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JOHNSTONE CENTRE – ENVIRONMENTAL CONSULTING

Report No. 97

**Environmental Monitoring of the Mitta Mitta River  
associated with the major transfer of water resources  
from Dartmouth Reservoir to Hume Reservoir – 2004/05**

Prepared for the  
**Murray-Darling Basin Commission**



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## **Executive Summary**

### ***Project background and study design***

- The Johnstone Centre – Environmental Consulting (JC-EC), Charles Sturt University (CSU) was engaged by the Murray-Darling Basin Commission (MDBC) to undertake environmental monitoring of the Mitta Mitta River associated with the planned major transfer of water resources from Dartmouth Reservoir to the Hume Reservoir in 2004/2005.
- The aim of the project was to evaluate the environmental response to a Cyclic Release Pattern (CRP) that was to be introduced into the transfer of water from Dartmouth Reservoir to Hume Reservoir.
- Four sites in the Mitta Mitta River, one reference site in the unregulated tributary Snowy Creek, and a control site in the Buffalo River were sampled during this study.
- Samples were collected on twelve sampling dates. The study design included five sampling events prior to the CRP, three during the CRP, and five after the CRP during a period of constant flow from Dartmouth Reservoir.
- Water quality, biofilm structure and taxonomic composition and benthic macroinvertebrates indicators were assessed. Water quality indicators were: dissolved organic carbon, particulate organic matter, total suspended solids, chlorophyll-*a*, temperature, turbidity and conductivity. The following biofilm parameters were assessed: Total, organic and algal biomass (dry weight, ash free dry weight and chlorophyll *a* respectively), and biofilm algal species composition. The following benthic macroinvertebrate parameters were assessed: SIGNAL-2 index, number of taxa, number of oligochaetes and number of chironomids.

### ***Results***

- The water quality in the Mitta Mitta River changed in response to the CRP event. Water temperature and conductivity decreased on the peak of the CRP and increased during the recession after the CRP. Turbidity, particulate organic matter, total suspended solids and water column chlorophyll-*a* in the Mitta Mitta River increased during the peak of the CRP and decreased during the recession of flow at the end of the CRP.
- There was a decrease in the total biomass of biofilms at the most upstream site (site 1) in the Mitta Mitta River during the peak of the CRP but this increased again after the CRP. At site 4 further downstream, there was a decrease in the total, organic and algal biomass of biofilms during the peak of the CRP and all of these parameters increased again after the CRP. These data suggest that the variable flow releases scoured algal biofilms from cobble substrata along the Mitta Mitta River.

- The scouring of biofilm from the cobble substrata changed the community composition of biofilms by removing filamentous green algae and increasing the relative biovolume of early successional species of diatoms. The composition of the biofilm in the Mitta Mitta River became more similar to the reference site during the CRP event.
- There was an increase in the number of benthic macroinvertebrate taxa and the SIGNAL-2 index at site 1 in the Mitta Mitta River after the CRP. The composition of the macroinvertebrate community at site 1 became more similar to the reference site following the CRP event. This was due to the colonisation of several sensitive taxa at site 1 that had been absent from this site prior to the CRP. In contrast, there was no change in the SIGNAL-2 index or total number of taxa at site 4 further downstream in the Mitta Mitta River. The macroinvertebrate community composition at site 4 became more similar to the reference condition during the CRP, but moved back towards the original composition at the end of the CRP.
- This study demonstrates that the CRP in the Mitta Mitta River had a positive effect on river health, shifting the ecosystem condition towards that in the reference site in Snowy Creek. Several of the improvements in condition were only short lived. Within a week of the CRP peaking, several indices had shifted away from the reference condition, back towards values observed prior to the CRP.

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# 1 Introduction

## 1.1 Background

The Johnstone Centre – Environmental Consulting (JC-EC), Charles Sturt University (CSU) was engaged by the Murray-Darling Basin Commission (MDBC) to undertake environmental monitoring of the Mitta Mitta River associated with the planned major transfer of water resources from Dartmouth Reservoir to the Hume Reservoir in 2004/2005.

The Mitta Mitta River is operated as part of the River Murray system by River Murray Water (RMW). RMW has previously introduced a Cyclic Release Pattern (CRP) into the Dartmouth Reservoir release pattern on several occasions aimed at improving environmental conditions in the Mitta Mitta River downstream of the reservoir. In 2001/2002 the ecological responses to the CRP were examined by Sutherland *et al.* (2002). CRP's also took place in 2002/2003 and 2003/2004 as part of the Dartmouth Reservoir release program.

The specific objectives of RMW in introducing a CRP from Dartmouth Dam on previous occasions and in 2004/05 were to:

- reduce stream bank erosion caused by sustained flow release; and
- improve ecological processes and condition within the Mitta Mitta River.

River Murray Water announced the transfer of water from Dartmouth Reservoir to Hume Reservoir in late July 2004. The release was required to supplement storage in Hume Reservoir in preparation for the 2004/05 irrigation and water supply season. The program of transfer commenced at that time, with plans to continue during the 2004/05 irrigation season depending on subsequent conditions in the River Murray system. An early start in water release is sometimes required because of the relatively low flow carrying capacity of the Mitta Mitta River below Dartmouth Dam, particularly if storage in the Hume Reservoir is low. River Murray Water proposed to introduce a CRP into the 2004/05 Dartmouth release pattern to assist with the evaluation of environmental responses to an altered release pattern designed to improve environmental condition of the river (Appendix 1). This CRP was implemented and monitored during the transfer from December 2004 to February 2005.

### 1.1.1 Project aims

The project aims are to:

- describe the rationale of the project design and methodology in the context of the flow conditions during the period of study;
- present hydrographic information of the event;

- justify the choice of environmental indicators to examine the objectives and hypotheses;
- interpret the monitoring results in relation to the objectives and hypotheses;
- provide flow management recommendations for future operations of this kind; and
- provide advice on future monitoring requirements to address any outstanding knowledge gaps in relation to the objectives and hypotheses of the event.

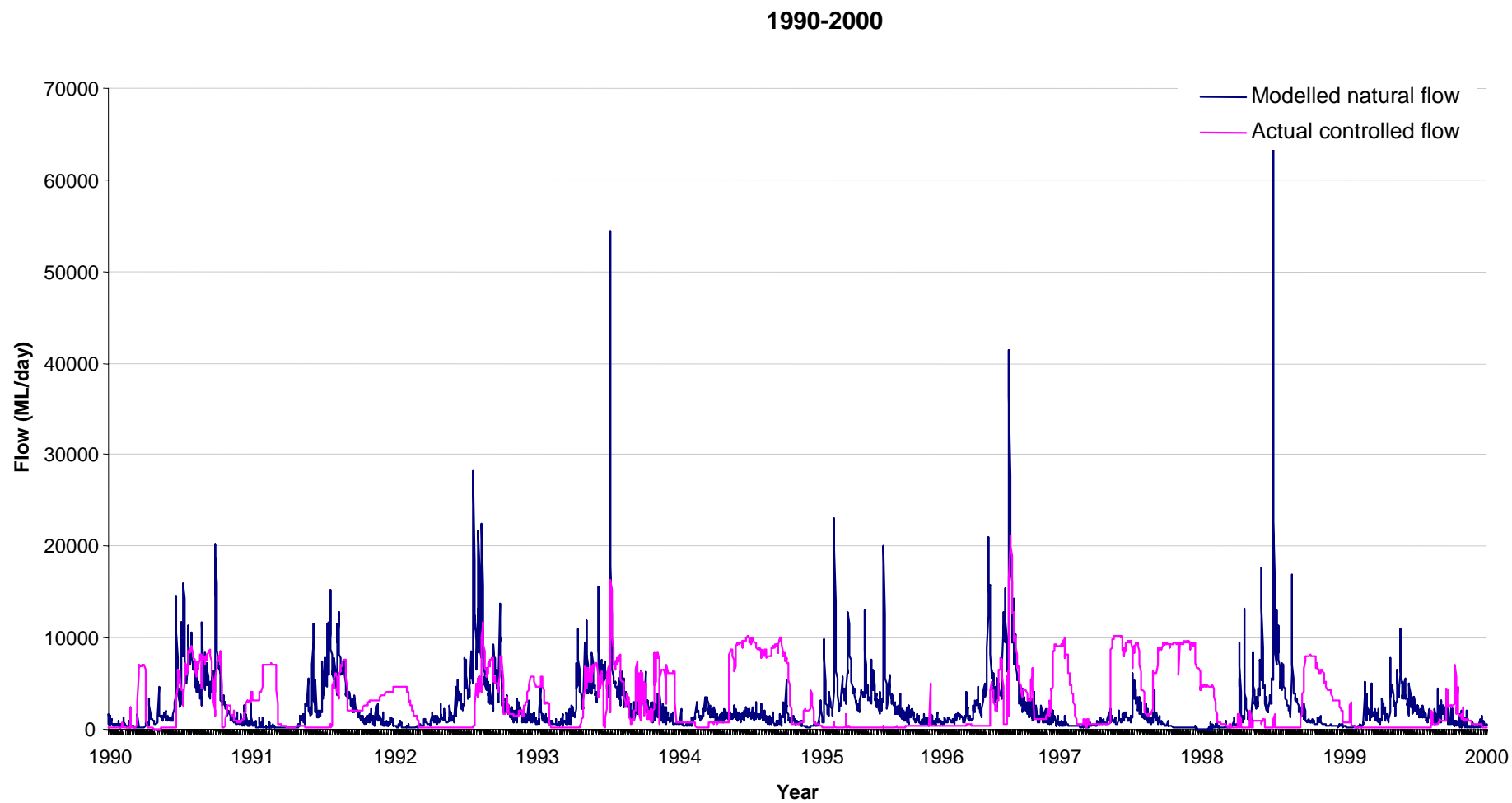
### **1.1.2 Dartmouth operation**

Dartmouth Reservoir has a capacity of 3,906 gigalitres and is the most upstream MDBC storage in the River Murray system. Used as a reserve storage, it is drawn down when necessary to supplement storage in the Hume Reservoir. Dartmouth Reservoir therefore has a less regular cycle of operation than Hume Reservoir, and Dartmouth storage behaviour tends to reflect longer cycles of wet and dry periods (MDBC n.d.). There are five main phases of operation:

- *Filling* - minimum release is maintained to provide for riparian needs downstream. The minimum release is 200 megalitres per day (ML/d) at Colemans gauging station and varies according to the percent capacity of Dartmouth Reservoir.
- *Release for water supply* - Release from Dartmouth Reservoir is made to supplement storage in Hume Reservoir. Transfers may take place months in advance due to the limited channel capacity of the Mitta Mitta River.
- *"Harmony" transfer to Hume Reservoir* - (only when storage levels in Dartmouth are high). They provide flood mitigation benefits in the Mitta Mitta valley, assist in maintaining groundwater levels, improve water quality, increase power generation due to reduced spill volumes, and enhance the recreational use of Hume Reservoir. It equalises the chance of spill of both the Hume and Dartmouth Reservoir.
- *Pre-release* - When the storage approaches full, depending on the time of year, pre-releases may be made to maintain a measure of airspace to help mitigate floods. They are calculated on the basis that after making allowance for the water that is "pre-released", the storage should still fill by the end of an inflow event.
- *Spilling* - When the storage exceeds full supply level, flow over the spillway commences. As spill from the main dam commences, water releases through the power station and the irrigation valves are generally turned off to mitigate downstream flow. At the same time, the release from the regulating dam is reduced to maintain the flow at Tallandoon below channel capacity as long as possible (MDBC n.d).

Dartmouth releases are made in 'harmony' with storage levels in Hume Reservoir. Dartmouth releases are generally characterised by periods of higher flow in the Mitta Mitta River (i.e. usually up to 9000 ML/day depending on demand). Minimum release from

Dartmouth Reservoir is 200 ML/day in order to conserve resources during the ‘filling’ phase or when extra release is not required. In wetter months there may be low releases for long periods in order to conserve water in Dartmouth. i.e. Dartmouth Reservoir serves as a ‘drought reserve’ to be utilised in conjunction with the Snowy and Hume to assist in meeting the downstream water user needs along the River Murray system (Figure 1).



**Figure 1:** Hydrograph for the Mitta Mitta River (Colemans Gauge) illustrating modelled natural flow conditions and actual current controlled flow conditions for the period 1990 to 2000. CRP releases began in the Mitta Mitta River in 2001. (Data source: MDBC)

## **2 Project Design & Methodology**

### **2.1 Environmental Indicators**

Assessing the ecological 'health' of river systems is an important issue for ensuring both the long term ecological condition of the river system and the sustainability of development dependant on the water resource. Indicators form the basis of most empirical systems for assessing the status of the environment (Fairweather 1999). Environmental indicators are measures of physical, chemical or biological responses to environmental change.

A CRP event in the Mitta Mitta River monitored by Sutherland *et al.* (2002) included 3 major indicators of river health; water quality, river productivity and macroinvertebrates. There were three recommendations from Sutherland *et al.* (2002) that were considered when developing the sampling design and selecting indicators for the current project:

*Recommendation 1 & 2 – Additional sampling events prior to first release to capture baseline conditions during constant and/or low flows.*

In response to this recommendation sampling was conducted on a minimum of three occasions prior to and after the CRP in 2004/2005. This enabled the ecological indicators in the period prior to the CRP to be compared to conditions during and after the CRP.

*Recommendation 4 –Increased replication of biofilm attributes.*

In response to this recommendation a minimum of eight rocks per habitat were collected during the 2004/2005 study to better describe within site variability.

*Recommendation 6 – Require a minimum of four surber sample replicates.*

In response to this recommendation four surber samples were collected for benthic macroinvertebrates at each habitat for each site and sampling event.

Three of the indicators monitored by Sutherland *et al.* (2002) were used within this study (2004/2005) with some modification to the way the attributes were sampled. The three indicators were:

- Water quality;
- Biofilm structure and taxonomic composition; and
- Benthic macroinvertebrates.

### **2.1.1 Water Quality**

The following water quality parameters were assessed:

- Dissolved Organic Carbon (DOC)
- Particulate Organic Matter (POM)
- Total Suspended Solids (TSS)
- Chlorophyll-*a* (Chl-*a*)
- Temperature
- Turbidity
- Conductivity

The following hypothesis was tested using the results of the water quality data collected before, during and after the CRP.

#### **Water Quality Hypothesis**

The concentration of DOC, POM and total suspended solids will increase during the CRP compared with the previous constant flow period as a result of the increased riverbank and floodplain inundation and in-channel re-suspension.

### **2.1.2 Biofilm structure and taxonomic composition**

The following biofilm parameters were assessed:

- Total, organic and algal biomass (dry weight, ash free dry weight and chlorophyll *a* respectively); and
- Biofilm algal species composition.

The following hypotheses were tested using the results of the biofilm structure and taxonomic composition data collected before, during and after the CRP.

#### **Biofilm Hypotheses**

Algal biomass (chlorophyll *a*) and total biomass (ash free dry weight) from cobble substrate will decrease following peak flows during the CRP compared with the biomass prior to the peak, due to scouring from increased velocity.

Peak flows will change the community composition of algal biofilm and promote early successional algal taxa on cobble substrata due to scouring from increased velocity.

### **2.1.3 Benthic macroinvertebrates**

The following benthic macroinvertebrate parameters were assessed;

- SIGNAL-2 index (Chessman 2003).
- Number of taxa;
- Number of individuals; and
- Number of chironomids

The following hypothesis was tested using the results of the benthic macroinvertebrate data collected before, during and after the CRP.

#### **Benthic macroinvertebrate hypothesis**

The CRP will alter the biofilm biomass and biofilm community composition on cobble substrata and this will result in a higher diversity of benthic macroinvertebrates and an increase in the proportion of sensitive taxa (as measured by the SIGNAL-2 Index) in cobble habitats following the CRP.

