far as Kyalite on the Wakool River downstream of its confluence with the Edward River.

Low water levels in both Lake Hume and Lake Mulwala, and that fact that both reservoirs were infested with cyanobacteria, meant that there was no clean, non-infested water available to provide flushing flows downstream.

Blooms in the mid-section of the river downstream of Torrumbarry Weir through to Euston may have developed in-situ, as a result of the low flow conditions and low water levels increasing residence times in this section of the river. The bloom downstream of Torrumbarry was more transient than that upstream, and there is some evidence to suggest that it was comprised of a different cyanobacterial population than upstream. In fact, it appears that there were at least three separate blooms, and possibly more, all occurring in different parts of the Murray River at the same time, rather than the bloom being one single long bloom down the entire system (see section 4.1.2).

Other physico-chemical data such as flow (from MDBA), nutrient concentrations, water temperature, pH and electrical conductivity have been collected, but their contributions to the bloom formation have yet to be assessed. However, initial indications are that in March water temperatures were sufficiently warm enough to support rapid cyanobacterial growth, and that one factor leading to the collapse of the bloom in May may have been decreasing water temperatures and the onset of colder autumn weather at this time of year.

A more complete analysis of the bloom, and of any physico-chemical factors that may have promoted its development has yet to be undertaken. It needs to be noted that the physico-chemical data available are not extensive, and may be insufficient to definitively show any cause and effect relationships with the bloom occurrence.

6.2 Management of the bloom

The previous sections have detailed the management responses initiated by the Office and MRACC stakeholders in managing the bloom. These included initiation of the Response Group, co-ordination and development of mostly effective communications strategies in order to manage publicity and inform water users and keep stakeholders informed. The Office and other MRACC water management stakeholders including GMW initiated an increased monitoring program to ensure that regular information about the extent and risk of the bloom was available to water managers. The Water Utilities section of the Office ensured that the NSW town water supply authorities were monitoring for algae at their intakes and treating water as required including undertaking a review of the performance of water treatment. Some toxin analysis was undertaken to determine the risk of the bloom and coincidentally a project trialling fluorometry was also being undertaken in the affected area at the time to trial insitu measures that may act as an early warning for the incidence of blue-green algae and trigger more rigorous monitoring.

The bloom conditions lasted some eight weeks and a debrief of the Murray RACC occurred on 1 June 2009 to evaluate the response. The overwhelming opinion was that the Murray RACC, through its regional implementation strategy known as the Murray Regional Algal Contingency Plan, performed its functions well and responded effectively to the bloom. Additionally, the federally appointed BGAAG reiterated that it was satisfied that NSW effectively managed the bloom under the auspices of the Murray RACC.

The Office is committed to continual evaluation and improvement and as such has also initiated a review of implementation of the NSW Algal Management Strategy state-wide in order to more effectively implement the strategy. This review, together with an evaluation of stakeholder feedback from consultation with the nine RACCs and the outcomes from this evaluation report are being used to formulate recommendations for more effective implementation of risk management within the Murray RACC area and more widely across NSW. Some of these recommendations are included in the following section.

7. Recommendations

The key recommendations for more effective management responses for future Murray River blooms include:

