Integrated Monitoring of Environmental Flows

Hunter River low flow phytoplankton study

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NSW Office of Water

Level 18, 227 Elizabeth Street
GPO Box 3889
Sydney NSW 2001

T 02 8281 7777 F 02 8281 7799

information@water.nsw.gov.au

www.water.nsw.gov.au

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Summary

The NSW Integrated Monitoring of Environmental Flows (IMEF) program was established to provide ecological monitoring to assess the performance of the environmental water allocations and associated flow rules adopted for NSW regulated river systems. To guide these monitoring activities a number of predictions, expressed as scientific hypothesis were developed, with these hypotheses used to describe the possible benefits that the environmental flow rules could deliver. These hypotheses in turn have provided the framework for the adopted monitoring program (Chessman and Jones 2001, Chessman et al 2003).

For the Hunter regulated river system the IMEF studies focused on three main areas:

1. Investigating Hunter River phytoplankton ecology and exploring the potential benefits that could be derived from changes in flow management /flow access rules to mitigate algal blooms
2. Investigating the fresh water inflow needs of the Hunter estuary
3. Investigating the importance of rain event organic carbon delivery to the Hunter River system.

The IMEF phytoplankton studies undertaken in the Hunter River system were designed to provide a broader understanding of the Hunter River's phytoplankton ecology. Results from these studies have been used to advance the understanding of the specific Hunter River phytoplankton growth, temperature and flow relationships. One of the issues identified from these studies was the potential risk of diatom blooms occurring in summer under low flow, warm water conditions (river water temperature greater than 23º C).

The drought conditions that prevailed across the Hunter Valley in 2005 and 2006 resulted in extremely low 'natural' river flows and also significantly reduced dam storage levels, thus further restricting options for flow supplementation from dam releases. These reduced river flows provided an opportunity to undertake a field sampling program to further investigate the low flow phytoplankton ecology of the Hunter River system. This report details the results from this three-month sampling program which investigated phytoplankton community dynamics in the mid reaches of the Hunter River at Jerry Plains under these low flow conditions.

During the three months of the targeted sampling program no diatom blooms were observed. The prevailing conditions however, were considered to be conducive to diatom growth based upon relationships reported from previous Hunter River phytoplankton studies. The results of this study however indicate that further factors (in addition to low flow and elevated water temperature) may have contributed to the previously reported diatom blooms. The results from this three-month low flow study clearly identify the need for additional work to better understand the Hunter River phytoplankton/low flow relationship.

The results from this study have particular relevance to the design and implementation of minimum flow rules based around avoidance of nuisance phytoplankton growth that may be applied in the mid reaches of the Hunter River. The study has identified factors, in addition to flow and temperature, may need to be considered as predictors of diatom bloom risk in the Hunter River, and that further work will be required to quantify these.

Introduction

The phytoplankton community of a river system is ever changing, with a number of interrelated factors, including the physical and chemical characteristics of the river water, contributing to the community structure. Water temperature, river flow (or more specifically flow speed and residence time) have been shown to be critical factors in the triggering of prolific phytoplankton growth (Mitrovic et al 2008).

In the Hunter River system (excluding the storage dams), the most common prolific algal growth reported is from the division Bacillariophyceae (Diatoms) with no significant cyanobacterial blooms reported (DLWC 2000). The reported diatom blooms have caused aesthetic issues and problems for irrigators due to pump clogging, and hence have become a concern for the irrigation community. Water quality studies of the Hunter River have identified that the river system is in a eutrophic (nutrient enriched) state, with instream available phosphorus levels not thought to be a limiting factor to prevent prolific algal growth (DLWC 2000).

As part of the NSW water reform process which commenced in the late 1990s, the Hunter River Management Committee (HRMC) was established to develop a water sharing plan for the Hunter Regulated River which incorporated the introduction of environmental flow rules. In its earliest deliberations, the HRMC considered the potential for flow rules to be introduced to 'manage' phytoplankton populations in the Hunter River, and hence identified the need for specific studies to be undertaken to provide the basic knowledge on the ecophysiology of the Hunter River phytoplankton communities. As an interim measure, a number of minimum flow targets were established for key locations along the regulated Hunter River system, which were introduced as part of the overall water sharing plan process to develop and implement ecologically relevant minimum flow rules for the Hunter Regulated River system. These flow rules were established with the understanding that a review would occur at a future date consistent with the water sharing plan requirements.