## **2.2 Project Site Design**

The project design aimed to assess the response of selected environmental indicators in cobble habitats under permanent inundation to variations in flow (discharge and inundation) during the CRP and during the constant flow period after the CRP. The initial design for the project proposed by RMW was for a number of CRP's to commence in mid to late spring 2004. However, RMW adjusted the release from Dartmouth Reservoir from time to time due to changes in demand as a result of changes in conditions in the River Murray system further downstream. The only CRP implemented during the study period commenced on the 4th of January 2005 (mid summer) and had a different release pattern to the 2001/02 event. As a result, a direct comparison of indicator responses among seasons (2004/2005) and between years (2001/2002 to 2004/2005) was not possible.

### **2.2.1 Sampling sites**

The study design aimed to compare ecological parameters at four sites along a 70 kilometre reach of the Mitta Mitta River downstream of Dartmouth Reservoir. Cobble benches were selected at each experimental site, as these habitats undergo considerable hydrological change during a CRP through increased velocity and area of inundation. Cobble benches are a common feature along the study reach in the Mitta Mitta River and are also a feature within the reference and control site. The same four sites in the Mitta Mitta River and the reference site in the Snowy creek that were included in the 2001/02 Sutherland *et al.* (2002) study of the Mitta Mitta River were selected for this 2004/2005 study, with the addition of a control site in the Buffalo River.

The reference stream is Snowy Creek, an unregulated upland tributary of the Mitta Mitta River. The flow pattern of Snowy Creek reflects natural rainfall and snow melt events within the creeks catchment, and is characterised by low flows in late summer and early autumn and high flows in late winter and spring. Snowy Creek is a suitable reference site as it is a relatively unregulated system.

Buffalo River is a regulated system that does not receive variable flows in the form of a CRP. The use of this river as a control site will add strength to the management

recommendations of the project and allow comparisons between two regulated systems of which only one receives variable flows in the form of a CRP. Vegetation and landuse in the both the upper reaches and downstream of the main storage reservoir of the Buffalo and Mitta Mitta Rivers are similar, making the Buffalo River a suitable control site.

Although it is desirable to have multiple reference and control sites, time and budget constraints (eg. cost of additional laboratory work) limited the number reference and control sites included in this study.

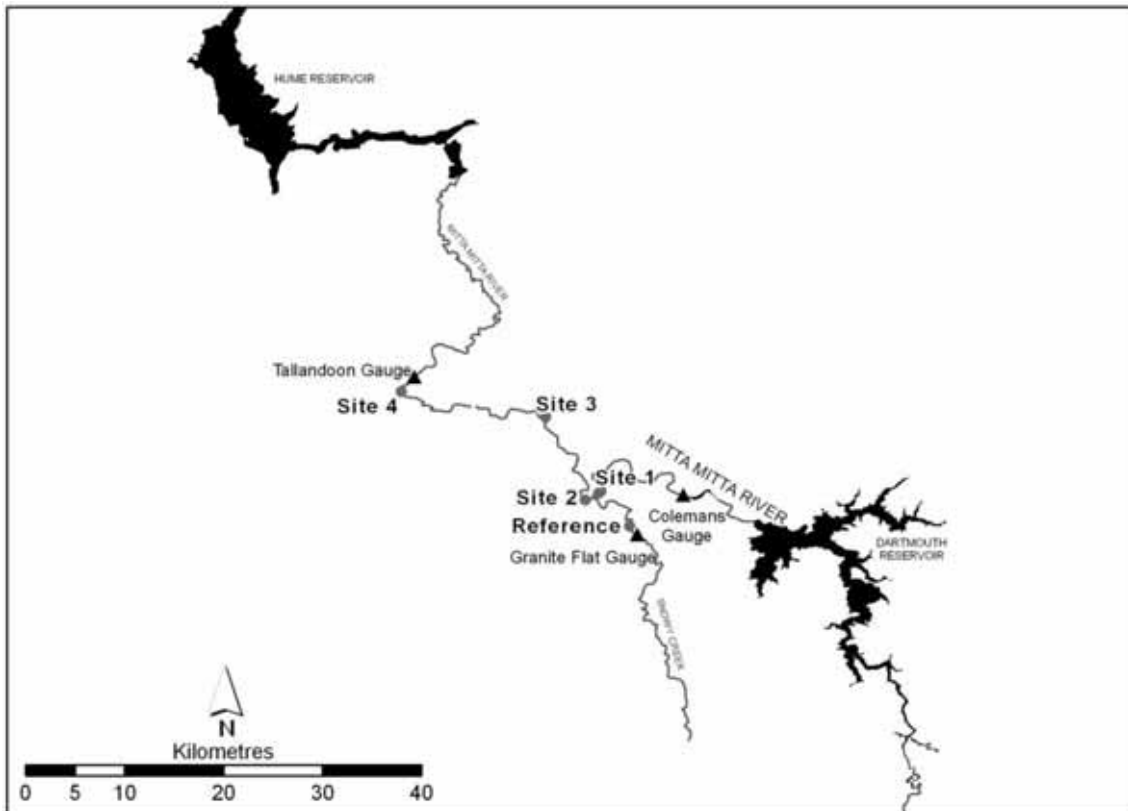
## **2.3 Study Area**

The study area is located in north-eastern Victoria within the upper catchment of the Murray River. The Mitta Mitta River and Snowy Creek are located upstream of the Hume Reservoir. Snowy Creek is one of the major tributaries of the Mitta Mitta River, and the Mitta Mitta River is a major tributary of the Murray River upstream of the Hume Reservoir. The Mitta Mitta River between Lake Banimboola and the confluence of Snowy Creek flows through upland and foothills habitat, with steep-sided valleys dominated by dry sclerophyll woodland. Downstream of the township of Mitta Mitta, the river flows into a wide floodplain that has been extensively cleared for agriculture, and is dominated by livestock enterprises (Koehn *et al.* 1995). The riparian zone is predominately cleared in the lower reaches with occasional stands of River Red Gum (*Eucalyptus camaldulensis*) and Willows (*Salix* spp.) (Sutherland *et al.* 2002).

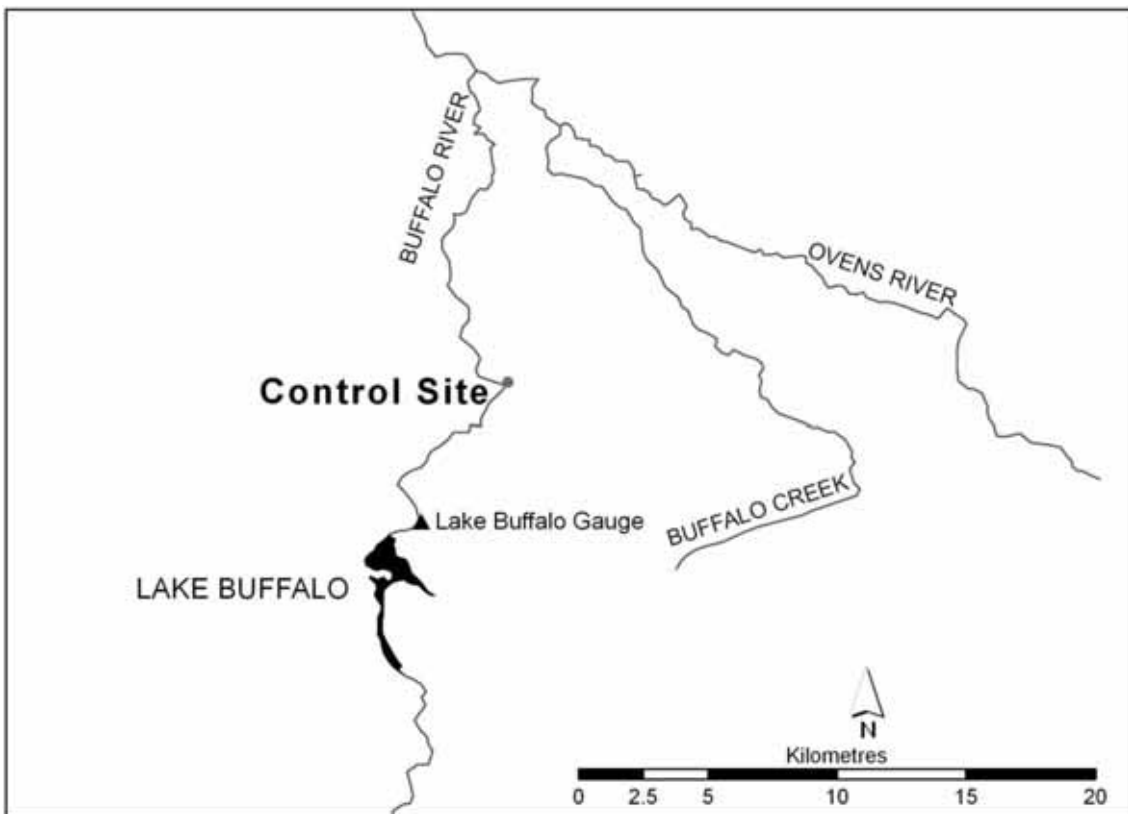
### **2.3.1 Site Locations**

Sites 1-4 inclusive are located on the Mitta Mitta River downstream of Dartmouth Reservoir (Figure 2, Table 1). The reference site is located on Snowy Creek which is a major tributary of the Mitta Mitta River and has its confluence with this river near the Mitta Mitta township, downstream of Dartmouth Reservoir (Figure 2). The control site is located on the Buffalo River, approximately 10 kilometres downstream of Lake Buffalo spillway near McGuffies Bridge (Figure 3, Table 1). The Buffalo River system is approximately 60 kilometres (straight line) from the Mitta Mitta River. All six sites are located within the North East Catchment Management Authority (NECMA) area.





**Figure 2:** Location of sampling sites 1-4 on the Mitta Mitta River and the reference site



**Figure 3:** Location of the control site on the Buffalo River downstream of Lake Buffalo.

The following gauging stations were used to obtain river flow (ML/day) and height data (metres) for each site during the period 01/11/04 to 28/02/05 inclusive.

- Coleman’s Gauge – Mitta Mitta River, downstream of Dartmouth Reservoir and upstream of site 1.
- Tallandoon Gauge – Mitta Mitta River, downstream of Dartmouth Reservoir and less than 2 kilometres downstream of site 4.
- Granite Flat Gauge – Snowy Creek, unregulated and less than 2 kilometres upstream of the reference site.
- Lake Buffalo Gauge – Buffalo River, downstream of Lake Buffalo and upstream of McGuffies Bridge and Reserve and the control site.

**Table 1:** Summary of site locations and details for the four sampling sites on the Mitta Mitta River, reference site on Snowy Creek and control site on Buffalo River. (N.B. easting and northing are in UTM co-ordinates and projected in WGS84).

| Site      | Easting | Northing | Rationale for inclusion   |
|-----------|---------|----------|---|
| 1         | 534206  | 5956959  | First accessible cobble bench downstream of Lake Banimboola used to assess ecological responses at the upstream section of the Mitta Mitta River. |
| 2         | 533114  | 5956322  | Downstream of the Snowy Creek and Mitta Mitta River junction, used to assess potential impacts from inflows of major tributary.                   |
| 3         | 529971  | 5964641  | In the mid-section of the study area used to gauge longitudinal responses to variable flows.  |
| 4         | 518232  | 5967211  | Used to assess ecological response to variable flows at the downstream end of the study area.   |
| Reference | 536704  | 5953633  | Snowy Creek downstream of Granite Flat gauging station. To be used as a reference site.   |
| Control   | 472928  | 6053664  | Buffalo River downstream of Lake Buffalo near McGuffies Bridge. Regulated system not receiving CRP’s. To be used as a control site.               |

## 2.4 Sampling Regime

The study design included sampling during a period of near constant flow prior to the CRP (where flow did not vary by more than 5% at Coleman’s and 10% at Tallandoon gauge between constant flow sampling events). Five sample events occurred during the period prior to the CRP, three during the CRP and five in the constant flow period after the CRP. The sampling dates and flow period are outlined in Table 2 and Figure 4.

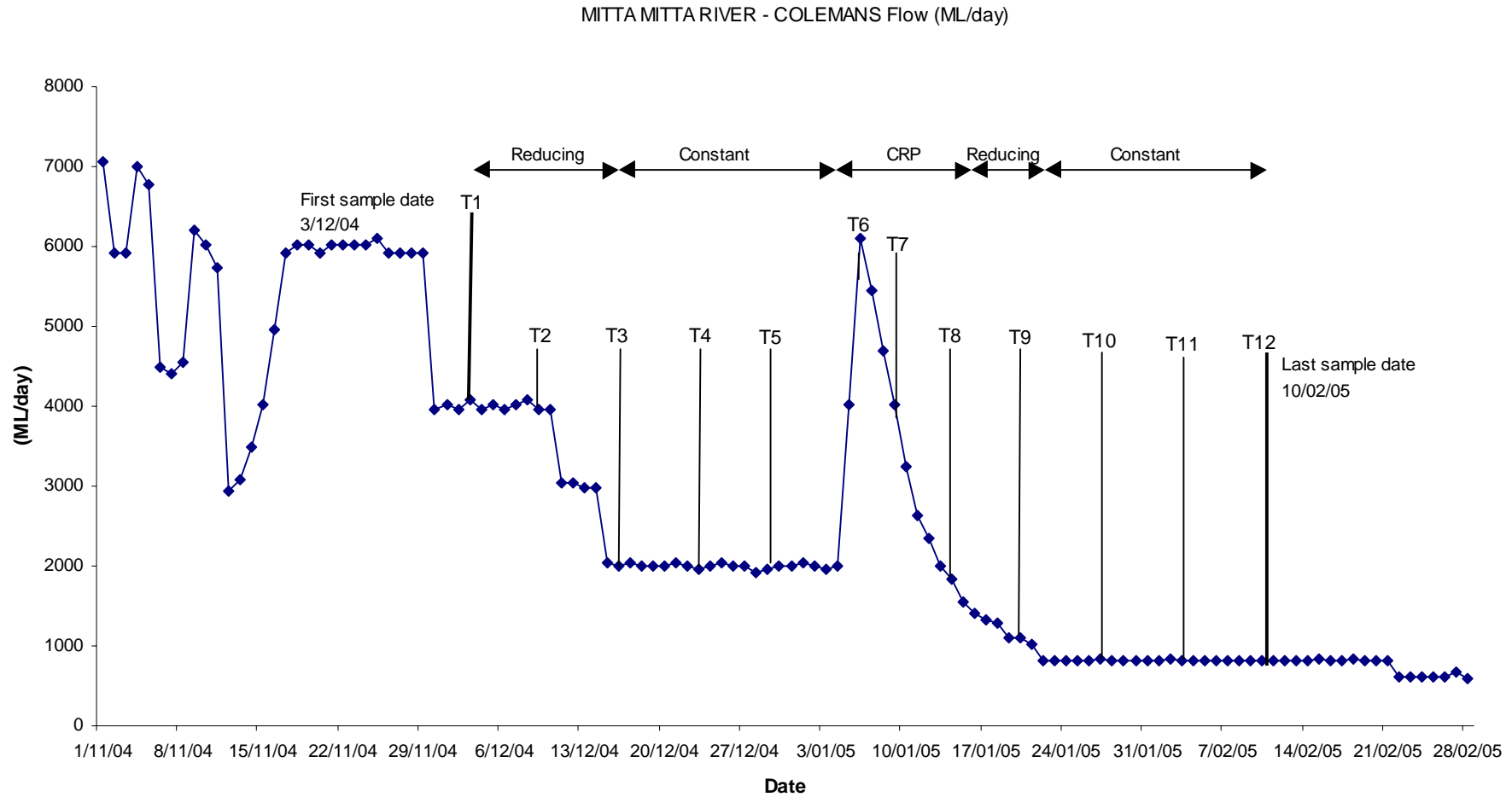
**Table 2:** Sampling dates, flow rates (at Coleman’s and Tallandoon Gauge on Mitta Mitta River) and sample type during the 2004/2005 CRP event within the Mitta Mitta River.

| Date       | Sample event | Discharge period (Coleman’s) | Flow (ML/day) at Coleman’s Gauge | Discharge period (Tallandoon) | Flow (ML/day) at Tallandoon Gauge |
|------------|--------------|------------------------------|----------------------------------|-------------------------------|-----------------------------------|
| 03/12/2004 | T1           | reducing                     | 4087                             | reducing                      | 5032                              |
| 09/12/2004 | T2           | reducing                     | 3961                             | reducing                      | 4973                              |
| 16/12/2004 | T3           | constant                     | 2002                             | reducing                      | 2873                              |
| 23/12/2004 | T4           | constant                     | 1961                             | constant                      | 2616                              |
| 29/12/2004 | T5           | constant                     | 1961                             | constant                      | 2616                              |
| 06/01/2005 | T6           | CRP                          | 6107                             | CRP                           | 6931                              |
| 09/01/2005 | T7           | CRP                          | 4024                             | CRP                           | 4800                              |
| 14/01/2005 | T8           | CRP                          | 1843                             | CRP                           | 2293                              |
| 20/01/2005 | T9           | reducing                     | 1108                             | reducing                      | 1623                              |
| 27/01/2005 | T10          | constant                     | 833                              | constant                      | 1158                              |
| 03/02/2005 | T11          | constant                     | 808                              | natural fresh                 | 1514                              |
| 10/02/2005 | T12          | constant                     | 808                              | natural fresh                 | 1586                              |

During the first two weeks of the study, there was a gradual reduction in daily discharge at Coleman’s gauge from 4087 ML/day on the first sample event (T1) to 2002 ML/day on the third sample event (T3) (Figure 4). Consequently, only T3, T4 and T5 will be considered to be part of the constant flow period prior to the CRP (Table 2).