- the two tiered level of management was successful in managing responses to this bloom, but in future more efficient knowledge brokering and technical co-ordination from the local/regional area would enable more effective implementation of the MRACC plan. The State Coordinator's role should be to provide expert technical assistance through interstate networks and to be responsible for coordinating management briefs, whilst the regional coordinator should be responsible for implementation of the MRACC responses. This should also include a more formal role of a Secretariat to organise meetings and assist the technical coordinator with administrative duties, as instructed
- the MRACC Algal Contingency Plan should be updated to include more detailed information about the management response that will enable stakeholders and other staff not normally involved in algal management to more effectively understand the framework and implement risk management responses. This should include more spatial information about:
 - the location of the Office algal monitoring sites, MDBA monitoring, GMW and other stakeholder monitoring locations
 - council area boundaries and surface water intake for country town water supplies
 - private irrigation districts (intakes and systems)
 - a review and incorporation of MRACC stakeholder information and needs to enable use of the spatial information to mobilise resources and identify risks more effectively
- improvement of engagement with all stakeholders including local councils that do not treat water for potable use, maintenance of a larger email string of stakeholders to ensure more wide spread and effective communication during a bloom
- the fluorometry data analysis be completed and the results fully analysed and published with recommendations presented to the TAG for consideration of adoption by the MRACC and the Office, within the resourcing constraints
- the toxicity testing, algal data, water quality and flow information be analysed and published with recommendations considered by the TAG for deliberation
- an updated algal training program be organised for the Office's water utility inspectors and subsequently country town water treatment operators with respect to algal sampling, identification and treatment, in particular for the use of Rapid Toxin Tests
- the Office investigate during the 2009-2010 summer, success of using Rapid Toxin Tests for Microcystin (Abraxis kits) and Saxitoxin (Jellett rapid test kits) at sites with blue-green algal taxa known to produce these toxins. Additionally, that the Office laboratory trial ELIZA tests for Saxitoxin, Microcystin and Cylindrospermopsin
- on the basis of the outcomes of the toxicity testing, the Office recommend triggers for use of toxin test kits and seek endorsement by the TAG, to enable the MRACC plan to be updated with these triggers
- when, or if, a bloom occurs again in the Murray that the Office's water utility inspectors consider investigation of the removal of toxins. NB: algal cell breakthrough analysis was undertaken during the 2009 bloom at water treatment works, but not toxin analysis
- ensuring adequate stocks of bottles and Lugols with the MRACC areas, in particular at the WTWs
- the maintenance of the algal information and retention of web page links and live information both regionally amongst the RACC stakeholders and State wide at a more strategic level. Examples may include ensuring linkages from the Office website to other stakeholder

information such as the Industry and Investment NSW Prime Fact Sheets or that consideration be given at the TAG and SAAG in developing formal Facts and Questions Sheets (F&Qs) with a NSW and Victorian Government logo reflecting a collaborative approach, one-stop-shop for information in consultation with the Victorian agencies

- the Office ensures ongoing maintenance of the algal information line 1800 service
- the establishment of effective contingent monitoring network of stakeholders and agencies, including engagement with the wastewater treatment operators and councils for assistance in sampling during blooms (Victoria and NSW), this can be facilitated through the spatial assessment
- the establishment of a prospectus for algal research and collaborations within the MRACC area, but also state and nationally
- the Office develop a formal Office phytoplankton database as a repository for historic and future data, the database could be the second phase of the current upgrade of the Office Water Quality database, noting that funds were received this year from the Bureau of Meteorology (BOM) for the Water Quality database upgrade. This will also allow the information to be in Water Data Transfer Format (WDTF), a requirement, if algal information will need to be collected to inform the Salinity and Water Quality Management Plan as part of the Basin Plan, under the Federal Water Act 2007. But, more importantly, to enable the Office officers to legitimately store, and then analyse data and share information more effectively with its stakeholders. At the moment data is stored in a LIMS database at the Wolli Laboratory but it is not readily available
- the Office undertake a socio-economic assessment of the Murray Algal Bloom either to highlight the cost of managing the bloom and/or an evaluation of the cost of the bloom to water users.

At a more strategic level, many of these recommendations could also be applied in other RACC areas. On the basis of the Office review of the NSW Algal Management Strategy some of the following strategic changes have already been implemented as a result of the Murray Bloom. These include:

- formalising governance arrangements for the NSW Algal Management strategy, and reaffirming NSW Government support for the process
- reviewing the membership of the State Algal Advisory Group (SAAG) to enable more strategic policy and guidance, and greater accountability, and increasing transparency of decision making through better communication with regional stakeholders
- re-affirming the responsibility of the Technical Advisory Group (TAG) in considering technical issues and provide recommendations for endorsement by the SAAG and the importance of new research to inform management decisions
- establishing a state resource manual for use by RACCs that includes point of truth information from the TAG about technical issues, that have been endorsed by the SAAG
- appointment of a regional technical coordinator to those RACCs without one, providing formal secretariat assistance to those with more contentious issues and providing training as required
- updating and modernising the RACC contingency plans to improve relevance and consistency
- improving communications strategies by ensuring greater engagement with local councils.

The recommendations presented here will be progressively implemented through the NSW Office of Water management team structure and facilitated through the RACC coordinators. Successful implementation will be reviewed by the Team Leader of Statewide Resource Condition in the Office and through review of implementation of the NSW Algal Management Strategy by the State Algal Advisory Group by establishment of project planning and performance milestones. An annual review of implementation should occur.

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