Results from the studies of the Hunter River's phytoplankton communities have provided data to be used in the intended reviews of the Hunter Regulated River Water Sharing Plan. These studies have provided the fundamental data to guide the development of more specific flow rules to promote healthy phytoplankton communities in the Hunter River. In addition, a further two reports detailing aspects of phytoplankton behaviour in the Hunter River have been produced. These are:

- 'Phytoplankton dynamics in the Hunter River and factors affecting them', an unpublished PhD thesis by Jodie Dabrovic (2007) which has provided a comprehensive study of phytoplankton community dynamics and identified critical determinants for species growth.
- 'Development of blooms of *Cyclotella meneghiniana* and *Nitzschia spp*. (Bacillariophyceae) in a shallow river and estimation of effective suppression flow' by Mitrovic, S., Chessman, B., Davie, A.W., Avery, E.L. & Ryan, N. (2008), which proposed flow speed as an important determinant for diatom growth in the Hunter River and proposed models for prediction of blooms.

These combined studies have identified flow velocity (discharge in megalitres per day) and water temperature as two of the critical determinants of phytoplankton community composition in the Hunter Regulated River. The findings from these studies further contribute to the deliberations that have continued concerning the design and implementation of minimum flow rules to maintain the Hunter Regulated River's health. The drought conditions of 2006, where there were sustained low flows and high water temperatures, provided further opportunity to investigate the relationships between flow and phytoplankton community composition in the Hunter Regulated River.

Study background

The Integrated Monitoring of Environmental Flows (IMEF) program was developed by the former Department of Land and Water Conservation as a statewide scientific program to undertake the ecological monitoring of environmental flow rules adopted as part of water sharing plans implemented for regulated rivers across NSW. The implemented water sharing plan flow rules were designed to meet the documented NSW river flow objectives. These river flow objectives were also used to guide the development of the IMEF program generic investigative hypothesis (numbered sequentially) which formed the basis of the specific catchment studies (Chessman and Jones 2001, Chessman et al 2003).

In the Hunter River system the IMEF Hypothesis 1 and 3 were considered most relevant and were used to shape the investigative studies:

- **Hypothesis 1. Suppressing blooms**

  Protecting natural low flows, for example by raising pumping thresholds, will reduce the frequency and severity of algal and cyanobacteria blooms by making conditions less favourable for bloom development (more turbulence; less stratification).

- **Hypothesis 3. Flushing blooms**

  Protecting or restoring a portion of freshes and high flows, and otherwise maintaining natural flow variability (River Flow Objectives 3 and 6), through off-allocation use restrictions and dam releases, will flush algal and cyanobacterial blooms from the water column, making blooms less prevalent.

These investigations have studied the link between flow and algal blooms in the Hunter River system and led to the development of some simple algal growth predictors and furthered the understanding of the Hunter River system's algal dynamics. This evolving knowledge has been used to predict the risk of cyanobacteria blooms (and hence guide management strategies), and to assist in the development of proposed uses of the Environmental Water Provisions adopted as part of the Hunter Regulated River Water Sharing Plan (DNR 2004) flow rules. In the adopted water sharing plan, the implemented flow rules were designed to improve river functioning, which when interpreted in context of phytoplankton management, can be considered as an attempt to reduce the risk of phytoplankton blooms. It has also been proposed that specific environmental water release could also be undertaken to further reduce the risk of 'nuisance' phytoplankton blooms.

Drought conditions in the Hunter Valley in the latter part of 2006 were severe with irrigators' water allocation (and hence dam release) significantly reduced. As a result of this reduced water availability, Macquarie Generation, the valley's largest water user, modified its water extraction program, with its planned major extraction completed by early December 2006. This action reduced dam releases in December 2006, resulting in further reduction in river flow.