The CRP occurred over a period of 14 days with sampling occurring on the 3<sup>rd</sup>, 6<sup>th</sup> and 14<sup>th</sup> day of the CRP. Peak flows were recorded on day 3 of the CRP (T6) with a drawdown/recession period of 11 days in total until day 14 of the CRP (Figure 4).

Between sampling events T11 and T12 (after the CRP) there was a rainfall event that caused an increase in discharge in Snowy Creek and Buffalo River (Figure 5). This did not affect site 1 in the Mitta Mitta River, but did affect sites 2, 3 and 4 downstream of the confluence of Snowy Creek.



**Figure 4:** Sampling events and discharge period (at Coleman’s Gauge) during the sampling period from December 2004 to February 2005. (Source: MDBC).

## **2.5 Sampling Methods**

### **2.5.1 Water Quality**

Three replicate water samples were taken from flowing surface waters at each study site on each sampling event for determination of DOC, TSS and water column Chl-*a*. A HydroLab was placed near the water surface at each site to determine the temperature, turbidity and specific conductivity of the water.

#### *Dissolved organic carbon*

Water column DOC was measured using filtered (0.45µm) water samples and analysed for the concentration of carbon (mg/L) using a Dohmann Total Organic Carbon Analyser.

#### *Total suspended solids*

TSS was calculated using the dry and combusted weights obtained by filtering water using 75µm glass fibre filter papers. TSS was calculated as the total dry weight of filtrate and estimated as g/m<sup>3</sup>.

#### *Chlorophyll-a*

Water column Chl-*a* was measured using filtered (75µm GFF) water samples. The Chl-*a* was fixed by placing filters and retained material into 10 millilitre vials containing a solution of 150 milligrams of magnesium carbonate and 8 millilitres of 90 percent aqueous methanol. Following 24 hour extraction at 4°C the vials were boiled at 70°C in a water bath for 2 minutes then were centrifuged at 4500 rpm for 3 minutes and the resulting supernatant was analysed for light absorbance at 750 and 666λm using a light spectrophotometer. One hundred microliters (100µL) of 1M hydrochloric acid was then added to the supernatant and the absorbance of light was measured again at 750 and 666λm for the determination of phaeophytin concentrations.

### **2.5.2 Biofilm structure and taxonomic composition**

Biofilms were collected from cobble that remained permanently inundated throughout the study on each sampling date. On each sampling occasion 8 cobbles (ranging between 12 and 25cm diameter) were randomly selected from the site, placed in labelled sealed plastic bags and stored on ice in the dark. The level of replication and size of cobble were based on the results of Watts *et al.* (2001).

In the laboratory, the biofilm was scrubbed from each cobble into 200 millilitres of distilled water using a soft toothbrush within 48 hours of field collection. Sub-samples were removed from the 200 millilitre residue for determination of Chl-*a* (filtered through a GFF 75µm filter), the amount filtered was recorded and taxonomic composition was prepared by storing a 10 millilitre sample with Lugols solutions.

Using pre-ashed GFF 75 $\mu$ m filter papers a recorded amount of the solution of residue was filtered, each biomass sample was dried at 80°C for 24 hours, weighed, combusted for 4 hours at 500°C and reweighed. All samples were weighed to four decimal places and converted to dry weight (DW) and ash free dry weight (AFDW). Chl-*a* was determined following Tett *et al.* (1975). Samples were placed in 8 millilitres of methanol containing 150 milligrams magnesium carbonate to prevent premature acidification, extracted for 18 hours at 4°C, transferred to a 70°C water bath and boiled for 2 minutes. Samples were centrifuged at 4500rpm for 3 minutes and optical densities at 750 and 666nm were measured pre- and post-acidification (1M HCl) using a UV/Visible Spectrophotometer.

Each cobble was measured for colonisable rock surface area (CRSA) by covering the exposed surface area of the rock (excluding the buried surface) with aluminium foil (after Doeg & Lake 1981). CRSA measurements were used to standardise biofilm dry weight (DW) and ash free dry weight (AFDW) to g/m<sup>2</sup> and Chl-*a* to mg/m<sup>2</sup>. Percent organic matter was calculated as the proportion of AFDW to DW and converted to a percentage to standardise across sites and dates.

Taxonomic composition of the algae was estimated by calculating the biovolume of the first 750 cells counted by light microscopy at 400x magnification of four replicate biofilm samples from all sites for all dates. The cell dimensions and approximated geometric shape of each taxon were recorded and used to calculate the biovolumes using the biovol program (Hillebrand *et al.* 1999). Biovolume provides a more accurate estimate of relative abundance than cell number as it standardises results by cell size and removes complications associated with species such as filamentous Cyanobacteria which do not have individual cells.

Taxonomy was confirmed at 1000x magnification for some specimens. Biovolume of each taxon was converted to a relative percentage of the total biovolume. Relative biovolume gives a good assessment of broad taxonomic shifts in biomass. The algae were grouped by division into Bacillariophytes (diatoms), Chlorophytes (green algae), filamentous Cyanobacteria (blue-green algae) and Rhodophytes (red algae). The algal cells were mainly identified to genus. Species were named where sufficient detail was available from microscopy, and keys were available for the genus.

### **2.5.3 Benthic macroinvertebrates**

Benthic macroinvertebrates in cobble habitats were sampled quantitatively using a surber sampler comprising a rectangular quadrat (20cm by 20cm) to delineate the area of bed to be sampled and a net (250  $\mu$ m mesh) into which the disturbed benthic invertebrates are swept by the current. The sampler was placed on the benthos facing upstream and the substrate within the quadrat was thoroughly disturbed for a standard time of 30 seconds. The contents of the net were emptied into labelled sealed bags (double bagged to ensure

security of contents) and were preserved in 70 percent alcohol. Benthic macroinvertebrates from permanently inundated cobble banks were sampled on six sampling dates (T4, T5, T7, T9, T11 and T12, Table 1) from two sites in the Mitta Mitta River (site 1 and site 4), one site on Snowy Creek (Figure 2) and one site on the Buffalo River (Figure 3). Four replicates were collected from each site on each sampling date.

In the laboratory samples were transferred to labelled jars with the use of a 250  $\mu$  m sieve, this allowed the removal of large cobbles. These cobbles were scrubbed gently to retain any invertebrates in the sample. All invertebrates were removed from each sample and were stored in 70 percent ethanol. Fauna from the surber samples were counted and identified to family level, with the exception of mites, flatworms, nematodes and oligochaetes. The following parameters were calculated for each replicate from the raw data:

- Number of taxa;
- Number of individuals; and
- SIGNAL-2 index (Chessman 2003).

## **2.6 Data analyses**

All univariate data were analysed using General Linear Models (GLMs) in the statistical software package SPSS (SPSS for Windows Release 11.5.0, SPSS Inc 2002), while multivariate analyses were conducted using PRIMER (Primer 5 for Windows Version 5.2.2, Primer E Ltd 2001).

### **2.6.1 Biofilm structure and taxonomic composition**

Data for biofilm attributes dry weight, ash free dry weight and chlorophyll *a* were assessed for normality and homogeneity of variances using Levene's test of Homogeneity. Heteroscedastic data were log-transformed [ $x' = \ln(x + 1)$ ] to improve normality and homogeneity of variances. Two factor GLMs were used to examine the interaction between all sites and sample dates from the last constant flow prior to the CRP (T5) to the second constant flow after the CRP (T11). Post-hoc tests using the Bonferroni-type correction were used to test the effect of habitat types and sample times.

Relative abundance of algal taxa data were log-transformed [ $x' = \ln(x + 1)$ ] before analysis in order to reduce the influence of highly abundant taxa. Similarities between samples were calculated using the Bray-Curtis similarity metric, and were represented visually using non-metric multidimensional scaling (NMDS) in the PRIMER statistical package. The more similar the sites are in species composition, the closer they will group together within the ordination. The ANOSIM routine in Primer (Clarke and Warwick 1994) was used to compute an R statistic that reflects the differences between treatments. Relative abundance

of algal taxa were examined using NMDS from the Mitta Mitta River sites 1 and 4, and the control and reference sites for the last sample during constant flow prior to the CRP (T5) to the first constant flow sample after the CRP (T9) and between T11 and T12 during constant flow after the CRP.

### **2.6.2 Benthic macroinvertebrates**

Data for the benthic macroinvertebrate variables SIGNAL-2 index, number of taxa, number of oligochaetes and number of chironomids were checked for normality and homogeneity of variances using P-P plots and residual plots. The oligochaete data were square root transformed ( $\times' = \sqrt{\times}$ ) to improve normality and homogeneity of variances. GLMs were used to examine the differences across six sample dates (T4, T5, T7, T9, T11 and T12) for sites 1 and 4 in the Mitta Mitta River, and the reference and control sites.

The invertebrate community structure was compared between sites using non-metric multidimensional scaling (NMDS). For community analyses, invertebrate data were log-transformed [ $\times' = \ln(\times + 1)$ ] before analysis in order to reduce the influence of highly abundant taxa. Similarities between invertebrate communities were calculated using the Bray-Curtis similarity metric, and were represented visually using non-metric multidimensional scaling (NMDS) in the PRIMER statistical package. Macroinvertebrate community analyses were examined using MDS ordination of samples from sites 1, 4, the reference and the control for one sample date prior to the CRP (T5), during the CRP (T7) and two post-CRP dates (T9, T11).

The ANOSIM routine in Primer (Clarke and Warwick 1994) was used to compute an R statistic that reflects the differences between treatments. ANOSIM calculates a test result 'R' identifying the observed differences between treatments compared with the differences among replicates within treatments (Clarke and Warwick 1994). 'R' values can be interpreted using the following:

- R = 1 indicates absolute separation of treatments
- R = >0.75 indicates treatments are well separated
- R = >0.5 indicates possible overlap between treatments but are still different
- R = <0.25 indicates treatments are hardly separated
- R = 0 indicates treatments are impossible to tell apart

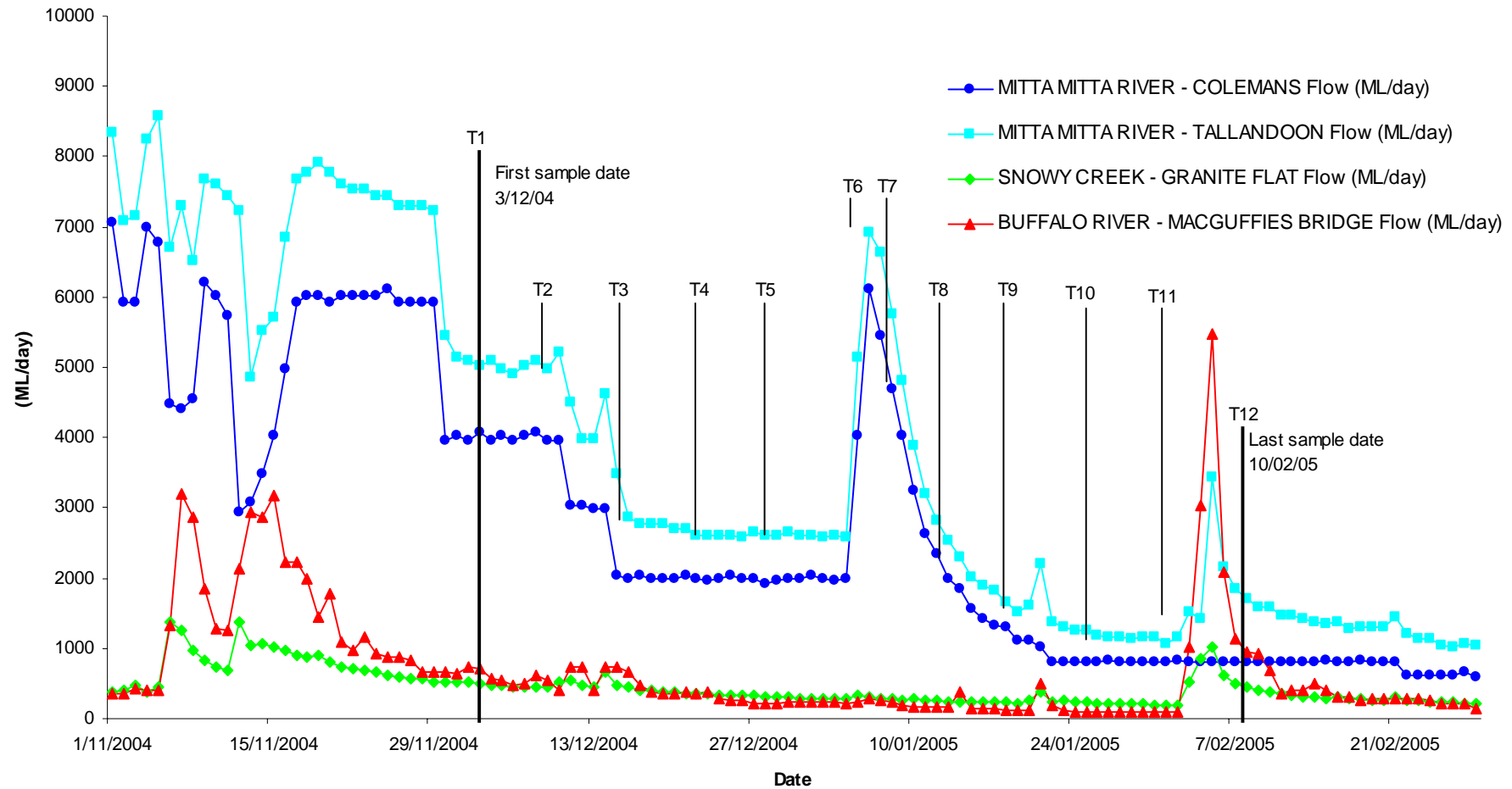


## **3 Results**

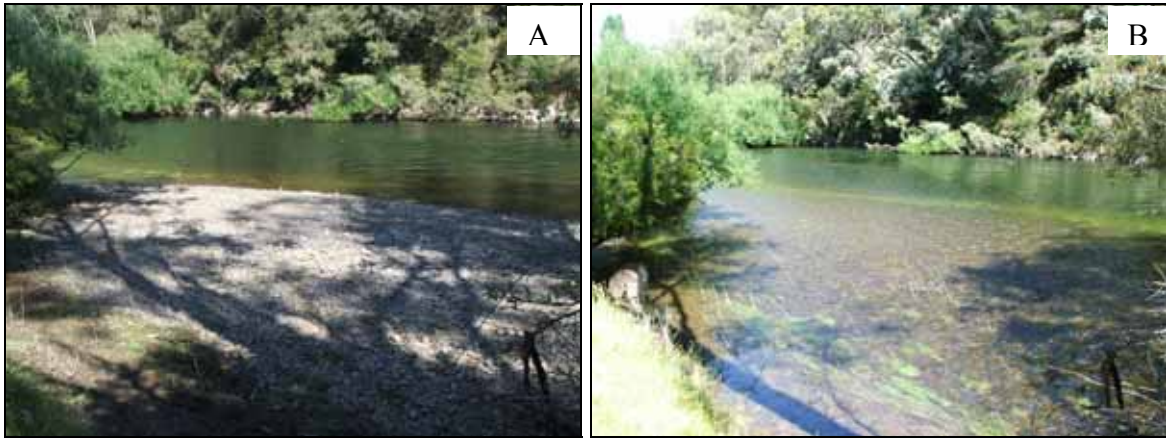
### **3.1 Hydrographical Data**

The hydrographic information for the study period is shown in Figure 5. Prior to the study period the release from Dartmouth Reservoir was high, reaching a maximum discharge of 7063 ML/day at Colemans gauge. Two natural freshes were also observed in Snowy Creek and Buffalo River during this time. All sites experienced a constant discharge period from the 16/12/2004 to 3/01/2005. Flow in the Mitta Mitta River remained at approximately 2000 ML/day at Colemans gauge during this period. The cyclic release pattern began on the 4/01/2005 with peak flows of 6107 ML/day recorded on day 3 of the CRP (T6 - 06/01/05) at Colemans gauge (Plate 1). The drawdown or recession period lasted 11 days in total until day 14 of the CRP where samples were taken with the discharge approximately 2000ML/day. However, discharge continued to fall until the 22/01/2005 and was then kept at approximately 800 ML/day at Colemans gauge for the remainder of the sampling period.

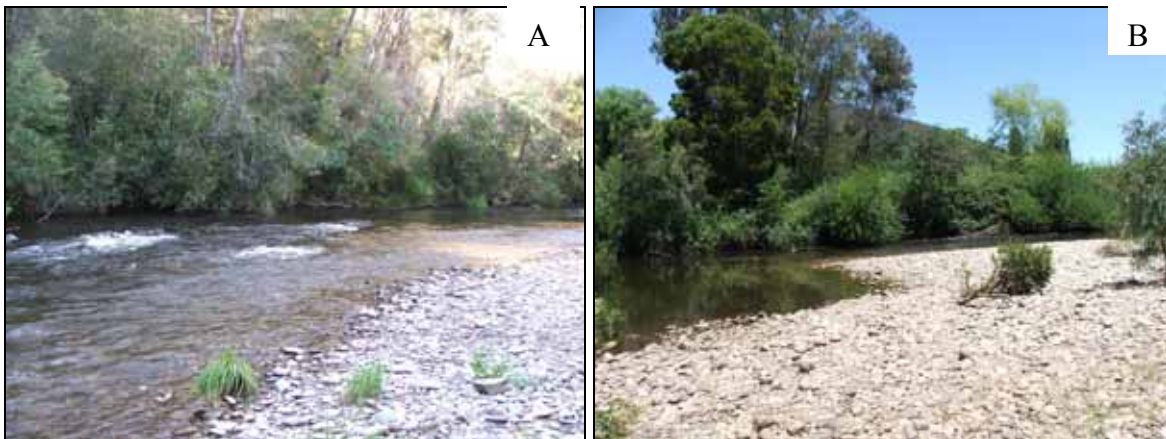
During this time, Snowy Creek and Buffalo River experienced relatively constant discharge (Plate 2). Between the sample events 11 and 12 (3<sup>rd</sup> to 10<sup>th</sup> February 2005), there was a natural fresh in the Snowy Creek and Buffalo River caused by rainfall. Peaks in discharge were experienced at all sites, with the exception of site 1 in the Mitta Mitta River. This natural fresh allowed a comparison among site 1 on the Mitta Mitta River which retained a constant flow, and site 4 (Plate 3) on the Mitta Mitta River, Snowy Creek and Buffalo River that received variable flows. This comparison can provide an indication of the potential benefits of a second flow release within the same season in the Mitta Mitta River.



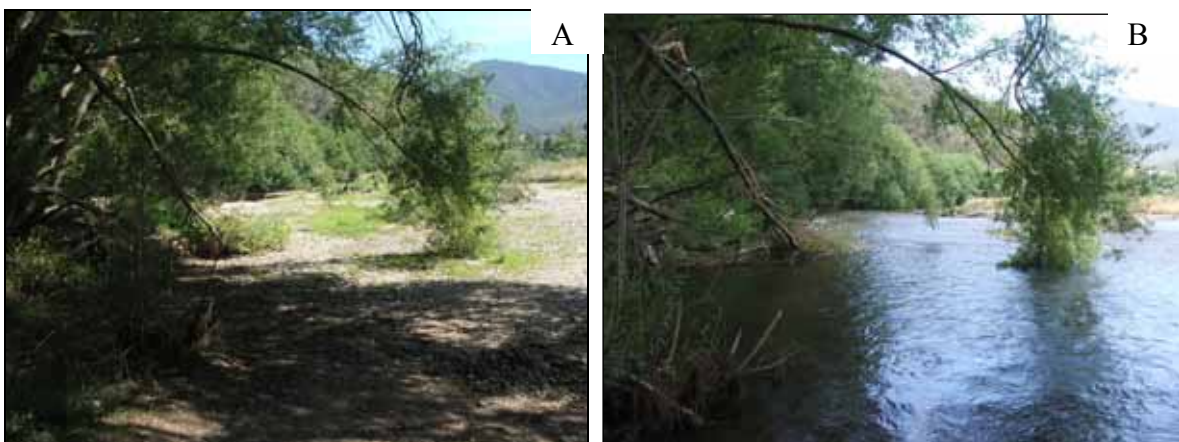
**Figure 5:** Hydrograph for the Mitta Mitta River recorded at Tallandoon and Colemans gauging stations, Snowy Creek recorded at Granite Flat gauging station, and Buffalo River recorded at Lake Buffalo gauging station (McGuffies Bridge) for the period 1/11/2004 to 29/2/2005. See Figure 2 and 3 for locations of each gauging station. (Source : MDBC and Goulburn Murray Water)



**Plate 1:** Mitta Mitta River at site 1 during (a) constant flow at T3 (16/12/04) at 2002ML/day and (b) CRP at T7 (09/01/05) 4024ML/day at Colemans Gauge.



**Plate 2:** (a) Reference site on the unregulated Snowy Creek and (b) control site on the regulated Buffalo River.



**Plate 3:** Mitta Mitta River at site 4 during (a) constant flow during T10 (27/01/05) at 833ML/day and (b) CRP during T7 (09/01/05) 4024ML/day at Colemans Gauge.

## **3.2 Water Quality**

### **Water Quality Hypothesis**

The concentration of DOC, POM and suspended solids will increase during the CRP compared to the previous constant flow period as a result of the increased riverbank and floodplain inundation and in-channel resuspension.

### *Dissolved organic carbon*

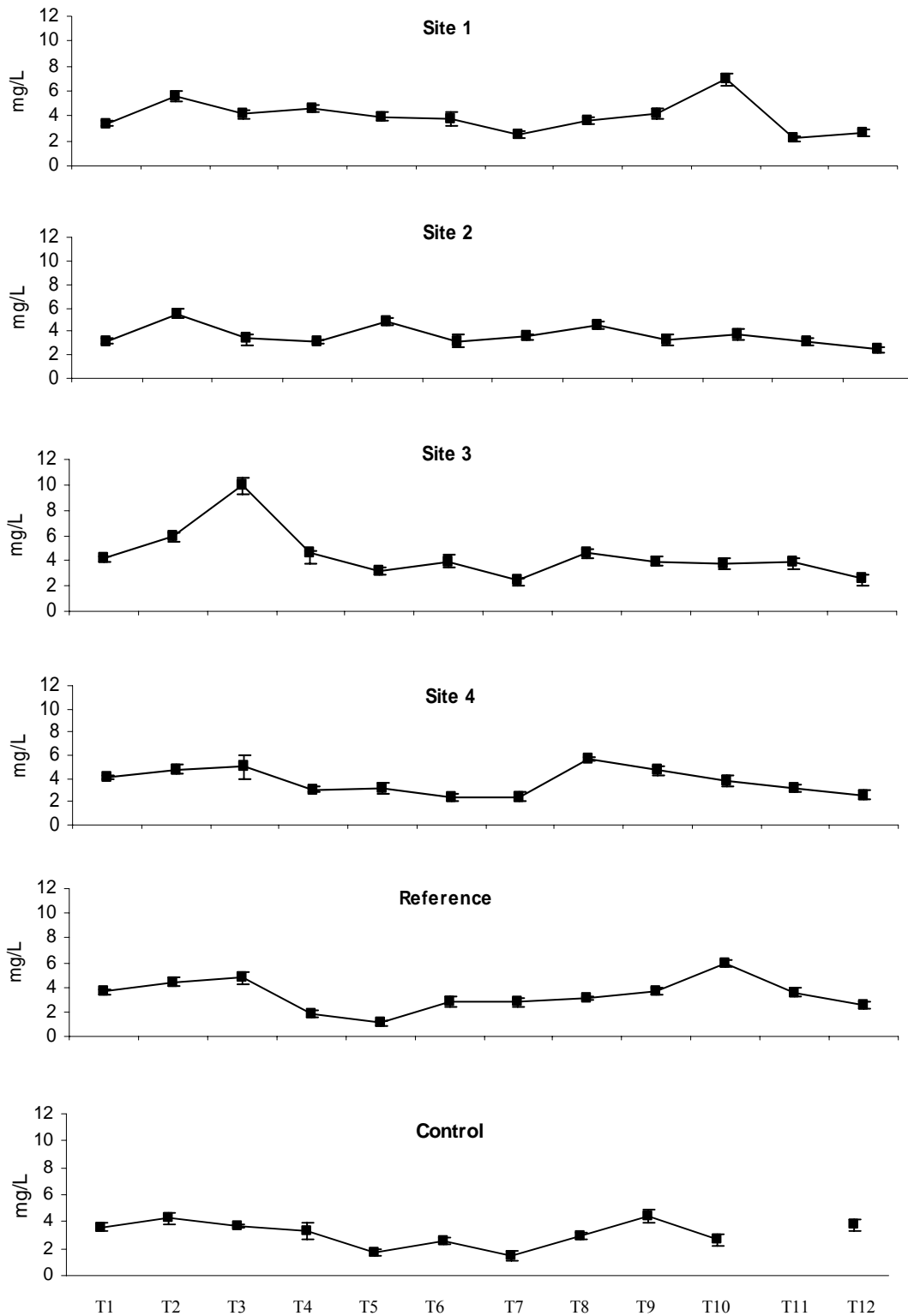
The concentration of DOC was generally low at all sites throughout the study period. The concentration of dissolved organic carbon ranged from 2.1 mg/L to 10 mg/L at all sites along the Mitta Mitta River. DOC concentrations in the reference site on Snowy Creek, ranged from 1.1 mg/L to 5.9 mg/L and at the control site on Buffalo River 1.4 mg/L to 4.4 mg/L (Figure 6).

DOC concentrations did not vary considerably throughout the sampling period and did not increase significantly during the CRP. It is possible that the high discharge prior to the study period (max 7063 ML/day, Coleman's gauge) removed the majority of organic matter that had built up on cobble banks, so there was only a small remaining amount to leach during the CRP.

There was a reduction in the concentration of DOC at the beginning of the constant flow period prior to the CRP and it remained low throughout this constant flow period. All sites on the Mitta Mitta River showed a slight increase in DOC during the recession period (T8) on the last day of the CRP and this was more notable at sites 3 and 4. DOC also increased at site 1 at sample time T10 and then decreased again by sample event T11 constant flow after CRP. At the reference site, concentration of DOC decreased after the third sampling event (T3) following a small natural flow event on the 14/01/2005. However, an increase in DOC at the reference site on T10 does not coincide with any increase or decrease in flow. DOC concentration at the control site on the Buffalo River was generally stable but was highest during a small increase in flow on the 21/01/2005.

### **Summary of DOC results**

DOC was predominately stable with minimal peaks after the CRP and the natural flow event from Snowy Creek into the Mitta Mitta River.



**Figure 6:** Water column concentrations (mg/L) of dissolved organic carbon (DOC) at sites 1 to 4 on the Mitta Mitta River, a reference site on Snowy Creek and the control site on Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005 (mean  $\pm$  SD, n=3). N.B. data at control site T11 not collected due to high flow.

### *Particulate organic matter*

Particulate Organic Matter (POM) in the Mitta Mitta River ranged from 5 g/m<sup>3</sup> to 52.5 g/m<sup>3</sup> during the study period (Figure 7). At sites 1 and 2 the concentration of POM increased marginally at the peak of the CRP (T6) but then decreased 3 days after the peak of the CRP (T7). In comparison, at sites 3 and 4 further downstream, POM increased 3 days after the peak of the CRP (T7) and then decreased by the next sampling event (T8). This supports the hypothesis that the concentration of POM will increase during the CRP, although a delay in this increase was observed at sites 3 and 4. This is consistent with the findings of a study of a CRP in the Mitta Mitta River in 2001/2002 (Sutherland *et al.* 2002). POM concentrations at the reference site in Snowy Creek remained stable until late in the sampling period. The POM concentration at the reference site increased following a natural high flow event (T11) and then decreased again following the flow event (T12). This second rise in concentration of POM was also experienced at sites 2, 3 and 4 on T11 (after the CRP), but not at site 1 which did not experience this natural flow even from the Snowy Creek. POM concentrations were more variable at the control site on the Buffalo River, however, a POM increase at T9 coincided with a high flow event in this system.