Results from earlier studies undertaken as part of the Hunter IMEF Hypothesis 3 project established a link between low flow condition, water temperature and the potential for algal growth (Ryan et al 2006). Results from this four-year study (1999-2003) found that water temperature during this period was positively related to growth of diatoms (*Cyclotella* and *Nitzschia spp*) with water flow (megalitres per day) found to be negatively related to diatom growth. During the time of the study the instream silica and phosphorus levels were found to be statistically unrelated to diatom growth. Oxidised nitrogen levels however were found to be negatively correlated to *Cyclotella* and *Nitzschia spp* growth, and in contrast it was found to be positively related to *Aulacoseira spp* growth. Mitrovic et. al. (2003) documented the use of a phytoplankton flow models as a tool to assist management of flow to suppress cyanobacteria blooms in the weir pools of the Barwon-Darling River, and it was thought that the similar methodology could be applied to Hunter River system. As an extension of this modelling work it was thought that if relationship between flow and potential for diatom growth could be determined, theoretically consideration may then be given for the potential to use specific environmental release water to supplement flows so that the minimum flow triggers (indicating risk of diatom growth potential) are not reached.

Study aim

This study was undertaken to further understand factors associated with phytoplankton growth in the Hunter River system and thus contribute information that can be used to assist in the development of minimum flow rules to maintain Hunter River health.

This study specifically collected data to describe the phytoplankton community structure at key sites in the Hunter River system during spring and summer, catchment wide drought conditions which resulted in prolonged low flow conditions. Conditions which results from previous reported Hunter River phytoplankton studies (Mitrovic et. al 2008) indicate were at high risk for phytoplankton blooms to occur.

Methods

To minimise costs incurred from sample analysis and field work time, a staged sampling program was developed which commenced in 1 0ctober 2006 and was finished on 30 December 2006. It initially involved a 14-day interval baseline sampling program which was to be intensified when or if phytoplankton bloom developed.

Sampling sites

Samples were collected from three sampling sites located in the Mid Hunter River catchment between Muswellbrook and Singleton, and a third site in the Lower Hunter River system. The two mid reach sampling sites were chosen because they were in reaches where large surface water extraction occurs and previous history of diatom blooms were reported under low flow conditions. The third site was included as a comparison site (Luskintyre) at end of system and to consider if there were any downstream impacts, if and when a bloom may have occurred.

Table 1: Phytoplankton sampling sites

Site Name	Rationale
21010091 Hunter River at Bowmans Crossing	Above major extraction weir
21010092 Hunter River at Mosses crossing	Low flow section of river below extraction point
210009 Hunter River at Luskintyre	End of system summation low flow site

Phytoplankton sampling and enumeration

A single one litre composite sample was analysed from each site. The composite sample was sourced from a bucket containing five by one litre integrated samples taken surface to depth from a walked cross-section at each site. Initially, reconnaissance sampling was undertaken every 14 days, with sample frequency to be increased in response to phytoplankton growth.

Samples were preserved with Lugol's iodine solution and transported in a chilled esky to the laboratory where they were identified to genus levels and counted using a calibrated Lund cell, viewed through a compound microscope, after concentration by sedimentation (APHA 1995). Counting precision was to accepted standard +/- 20% (Hötzel and Croome 1999).

Water quality analysis

Water quality information was collected to describe river physical conditions. At each site the electrical conductivity (EC), pH and temperature were recorded using calibrated YSI brand water quality meters. Turbidity was determined using HACH portable turbidity meter. Nutrient levels were determined from laboratory analysed single grab samples collected from each site. For Total Nitrogen and Total Phosphorous analysis, samples were collected in tipple rinsed 200 ml PVC bottles and stored in portable freezer. The samples to be analysed for soluble nutrient levels were filtered on site using a hand held vacuum filter and filtered through a 0.45 µm filter paper. Samples were then transferred to a triple rinsed 200 ml PVC bottle and stored in portable freezer before being transported back to laboratory for subsequent analysis using standard methods.

Flow measurements

River discharge (megalitres per day) was recorded from continuous flow monitoring sites most relevant to study area (or where equipment was not working, the closest functioning monitoring station to that point). Data collected at these sites included mean daily flow, water temperature and electrical conductivity (EC) data. An assessment was also made of relative proportion of flow sourced from Glenbawn Reservoir as compared to that sourced from tributary inflows. This involved comparing flow at gauge site 210015 (downstream Glenbawn Reservoir) with that recorded at Denman and Liddell. Where the latter were greater than the volume discharged from the dam it was assumed that these flows were from tributaries. A full list of flow monitoring and temperature sites was used in the study and justification for use is shown in Table 2.