#### **Summary of POM results**

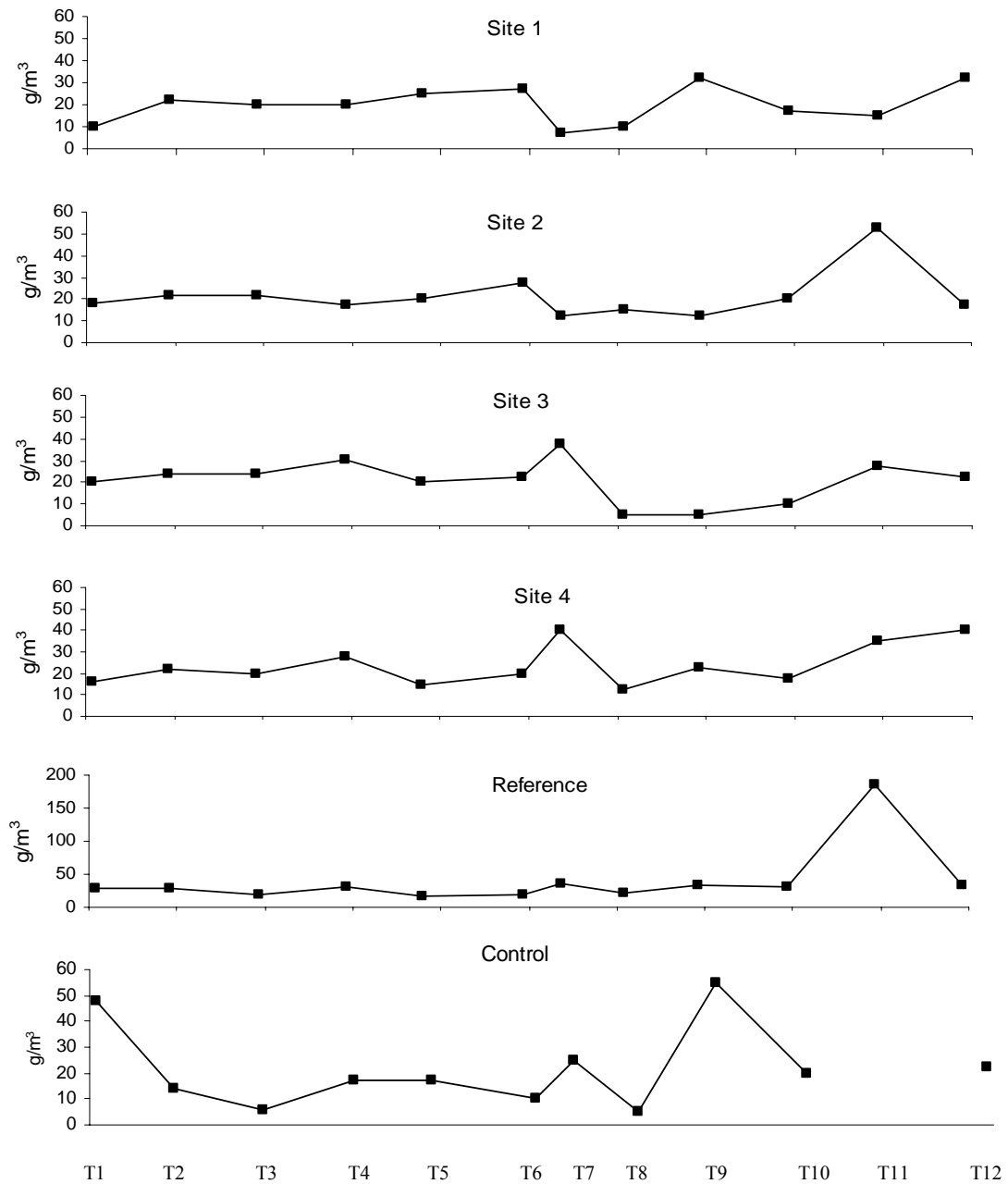
POM increased during the peak releases of the CRP, although this increase was delayed as the water travelled to downstream sites.

### *Total suspended solids*

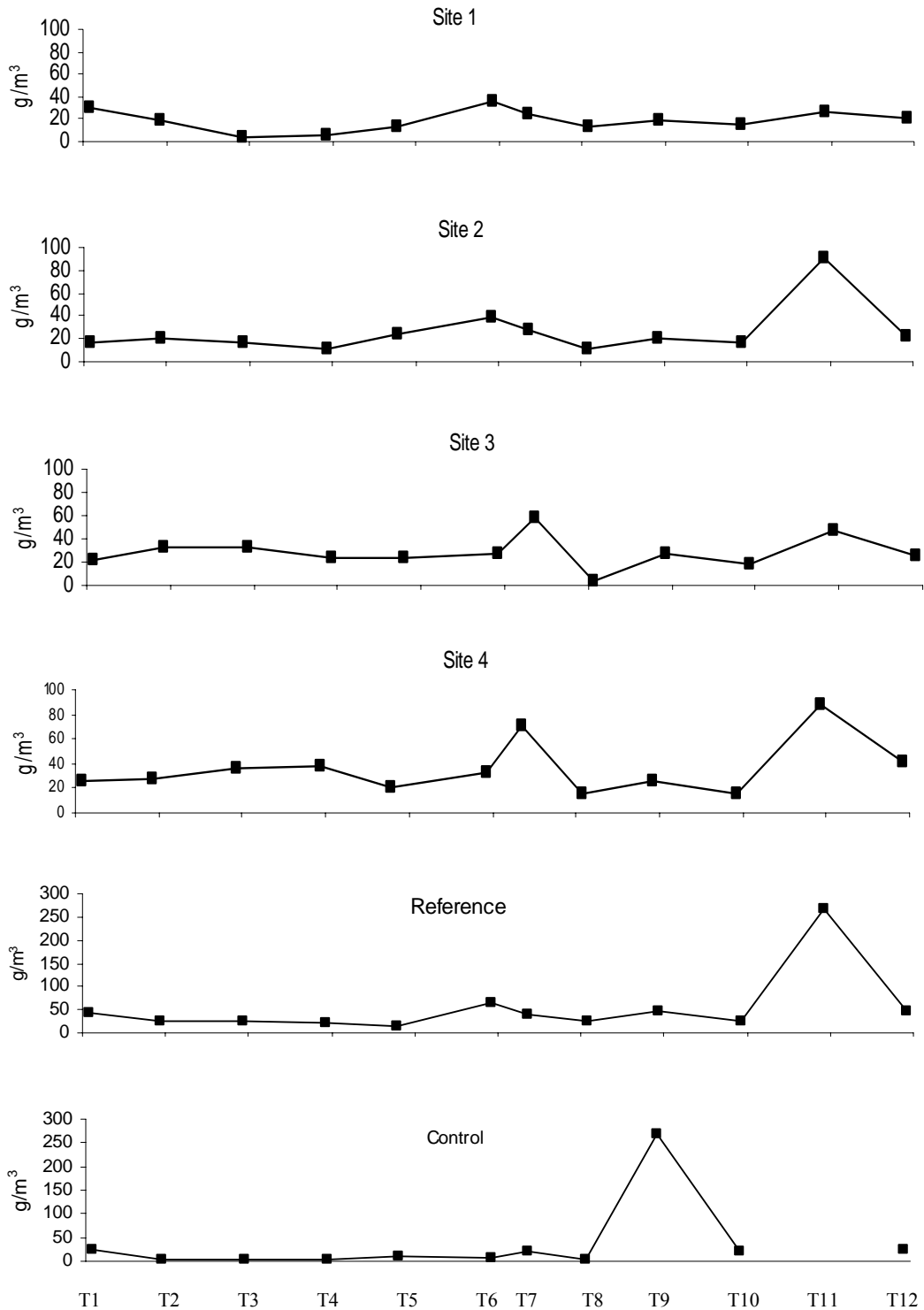
There was an increase in Total Suspended Solids (TSS) during the CRP event at all Mitta Mitta River sites supporting the hypothesis that sites would experience an increase in TSS during the CRP. TSS was at highest concentrations at sites 1 and 2 at the peak of the CRP (T6), and three days after the peak of the CRP (T7) TSS was high at sites 3 and 4 as the flow peak moved downstream (Figure 8). TSS levels decreased during the recession period at all sites, however this was more pronounced at sites 3 and 4. High levels of TSS in the water column were also recorded late in the sampling at sample time 11 as a result of the natural high flow event in Snowy Creek. This high level of TSS was also recorded at the reference sampling site on this date, but was not recorded at site 1 that did not experience this natural flow event. TSS levels at the control site on the Buffalo River remained low for the majority of the sampling period; although a high TSS level was recorded on T9, again following an increase in flow. These findings are also consistent with the findings of Sutherland *et al.* (2002) who studied a CRP in the Mitta Mitta River in 2001/2002.

#### **Summary of TSS results**

TSS increased at all sites in the Mitta Mitta River during the CRP event with a lag of three days at sites 3 and 4 further downstream. TSS decreased during the recession period particularly at sites 3 and 4 further downstream.



**Figure 7:** Water column concentrations ( $\text{g/m}^3$ ) of particulate organic matter (POM) at sites 1 to 4 on the Mitta Mitta River, a reference site on Snowy Creek and control site on the Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005. N.B. data at control site T11 not collected due to high flow.



**Figure 8:** Water column concentrations ( $\text{g/m}^3$ ) total suspended solids (TSS) at sites 1 to 4 on the Mitta Mitta River, a reference site on Snowy Creek and control site on the Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005. N.B. data at control site T11 not collected due to high flow.



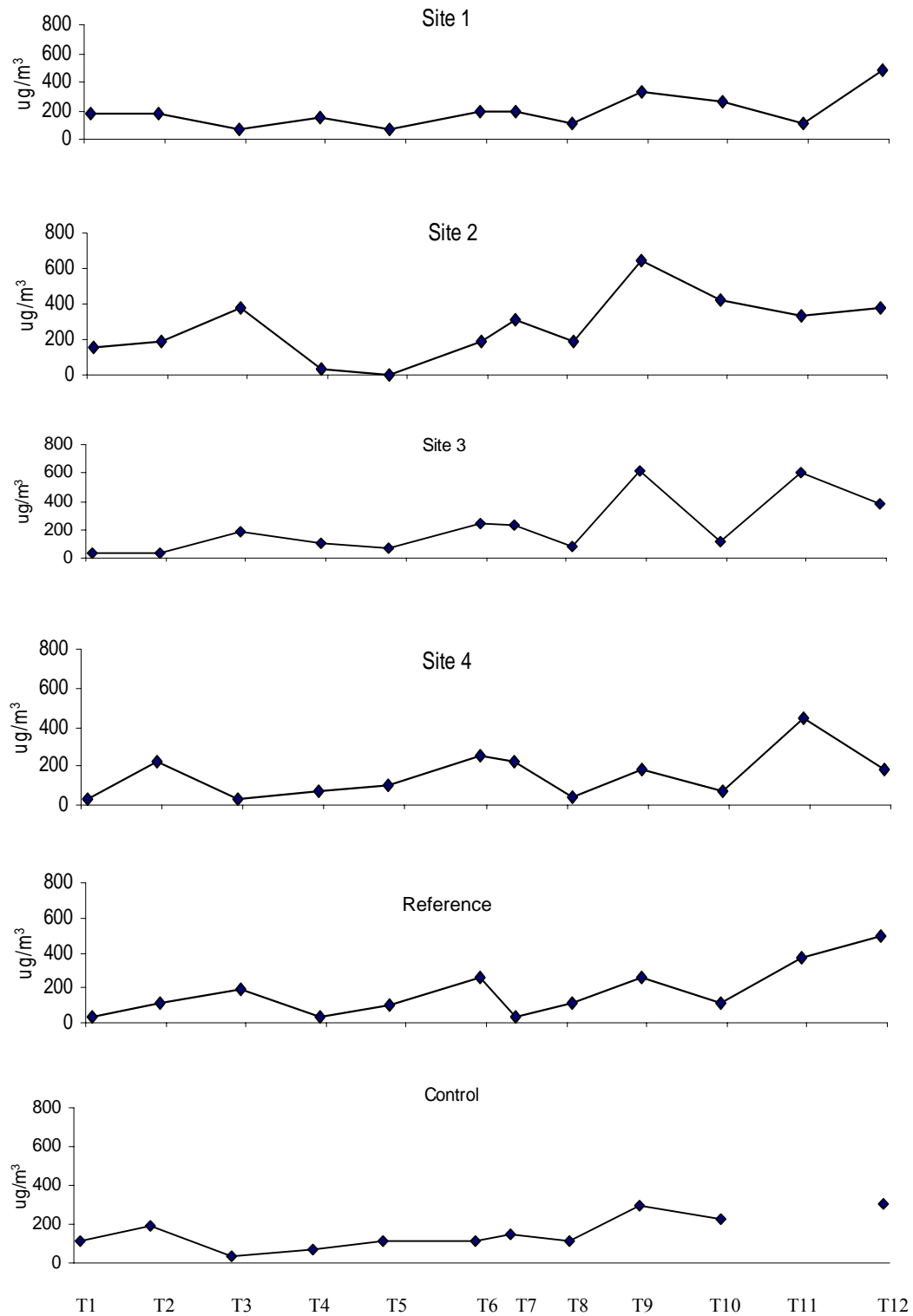
### *Chlorophyll a*

Chlorophyll *a* (Chl-*a*) concentrations were variable throughout the sampling period at all Mitta Mitta River sites, the highest concentration being 650µg/m<sup>3</sup> at site 2 at sample time 9 (Figure 9). Increases in Chl-*a* were recorded at all sites on the Mitta Mitta River during the CRP, and this was followed by a decrease in concentrations during the recession period. However, even higher concentrations of Chl-*a* were recorded at sites 2 and 3 coinciding with a rise in flow from the Snowy Creek between T9 and T10. Chl-*a* concentrations again decreased after this event. Site 3 and 4 on the Mitta Mitta River and the reference site again showed increases in Chl-*a* level at the beginning of a large natural flow event late during the constant flow period after the CRP (T11). Concentrations of Chl-*a* were more stable at the control site on the Buffalo River, however this site could not be sampled on the 03/02/2005 (T11) due to high discharge conditions.

The patterns observed in this study are consistent with the study of Sutherland *et al.* (2002). The increase in water column Chl-*a* during the CRP is most likely due to the entrapment of scoured benthic algae in the water column caused by increased flow velocity.

#### **Summary of Chlorophyll-*a* results**

Chl-*a* increased during the CRP and decreased during the recession period at all sites.



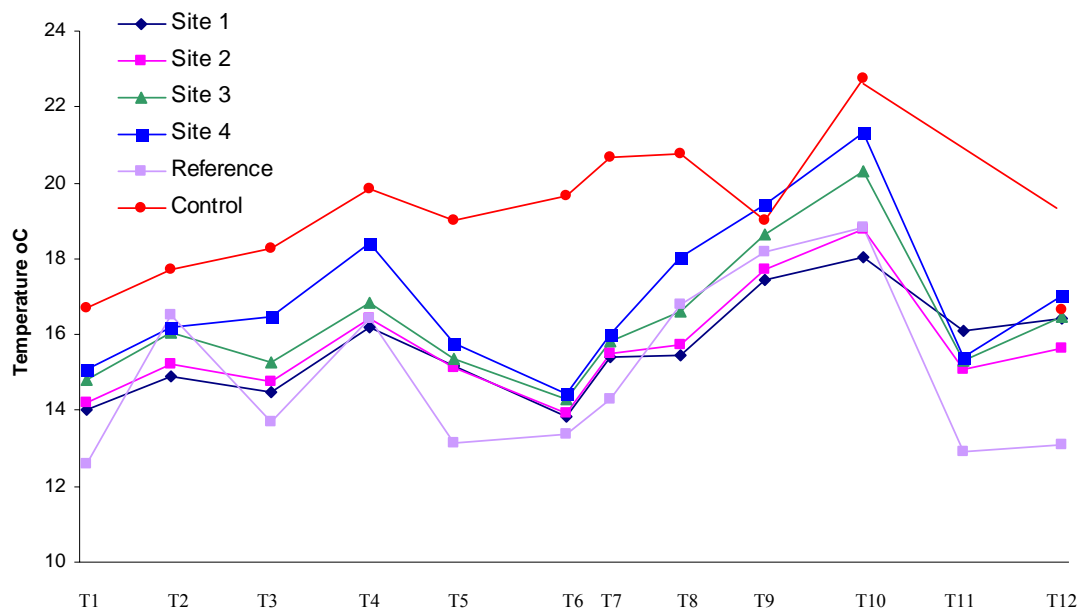
**Figure 9:** Water column concentrations ( $\mu\text{g}/\text{m}^3$ ) of Chlorophyll-*a* (Chl-*a*) at sites 1 to 4 on the Mitta Mitta River, a reference site on Snowy Creek and control site on the Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005. N.B. data at control site T11 not collected due to high flow.