Table 2: Flow and temperature assessment sites

Site number	Name
210015	Hunter River downstream Glenbawn storage (dam discharge)
210055	Hunter River at Denman
210083	Hunter River at Liddel (temperature probe not working)
210125	Hunter River at Salt Water Creek (downstream Liddel)
210126	Hunter River upstream Foy Brook
210064	Hunter River at Greta (End of system flow)

Results

The sampling period October 2006 to December 2006, was a period of extreme low flow conditions (flow less than 100 megalitres per day (ML/day)) and high water temperatures (>23º C). During this sampling period there was only limited diatom growth, with no nuisance algal blooms developing. Graphical representation of daily average water temperature, flow and salinity (electrical conductivity) readings are shown in Figures 1 to 3.

Nutrient concentrations during these low flow conditions were also found to be relative consistent with median Hunter River values (Total Nitrogen 0.35 mg/L and Soluble Phosphorus 0.005 mg/L). The assessed river turbidity levels were however found to be above the long-term median values recorded for the assessment sites: Bowmans Crossing turbidity was approximately 20 NTU as opposed to long-term median value of 16 NTU, with Mosses Crossing turbidity approximately 22 NTU as opposed to the long-term median value of 12.5 NTU. It was noted that at the Hunter River Bowmans Crossing site there were a number of large mature carp (*Cyprinus carpio*) present, with their swimming action in the very low flows (water depth 40 cm or less) disturbing stream bed sediments. It was also noted that during the sampling period that the surface air temperature was seasonally lower, with a number of days having some degree of cloud cover.

A summary of the individual grab sample algal enumeration and water quality results are provided in Tables 3 to 5.