### 3.2.1 HydroLab readings

Water temperature increased at all sites across the duration of the study (Figure 10). The release of water for the CRP decreased water temperatures up to 3°C between T5 and T6 at all sites in the Mitta Mitta River. Water temperatures increased after the cyclic release at all sites, but fell sharply at all sites (up to 6°C at site 4) between T10 and T11 (constant flow after the CRP) due to cooler atmospheric conditions. Water temperatures at the control site were higher than those recorded in the Mitta Mitta River and Snowy Creek.

#### Summary of temperature results

Water temperature decreased during the CRP and increased during the constant flow period after the CRP.

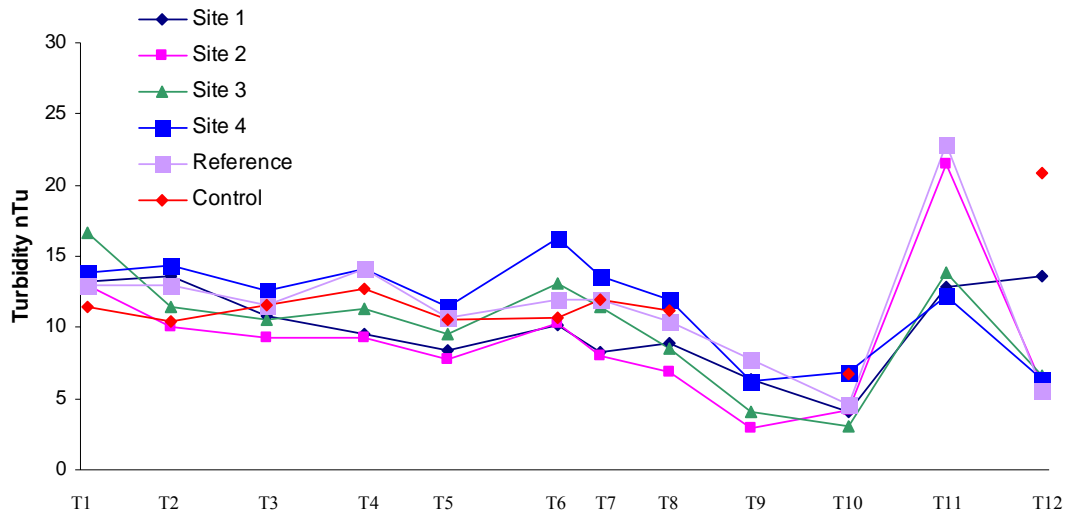


**Figure 10:** HydroLab water temperature data collected from at sites 1 to 4 on the Mitta Mitta River, a reference site on Snowy Creek and control site on the Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005.

Turbidity was relatively constant at all sites in the Mitta Mitta River during the constant flow period prior to the CRP. The turbidity increased slightly during the peak of the CRP and then decreased after the CRP (Figure 11). This increase was not observed at the reference or control site. A natural flow event after T11 resulted in increased turbidity at sites 2, 3 and 4 on the Mitta Mitta River downstream of the Snowy Creek confluence.

#### Summary of turbidity results

Turbidity was relatively constant throughout the constant flow period prior to the CRP. There was a slight increase during the peak of the CRP and then a decrease after the CRP.

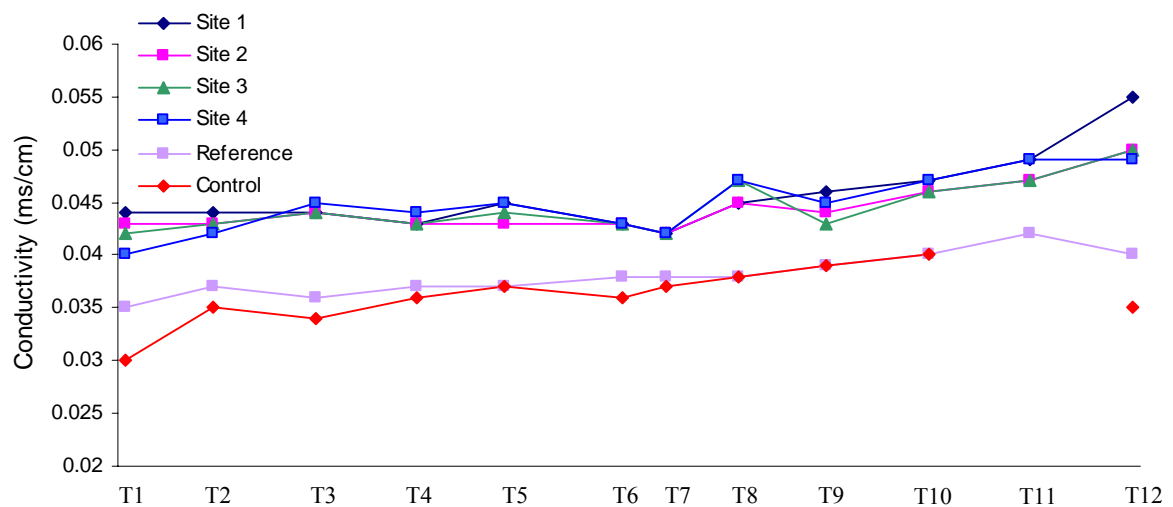


**Figure 11:** HydroLab turbidity data collected from at sites 1 to 4 on the Mitta Mitta River, a reference site on Snowy Creek and control site on Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005.

Water conductivity was relatively constant at all sites on the Mitta Mitta during the constant flow period prior to the CRP. At sampling time 6 and 7 during the CRP, conductivity decreased slightly and then increased at all sites following the CRP (Figure 12). A natural high flow event late in the sampling period resulted in decreased conductivity at the reference and control sites but not any sites in the Mitta Mitta River.

**Summary of conductivity results**

Conductivity decreased during the CRP and increased during the constant flow period after the CRP.

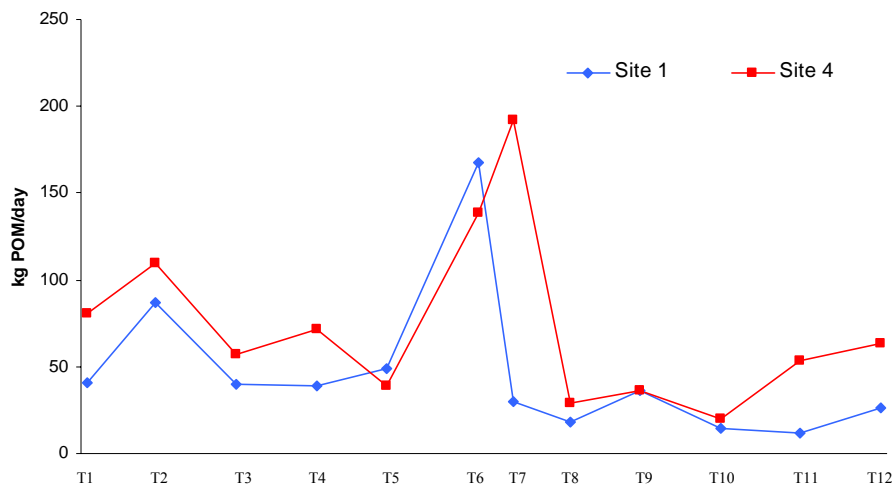


**Figure 12:** HydroLab conductivity data collected from at sites 1 to 4 on the Mitta Mitta River, a reference site on Snowy Creek and control site on Buffalo River.

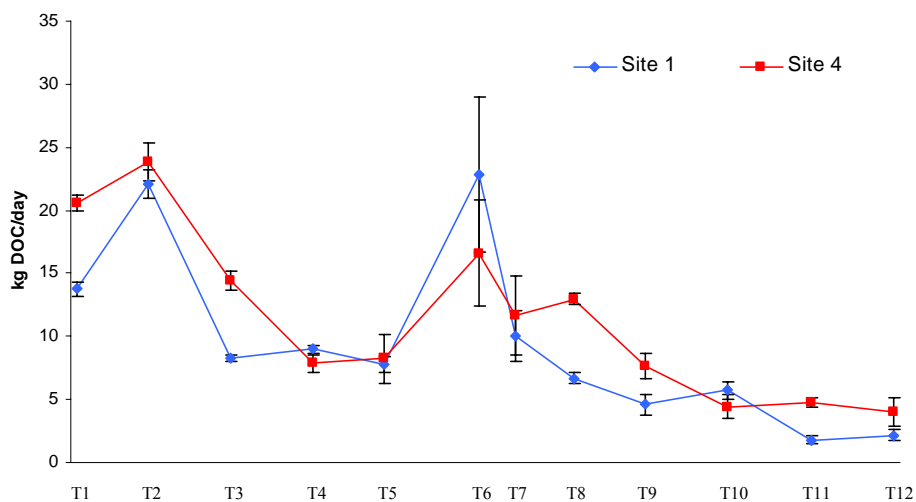
### 3.2.2 Particulate Organic Matter and Dissolved Organic Carbon loading

Water column loads of POM were consistently higher at site 4 throughout the sampling period, except for just before and during the peak of the CRP (T7) (Figure 13). The higher loads at site 4 suggest there are organic matter inputs from floodplain inundation or runoff from streams along the Mitta Mitta River so that POM accumulates in the water column. The water column loads of POM increased substantially during the CRP at site 1 and site 4, however these decreased as the flow levels receded.

Water column loads of DOC were similar between sites 1 and 4 (Figure 14). Initially DOC loads were around 15 to 25 kg/day through the study reach. These loads decreased as flow was reduced to a consistent 2000ml/day. DOC loads increased sharply with the CRP but decreased as flow levels receded and continued to fall over the remaining sampling period.

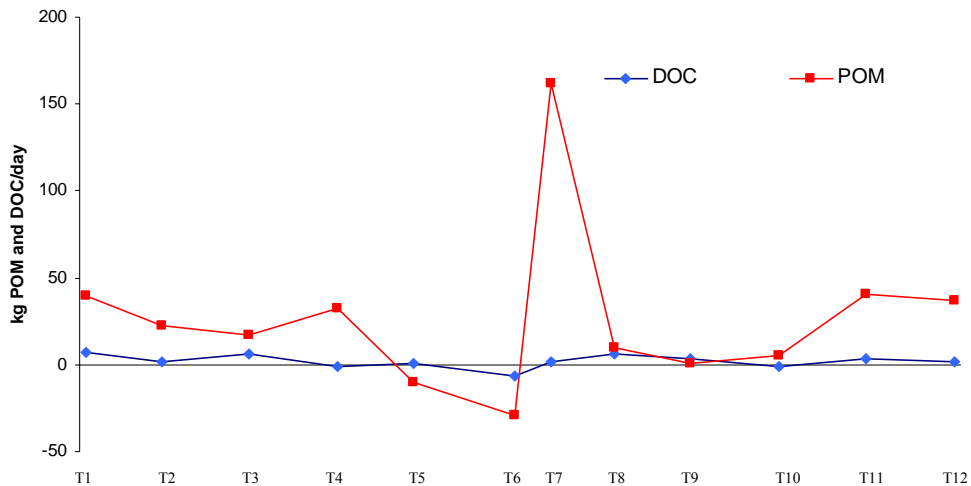


**Figure 13:** Mean loadings of POM per day at sites 1 and 4 on the Mitta Mitta River



**Figure 14:** Mean loadings of DOC per day at sites 1 and 4 on the Mitta Mitta River

The net gain of POM in the water column between sites 1 and 4 remained stable over the first four sampling dates (Figure 15). The net gain of POM became negative over the next two sampling dates but then increased sharply during the CRP. Net POM decreased following the CRP to close to zero until it increased again over the last two constant sampling periods. Net DOC remained low throughout the sampling period, but was however negative during the peak of the CRP.



**Figure 15:** A reach scale budget of POM and DOC between sites 1 and 4 on the Mitta Mitta River.

#### **Summary of POM and DOC loading results**

POM loading was higher at site 4 than site 1 in the Mitta Mitta River, whereas DOC loading was similar at site 1 and site 4 throughout the study. Both the POM and DOC loading increased during the CRP but decreased after the CRP.

### **3.3 Biofilm structure and taxonomic composition**

#### **Biofilm Structure Hypothesis**

Algal biomass (chlorophyll *a*) and total biomass (ash free dry weight) from cobble substrate will decrease following peak flows during the CRP compared to the biomass prior to the peak due to the scouring from increased velocity.

#### **3.3.1 Biofilm total, organic and algal biomass**

The biomass of permanently inundated biofilms did not display consistent trends among Mitta Mitta River sites throughout the CRP and constant flow periods (Figure 16). Dry weights ranged from 4.81 g/m<sup>2</sup> at site 1 during the peak of the CRP to 53.74 g/m<sup>2</sup> at site 4 during the constant flow period following the CRP. Biofilm dry weight decreased significantly on the peak of the CRP release (T5xT6, Table 3) at sites 2 ( $p=0.048^*$ ), 3

( $p=0.019^*$ ) and 4 ( $p=0.000^{***}$ ) on the Mitta Mitta River, resulting in a shift towards the biofilm biomass recorded at the reference site. This suggests there was scouring and sloughing of biofilms in response to the higher velocity flows of the CRP. Dry weights were lower at site 1 prior to the CRP and as such, a significant decrease was not recorded at this site on the peak of the CRP.

The dry weight at sites 3 and 4 increased significantly ( $p=0.001^{***}$  and  $p=0.003^{**}$  respectively) immediately following the peak of the CRP (T6xT7, Table 3) suggesting there was deposition of fine sediments during the lag of the flow release. At the reference site in Snowy Creek, biofilm dry weight was consistently less than that collected in the Mitta Mitta River and did not exceed  $5.11 \text{ g/m}^2$ . Dry weights recorded at the control site in the Buffalo River were low during the first half of the sampling period but then significantly increased after T7 (Figure 16).

#### **Summary of biofilm total biomass results**

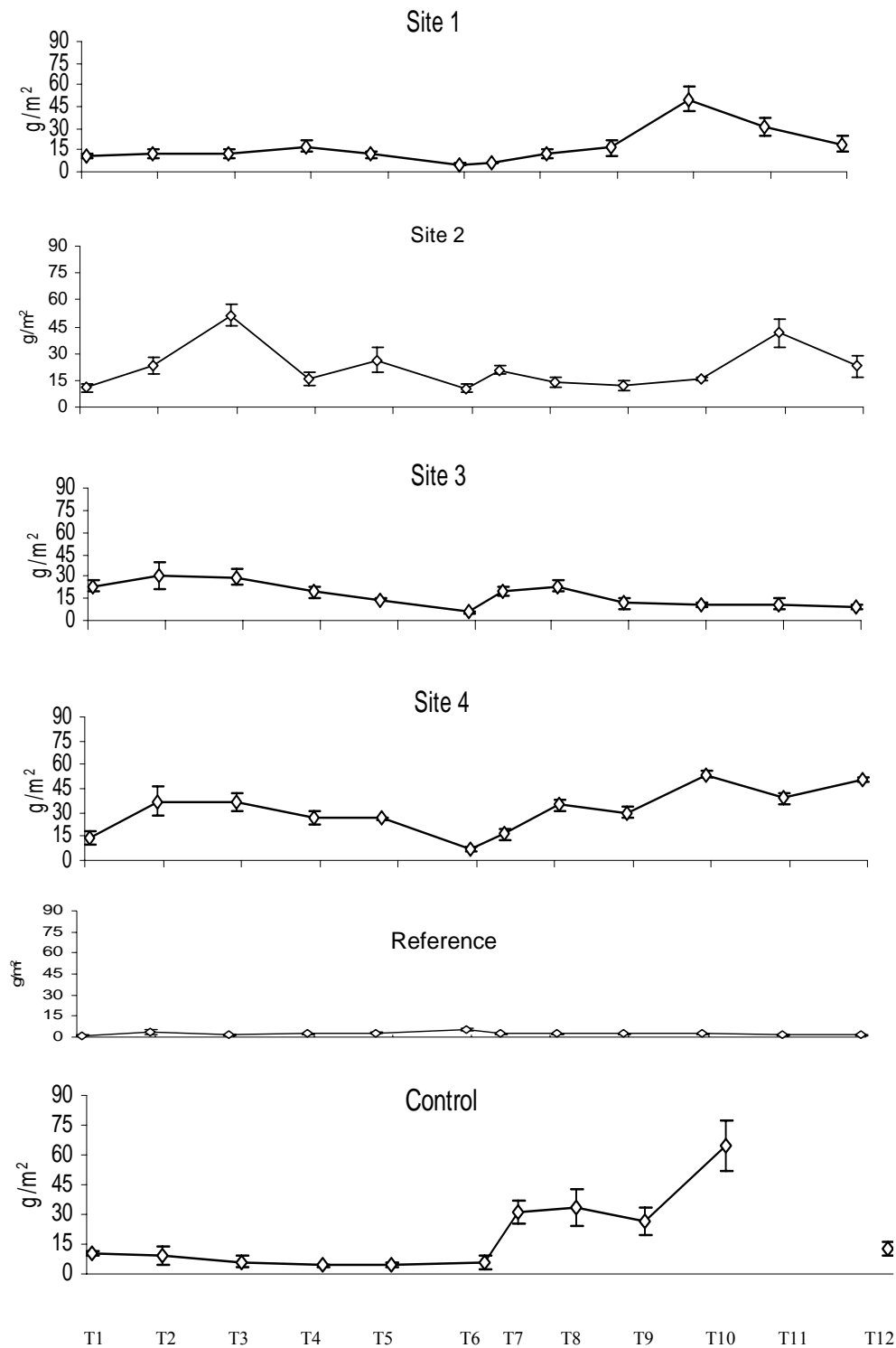
Biofilm dry weight decreased during the CRP at sites 2, 3 and 4 suggesting there was scouring and sloughing of biofilms during the CRP. Biofilm dry weight increased following the CRP with the onset of constant low flows suggesting there was deposition of fine sediments during the lag of the CRP releases.

The organic biomass of biofilms (ash free dry weights) recorded in the Mitta Mitta River sites ranged from  $2.26 \text{ g/m}^2$  at site 1 prior to the CRP to  $11.92 \text{ g/m}^2$  at site 2 prior to the CRP (Figure 17). Ash free dry weights at site 1 and 3 before the CRP remained relatively stable and were lower than at sites 2 and 4 at the onset of the CRP. Decreases in ash free dry weight were recorded at all sites on the Mitta Mitta River during the CRP (sample events 5 to 6) supporting the biofilm structure hypothesis, resulting in a shift towards lower levels of ash free dry weights recorded in the reference and control sites (Table 3). However, as ash free dry weights were initially at higher levels at site 2 and 4, the decrease was only significant at these sites ( $p=0.003^{**}$  and  $p=0.000^{***}$  respectively, Table 3).

At all sites on the Mitta Mitta River, organic biomass increased immediately after the CRP peak to weights similar to that recorded prior to the CRP (Table 3), again reflecting the settling of POM in the lag of the flow release. Biofilm organic biomass at the reference site in the Snowy Creek and at the control site in the Buffalo River were much lower than that of the Mitta Mitta River sites and remained relatively stable throughout the study period (Figure 17).

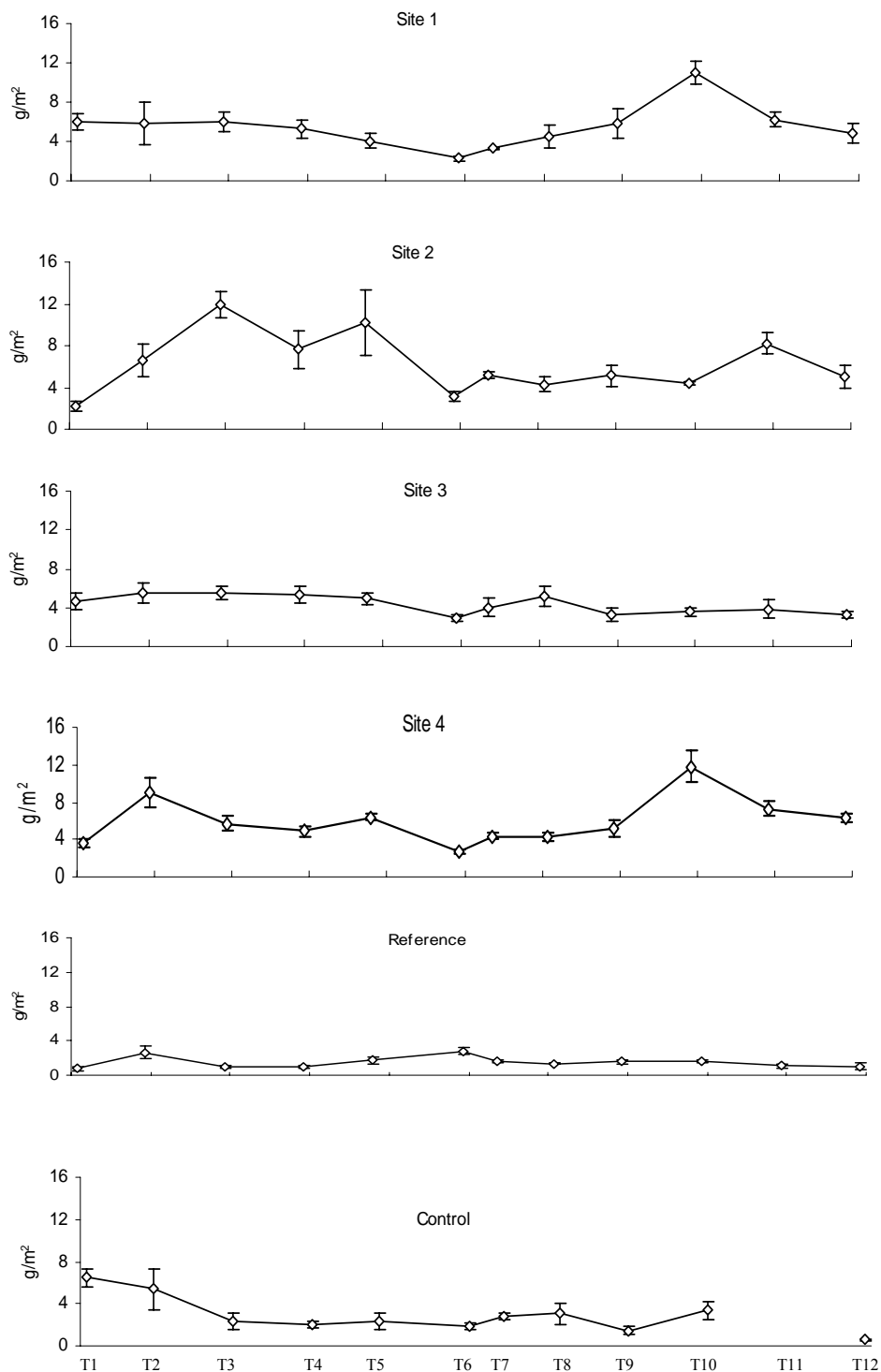
#### **Summary of biofilm organic biomass results**

The organic biomass of biofilms decreased in the Mitta Mitta River at the onset of the CRP and then increased after the peak of the CRP back towards levels recorded prior to the CRP. In contrast, the organic biomass of biofilms remained relatively stable in the reference stream throughout the study period.



**Figure 16:** Biofilm dry weight (g/m<sup>2</sup>) in permanently inundated cobble habitats at sites 1 to 4 on the Mitta Mitta River, site 5 on Snowy Creek (reference site) and control site on the Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005 (mean  $\pm$ SE, n=8). N.B. data at control site T11 not collected due to high flow.



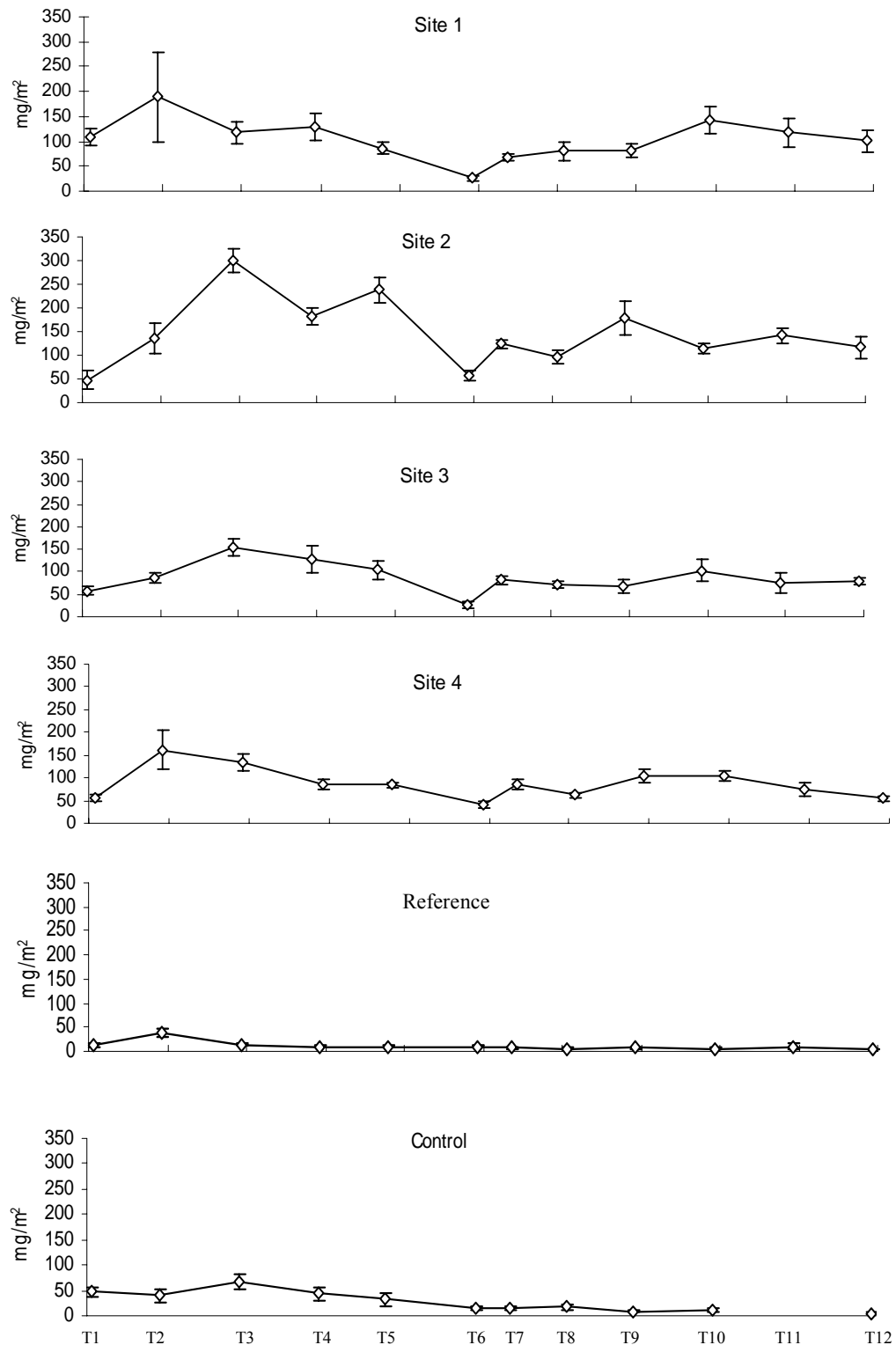


**Figure 17:** Biofilm ash free dry weight ( $\text{g/m}^2$ ) in permanently inundated cobble habitats at sites 1 to 4 on the Mitta Mitta River, reference site on Snowy Creek and control site on the Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005 (mean  $\pm$  SE,  $n=8$ ). N.B. data at control site T11 not collected due to high flow.

Similar to the other biomass estimates, the concentrations of Chlorophyll *a* (algal biomass) in permanently inundated biofilms in the Mitta Mitta River were highly variable, ranging from 27 mg/m<sup>2</sup> to 300 mg/m<sup>2</sup> (Figure 18). Algal biomass decreased significantly (p=0.002\*\*, p=0.000\*\*\*, p=0.000\*\*\* and p=0.002\*\* at sites 1-4 respectively) at all sites on the Mitta Mitta River at the onset of the CRP (T5 to T6) (Table 3) supporting the biofilm structure hypothesis, resulting in a shift towards levels of Chlorophyll-*a* recorded in the reference and control site. Chlorophyll *a* at all sites on the Mitta Mitta River increased immediately after the CRP peak to weights similar to that recorded prior to the CRP (Figure 18). Concentrations of Chl-*a* at the reference and control sites were consistently much lower than in the Mitta Mitta River.

**Summary of biofilm algal biomass (chlorophyll-*a*) results**

Biofilm chlorophyll-*a* decreased in the Mitta Mitta River at the onset of the CRP and then increased after the peak of the CRP back towards levels recorded prior to the CRP.



**Figure 18:** Biofilm chlorophyll *a* concentrations (mg/m<sup>2</sup>) in permanently inundated cobble habitats at sites 1 to 4 on the Mitta Mitta River, reference site on Snowy Creek and control site on the Buffalo River. Samples were taken on twelve sample dates from December 2004 to February 2005 (mean ± SE, n=8). N.B. data at control site T11 not collected due to high flow.