Figure 1: Hunter River flow (ML/day) during sampling period

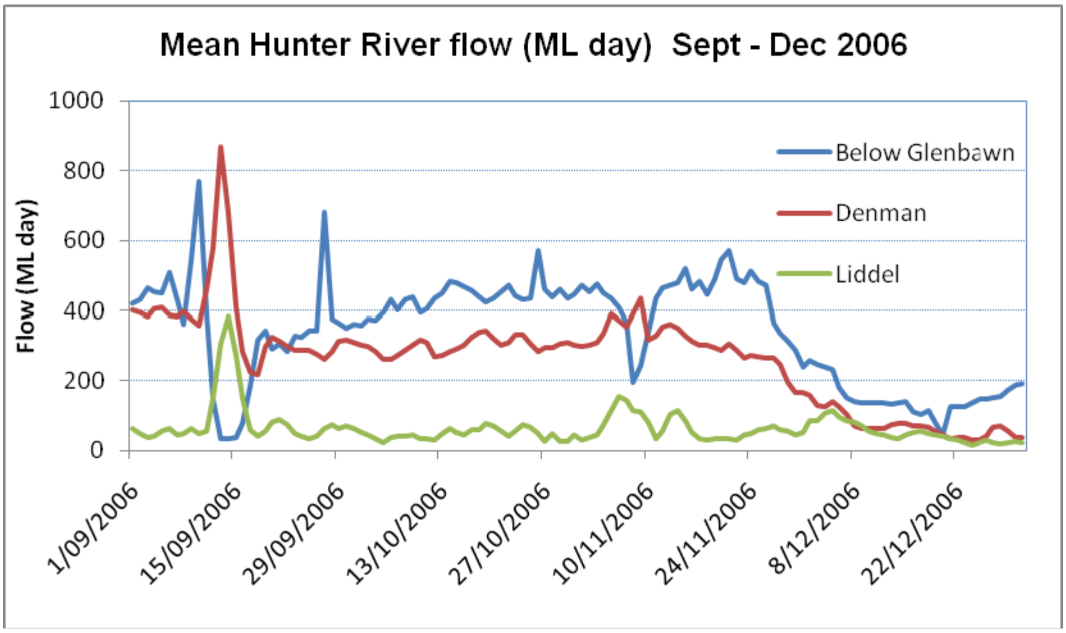

Figure 2: Hunter River temperature (ºC) during sampling period

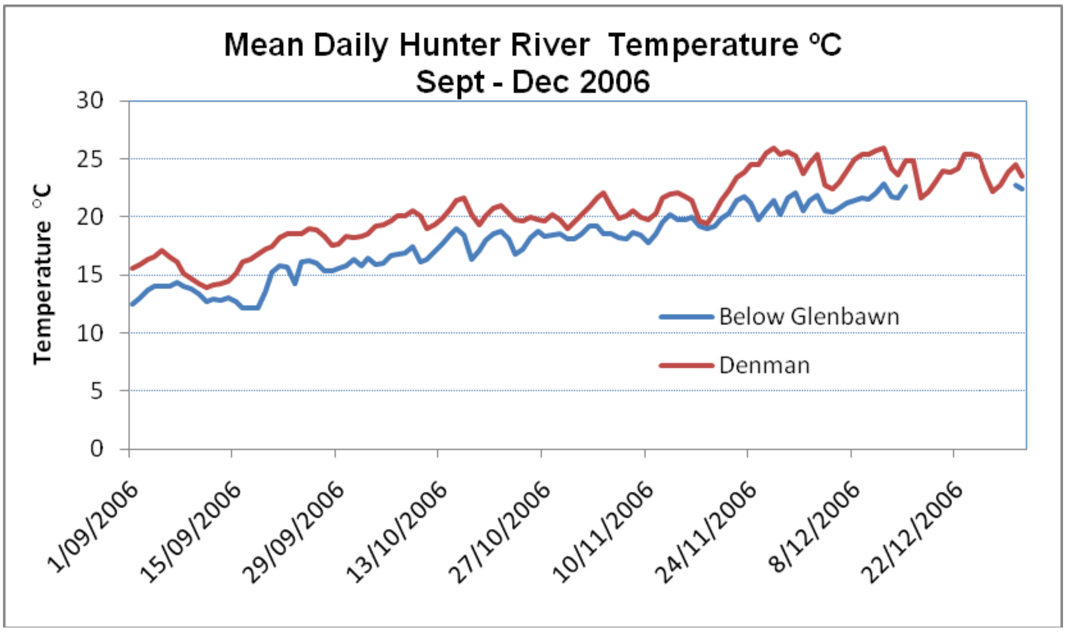

Figure 3: Hunter River electrical conductivity (EC - µS/cm) during sampling period

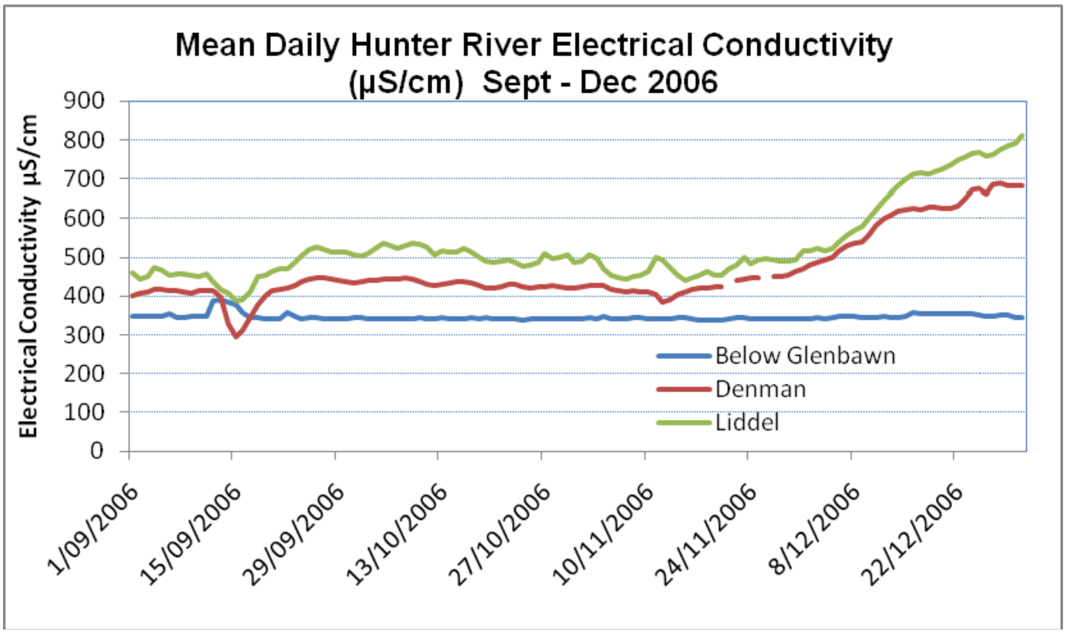

Table 3. 2006 Low flow drought sampling results

Approximate data for Hunter River at Bowmans Crossing (flow, EC and temp data from Hunter River at Denman)							210083 Hunter River at Liddel (Mosses Crossing)				
Sample Date	Flow (ML/day)	EC	Temp ºC	Diatoms	Algae (tot)	Turbidity NTU	Flow (ML/day)	EC	Diatoms	Algae (tot)	Turbidity NTU
06/10/2006	279.8								443	2118	14.3
17/10/2006	297.3	292.3	13.4	565	1272	10.8	33.0	348.6	300	988	17.9
31/10/2006	310.6	410.4	19.3	445	1780	39.4	52.4	482.7	810	965	27.9
08/11/2006	338.2	405.5	19.4	1640	115	11.2	63.8	464.8	710	745	25.1
28/11/2006	311.9	406.3	21.2	910	1085	19.8	64.2	450.3	395	620	27.6
05/12/2006	124.6	514.6	23.0	3250	3450	19.9	91.3	541.2	345	5130	20.1
12/12/2006	66.4	608.6	24.1	970	1590	19.0	42.4	666.4	360	990	25.6
18/12/2006	48.0	632.7	23.1	740	1225	22.7	48.7	719.7	230	645	22.3
09/02/2007	49.6	561	25.7	5426	7252	15.7	28	744	3903	5239	18.1

Summary Data 1990 - 2007 Bowmans Crossing median turbidity 16.9 NTU

Summary data 1990-2007 median turbidity Mosses Crossing12.5 NTU

210125 Hunter River at Salt Water Creek (d/s Liddel)				210064/210009 Hunter River at Greta / Luskintyre					
Sample Date	Flow (ML/day)	EC	Temp ºC	Flow (ML/day)	EC	Temp ºC	Diatoms	Algae (tot)	Turbidity NTU
06/10/2006				28.7					
17/10/2006	23.2	453.4	14.1	66.1	509.4	13.9	690	967	9.3
31/10/2006	41.6	647.0	20.1	78.5	679.0	19.7	570	1570	15.4
08/11/2006	59.3	626.0	20.2	95.5	602.8	19.8	1650	4720	13.1
28/11/2006	63.6	607.7	22.0	84.3	637.2	21.4	320	545	12.9
05/12/2006	69.4	669.4	23.7	75.5	296.3	23.2	1340	1895	14.3
12/12/2006	26.4	777.7	23.7	63.5	286.7	23.3	485	1615	10.3
18/12/2006	34.3	882.7	24.6	49.6	264.1	24.2	205	525	13.3
9/02/2007	-	1084	25.8						

Summary data 1990-2007 median turbidity for Luskintyre 14.5 NTU

Table 4. Data site 21010092 Hunter River at Mosses Crossing

Collect date	EC @ 25 ° C	NOx (mg/L)	Total N (mg/L)	pH	Filter reactive phosphorus (mg/L)	Total phosphorus (mg/L)	Water temperature (°C)	Turbidity (NTUs)
08/06/2006	532	0.01	0.26	8.1	0.003	0.018	12.7	4.2
02/08/2006	556	0.005	0.29	8.45	<0.005	0.022	13.7	10.7
05/09/2006	527	0.02	0.28	8.3	0.003	0.027	18	4
06/10/2006	519	0.01	0.33	8.1	0.003	0.037	19.7	14.3
17/10/2006	565	0.01	0.27	8.3	0.004	0.046	18.5	17.9
31/10/2006	404			8.1			25.1	27.9
08/11/2006	495	0.01	0.38	8.2	0.005	0.07	19.8	25.1
28/11/2006	562			8.26			26.5	27.6
05/12/2006	618			8.2			22.5	20.1
12/12/2006	757			8.1			22.2	25.6
18/12/2006	845			8.3			24.6	22.3

Table 5. Data site 21010091 Hunter River at Bowmans Crossing

Collect date	EC @ 25 ° C	NOx (mg/L)	Total N (mg/L)	pH	Filter reactive phosphorus (mg/L)	Total phosphorus (mg/L)	Water temperature (°C)	Turbidity (NTUs)
17/10/2006	474	0.01	0.37	8.22	0.004	0.031	19.5	10.8
31/10/2006	488			7.98			23.7	39.4
08/11/2006	472	0.01	0.36	8.1	0.004	0.041	20.9	11.2
28/11/2006	471			8.16			26.2	19.8
05/12/2006	617			8.14			23.5	19.9
12/12/2006	767			7.93			23.3	19
18/12/2006	565			8.1			24.1	22.7

Discussion

There has been a history of diatom blooms reported in the Hunter River. Results from the intensive IMEF phytoplankton sampling program undertaken during the years 1998-2002 documented that substantial diatom growth was recorded under low flow conditions at the Hunter River Bowmans Crossing site in January 1999, February 2000 and January 2001. Samplings at the downstream Hunter River Mosses Crossing site (where flow was further reduced) documented diatom growths occurring January to March 1999, March 2002, and for January and March 2001 (E. Avery pers. comm. 2006). The lack of a bloom during the sampling period therefore begs the question as to what factors were different during the 2006 spring summer.

A limited review of river turbidity data for these bloom periods found that the Hunter River turbidity levels were lower than that reported for the current December sampling period. Results from long-term water quality sampling program in the Hunter River catchment has found that the Hunter River is generally not nutrient limiting for algal growth (Ryan et al 2006), however it is hypothesized that nutrient levels are reduced during periods of sustained dam release base flow. Results from the comparison of nutrients concentrations for Hunter River below Glenbawn (dam release water) and Hunter River at Moses Crossing (detailed in Table 6), show relative low soluble and total nitrogen and total phosphorus nutrient concentrations, and thus it can be seen that there is only small increase in nutrients between the two sites. These results further demonstrate the low nutrient concentrations present in the flowing Hunter River when water is sourced only from Glenbawn Reservoir releases. It is not known whether these nutrient levels were low enough to provide any nutrient limitation effects.

Table 6. Median nutrient levels 2004-2006

	Nutrient levels (median)			
Site	**NOx (mg/L)**	**Total nitrogen (mg/L)**	**Soluble P (mg/L)**	**Total phosphorus (mg/L)**
Hunter River Below Glenbawn Dam	0.04	0.35	<0.005	0.0255
Hunter R @ Mosses Crossing	0.01	0.345	0.005	0.0715

The reported results from this study which show the lack of diatom blooms under previously identified critical risk conditions identify a number of additional factors that should be considered as part of the ongoing investigations into the link between flow conditions and phytoplankton growth in the Hunter River system. It is possible that there may be differences in the instream water type depending on river water source (dam versus catchment and/or specific tributary inflows) with the catchment water source being a possible further contributing factor for the potential for diatom blooms to develop in the Hunter River. Hence it may be that under certain circumstances the impacts of river regulation in the Hunter River catchment could be such that it reduces the risk of diatom blooms.

An additional factor identified during this study period was the apparent influence of carp on instream water quality under low flow conditions. The observation made that instream turbidity increased (which has the potential to reduce light penetration and hence reduce phytoplankton growth) reflect the findings made by Driver et al (2005) in their work looking at carp (*Cyprinus carpio*) size and density related disturbance of sediments in experimental ponds and impacts on turbidity.

Summary and recommendations

Results from this study show that for the Hunter regulated river system, the previously identified specific low flow and high water temperature conditions are not always precursors to prolific diatom growth in the mid section of the Hunter River. The study results suggest that total daily discharge (volume) and water temperature are risk factors. However, by themselves these are possibly 'precursors' with additional factors at play that may all combine to lead to the development of diatom blooms in the mid section of the Hunter River.

To further assist in the development of specific low flow rules for the river sections in the mid Hunter River catchment it is recommended that additional studies are undertaken to better understand the 'causal' associations between low flow and diatom growth. The results from this study provides evidence that in the Hunter River system nuisance phytoplankton growth risk cannot be defined by flow speed and water temperature alone. The study results suggest that additional factors should be investigated such as the influence of water source on bloom development and issues of localised in stream disturbances. It will be important to include consideration of such factors in discussion of low flow management targets for the mid Hunter River, particularly in discussion considering low flow targets to reduce phytoplankton bloom risk.

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