**Table 3:** Summary of results from Bonferroni post-hoc tests examining differences in biofilm attributes between sites between the last sample of the constant flow period prior to the CRP (T5) to the first sample during the constant flow after the CRP (T9). Asterisks represent statistically significant change between sample dates (\*\*\* p < 0.001, \*\* p < 0.01, \* p < 0.05, ns: not significant, arrows indicate the significant change between the dates). T5 = constant (before CRP), T6 = CRP (3rd day), T7 = CRP (6<sup>th</sup> day), T8 = CRP (14<sup>th</sup> day), T9 = constant (after CRP). ↑ indicates there was a significant increase in variable and ↓ indicates there was a significant decrease in the variable.

|       | Site 1      |          |            |          |             |             |             |            |          |           |            |
|-------|-------------|----------|------------|----------|-------------|-------------|-------------|------------|----------|-----------|------------|
|       | T5 x T6     | T5 x T7  | T5 x T8    | T5 X T9  | T6 x T7     | T6 x T8     | T6 x T9     | T7 x T8    | T7 X T9  | T8 x T9   | T9 x T11   |
| DW    | 0.264 ns    | 1.000 ns | 1.000 ns   | 1.000 ns | 1.000 ns    | 0.412 ns    | 0.096 ns    | 1.000 ns   | 0.479 ns | 1.000 ns  | 0.020* ↑   |
| AFDW  | 1.000 ns    | 1.000 ns | 1.000 ns   | 1.000 ns | 1.000 ns    | 0.958 ns    | 0.071 ns    | 1.000 ns   | 0.985 ns | 1.000 ns  | 0.562 ns   |
| Chl-a | 0.002 ** ↓  | 1.000 ns | 1.000 ns   | 1.000 ns | 0.001 *** ↑ | 0.043 * ↑   | 0.004 ** ↑  | 1.000 ns   | 1.000 ns | 1.000 ns  | 0.107 ns   |
|       | Site 2      |          |            |          |             |             |             |            |          |           |            |
|       | T5 x T6     | T5 x T7  | T5 x T8    | T5 X T9  | T6 x T7     | T6 x T8     | T6 x T9     | T7 x T8    | T7 X T9  | T8 x T9   | T9 x T11   |
| DW    | 0.048 * ↓   | 1.000 ns | 0.541 ns   | 0.170 ns | 0.138 ns    | 1.000 ns    | 1.000 ns    | 1.000 ns   | 0.439 ns | 1.000 ns  | 0.001*** ↑ |
| AFDW  | 0.003 ** ↓  | 0.536 ns | 0.062 ns   | 0.290 ns | 0.521 ns    | 1.000 ns    | 0.922 ns    | 1.000 ns   | 1.000 ns | 1.000 ns  | 0.083 ns   |
| Chl-a | 0.000 *** ↓ | 0.247 ns | 0.008 ** ↓ | 1.000 ns | 0.007 ** ↑  | 0.229 ns    | 0.000 *** ↑ | 1.000 ns   | 1.000 ns | 0.221 ns  | 0.583 ns   |
|       | Site 3      |          |            |          |             |             |             |            |          |           |            |
|       | T5 x T6     | T5 x T7  | T5 x T8    | T5 X T9  | T6 x T7     | T6 x T8     | T6 x T9     | T7 x T8    | T7 X T9  | T8 x T9   | T9 x T11   |
| DW    | 0.019 * ↓   | 1.000 ns | 1.000 ns   | 1.000 ns | 0.001 *** ↑ | 0.000 *** ↑ | 0.699 ns    | 1.000 ns   | 0.214 ns | 0.041 * ↓ | 0.641 ns   |
| AFDW  | 1.000 ns    | 0.560 ns | 1.000 ns   | 1.000 ns | 1.000 ns    | 1.000 ns    | 1.000 ns    | 0.322 ns   | 1.000 ns | 1.000 ns  | 0.640 ns   |
| Chl-a | 0.000 *** ↓ | 1.000 ns | 1.000 ns   | 1.000 ns | 0.001 *** ↑ | 0.003 ** ↑  | 0.015 * ↑   | 1.000 ns   | 1.000 ns | 1.000 ns  | 0.960 ns   |
|       | Site 4      |          |            |          |             |             |             |            |          |           |            |
|       | T5 x T6     | T5 x T7  | T5 x T8    | T5 X T9  | T6 x T7     | T6 x T8     | T6 x T9     | T7 x T8    | T7 X T9  | T8 x T9   | T9 x T11   |
| DW    | 0.000 *** ↓ | 0.084 ns | 1.000 ns   | 1.000 ns | 0.003 ** ↑  | 0.000 *** ↑ | 0.000 *** ↑ | 0.002 ** ↑ | 0.054 ns | 1.000 ns  | 0.172 ns   |
| AFDW  | 0.000 *** ↓ | 0.124 ns | 0.092 ns   | 0.551 ns | 0.107 ns    | 0.104 ns    | 0.020 * ↑   | 1.000 ns   | 1.000 ns | 1.000 ns  | 0.067 ns   |
| Chl-a | 0.002 ** ↓  | 1.000 ns | 0.931 ns   | 1.000 ns | 0.006 ** ↑  | 0.238 ns    | 0.000 *** ↑ | 1.000 ns   | 1.000 ns | 0.152 ns  | 0.088 ns   |

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|       |                |                |                | <b>Reference</b> |                |                |                |                |                |                |                 |  |
|-------|----------------|----------------|----------------|------------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|--|
|       | <b>T5 x T6</b> | <b>T5 x T7</b> | <b>T5 x T8</b> | <b>T5 X T9</b>   | <b>T6 x T7</b> | <b>T6 x T8</b> | <b>T6 x T9</b> | <b>T7 x T8</b> | <b>T7 X T9</b> | <b>T8 x T9</b> | <b>T9 x T11</b> |  |
| DW    | 0.008 ** ↑     | 1.000 ns       | 1.000 ns       | 1.000 ns         | 0.001 *** ↓    | 0.002 ** ↓     | 0.002 ** ↓     | 1.000 ns       | 1.000 ns       | 1.000 ns       | 0.082 ns        |  |
| AFDW  | 0.091 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns         | 0.101 ns       | 0.085 ns       | 0.058 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       | 0.145 ns        |  |
| Chl-a | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns         | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       | 0.708 ns        |  |
|       |                |                |                |                  |                |                |                |                |                |                |                 |  |
|       |                |                |                | <b>Control</b>   |                |                |                |                |                |                |                 |  |
|       | <b>T5 x T6</b> | <b>T5 x T7</b> | <b>T5 x T8</b> | <b>T5 X T9</b>   | <b>T6 x T7</b> | <b>T6 x T8</b> | <b>T6 x T9</b> | <b>T7 x T8</b> | <b>T7 X T9</b> | <b>T8 x T9</b> | <b>T9 x T11</b> |  |
| DW    | 1.000 ns       | 0.001 *** ↑    | 0.001 *** ↑    | 0.004 ** ↑       | 0.001 *** ↑    | 0.001 *** ↑    | 0.004 ** ↑     | 1.000 ns       | 1.000 ns       | 1.000 ns       |                 |  |
| AFDW  | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns         | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       | 0.432 ns       | 0.881 ns       |                 |  |
| Chl-a | 1.000 ns       | 1.000 ns       | 1.000 ns       | 0.306 ns         | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       | 1.000 ns       |                 |  |

### 3.3.2 Biofilm algal species composition

#### **Biofilm taxonomic composition hypothesis**

Peak flows will change the community composition of algal biofilm and promote early successional algal taxa on cobble substrata due to scouring from increased velocity

Fifty eight algal taxa were identified from the Mitta Mitta River, control and reference sites during the study period (Appendix 2). Taxa included 34 Bacilariophytes (diatoms), 14 Chlorophytes (green algae), 9 filamentous Cyanobacteria (blue-green algae) and one Rhodophyte (red algae) (Appendix 2). Green algae dominated the overall biovolume of most biofilms when present, comprising up to 97 percent in the samples from the Mitta during flows pre- and -post CRP (Figure 19). The Genus *Ulothrix* alone formed 97 percent of the biovolume of samples from sites 1 and 4 during non-CRP flows. Four green taxa (*Drapnaldia*, *Spondylosium*, *Oedogonium* sp. 2 and *Bulbocheate*), one cyanobacteria (*Gleotrichia*) and three diatom taxa (*Aulocoseira granulata*, *Fragilaria constuens* and *Nitzschia* sp. 2) were unique to the Mitta Mitta River, all with <10 percent occurrence. No taxa were unique to Buffalo or Snowy Creeks. Taxa which had >40 percent occurrence were *Audounella* (Rhodophyte), *Ulothrix* (Chlorophyte), *Stigeoclonium* (Chlorophyte), *Achnantheidium minitissimum* (Bacilariophyte), *Cymbella* (Bacilariophyte), *Encynema silasiacum* (Bacilariophyte), *Tabellaria flocculosa* (Bacilariophyte), *Synedra ulna* (Bacilariophyte), and *Planothidium* (Bacilariophyte). The cosmopolitan diatom *Fragilaria capucina* had >90 percent occurrence of all diatoms across all sites and sample times.

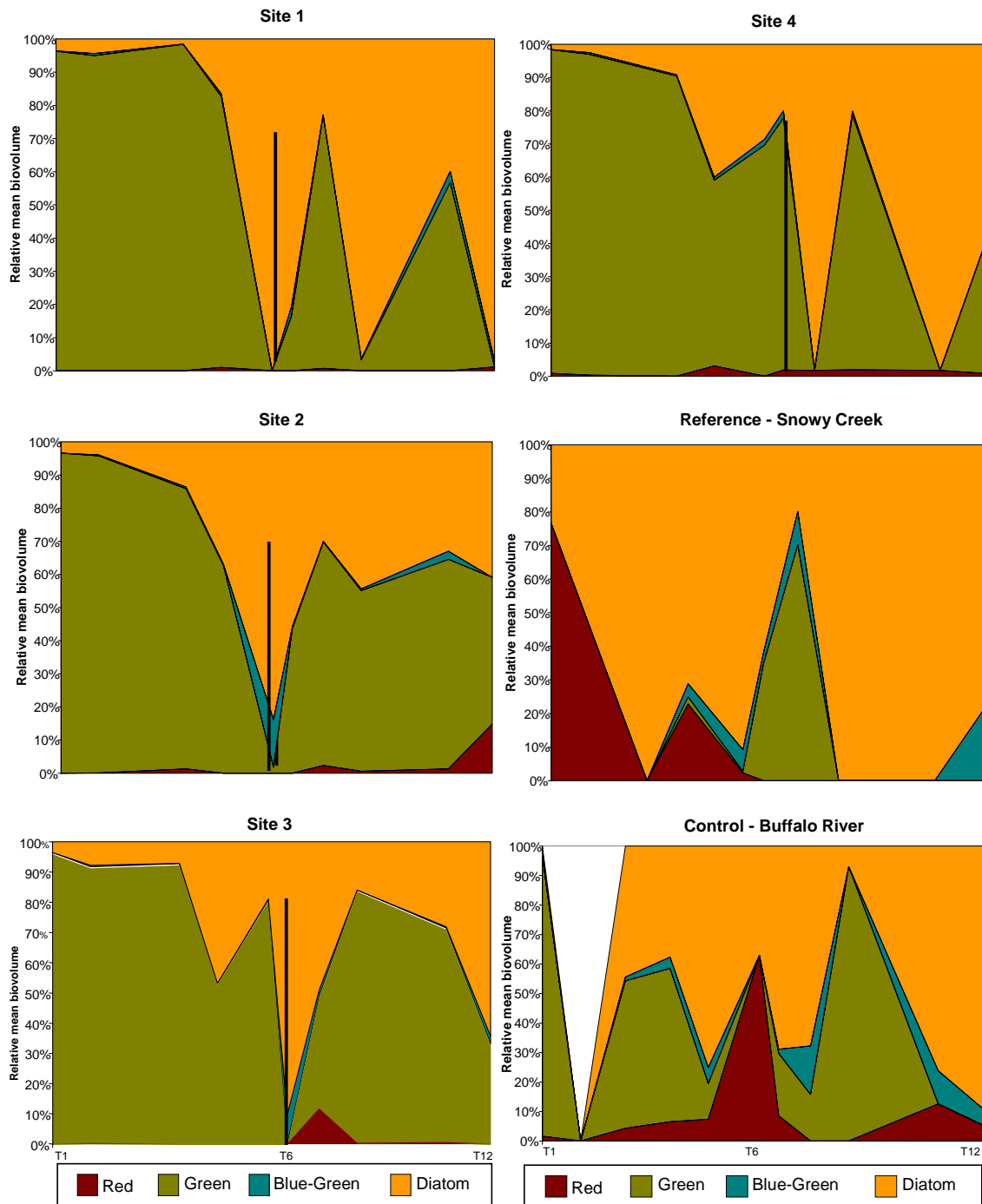
Mean species richness from all sites peaked at 21.25 (sd 0.5: n=4) at site 1 during the third constant flow sample after the CRP (T12) (Table 4). No algae were present in the biofilms at Buffalo River during the second sample of the constant flow prior to the CRP (in the Mitta Mitta River) (T2) (Table 4).

Species richness was significantly different between sites (F 7.35<sub>5,103</sub> P<0.001) with the reference, control and site 1 having significantly more species than the other sites. Similarly, there was a significant difference in species richness among sample dates (F 15.45<sub>10,103</sub> P<0.001), with the sample dates on the peak and recession of the CRP (T6, T7, T8) having similar, and lower species richness.

**Table 4:** Mean algal species richness (mean  $\pm$  s.e.) for the sample sites during the period December 2004 to February 2005.

| Sample Event | Discharge period | Site 1          | Site 2          | Site 3          | Site 4          | Reference       | Control         |
|--------------|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| (T1)         | reducing         | 11.75 $\pm$ 1.7 | 12.33 $\pm$ 2.1 | 15.00 $\pm$ 0.0 | 13.25 $\pm$ 2.1 | 8.00 $\pm$ 1.4  | 8.00 $\pm$ 1.4  |
| (T2)         | reducing         | 9.25 $\pm$ 0.5  | 12.67 $\pm$ 1.4 | 18.00 $\pm$ 2.4 | 13.25 $\pm$ 0.5 | 5.00 $\pm$ 0.8  | 5.00 $\pm$ 0.8  |
| (T3)         | constant         | 10.00 $\pm$ 2.1 | 9.50 $\pm$ 2.1  | 7.25 $\pm$ 0.9  | 8.50 $\pm$ 1.0  | 8.25 $\pm$ 0.9  | 8.25 $\pm$ 0.9  |
| (T4)         | constant         | 9.75 $\pm$ 0.5  | 15.50 $\pm$ 2.8 | 17.50 $\pm$ 0.5 | 14.00 $\pm$ 1.8 | 12.75 $\pm$ 0.5 | 12.75 $\pm$ 0.5 |
| (T5)         | constant         | 17.25 $\pm$ 3.3 | 16.00 $\pm$ 2.0 | 15.50 $\pm$ 1.3 | 14.20 $\pm$ 3.0 | 12.50 $\pm$ 2.8 | 12.50 $\pm$ 2.8 |
| (T6)         | CRP              | 8.25 $\pm$ 1.2  | 15.50 $\pm$ 0.5 | 6.00 $\pm$ 3.3  | 19.00 $\pm$ 3.4 | 11.00 $\pm$ 4.6 | 11.00 $\pm$ 4.6 |
| (T7)         | CRP              | 11.75 $\pm$ 0.9 | 17.75 $\pm$ 2.2 | 16.00 $\pm$ 1.8 | 12.75 $\pm$ 3.3 | 12.50 $\pm$ 3.1 | 12.50 $\pm$ 3.1 |
| (T8)         | CRP              | 11.00 $\pm$ 0.8 | 17.75 $\pm$ 2.2 | 14.00 $\pm$ 3.1 | 19.25 $\pm$ 1.5 | 12.75 $\pm$ 1.5 | 12.75 $\pm$ 1.5 |
| (T9)         | reducing         | 10.75 $\pm$ 0.5 | 15.00 $\pm$ 1.4 | 15.75 $\pm$ 1.5 | 17.25 $\pm$ 2.2 | 10.25 $\pm$ 0.5 | 10.25 $\pm$ 0.5 |
| (T11)        | constant         | 21.25 $\pm$ 0.5 | 19.00 $\pm$ 2.0 | 16.75 $\pm$ 0.5 | 17.75 $\pm$ 3.8 | 13.00 $\pm$ 2.3 | 13.00 $\pm$ 2.3 |
| (T12)        | constant         | 14.00 $\pm$ 0.0 | 15.75 $\pm$ 0.5 | 11.25 $\pm$ 2.6 | 17.25 $\pm$ 0.5 | 8.00 $\pm$ 0.0  | 8.00 $\pm$ 0.0  |

The green algae dominated the relative biovolume of the biofilms at all the Mitta sites (Figure 19), but were scoured from the rocks by high flows at sites 1 and 2 at peak CRP flows (T6), at site 3 during the second sample (6<sup>th</sup> day) of the CRP (T7) and site 4 during the last sample (14<sup>th</sup> day) of the CRP (T8)) as the flow peak progressed downstream (Figure 19). In post-CRP algal communities, diatoms formed >95 percent of the biofilm. At site 1 the relative abundance of green algae was also reduced substantially at the third constant flow sample after the CRP (T12), also occurring during an increase in river flows (from Snowy Creek). In contrast, the red algae (*Audouenella*) fluctuated in relative abundance at Snowy Creek from 22 – 74 percent during December 2004 and early January 2005, briefly being replaced by the green algae (*Oedogonium* and *Stigeoclonium*) on the last sample (14<sup>th</sup> day) of the CRP (T8) before a dominance by the diatoms for the remaining sampling period (Figure 19). The green algae, red algae and diatoms fluctuated widely in their relative dominance of >50 percent, in Buffalo River during the sampling period. The biofilms in Buffalo River were completely scoured on T2 after a 95 percent dominance of the green algae, *Ulothrix zonata* earlier that month.

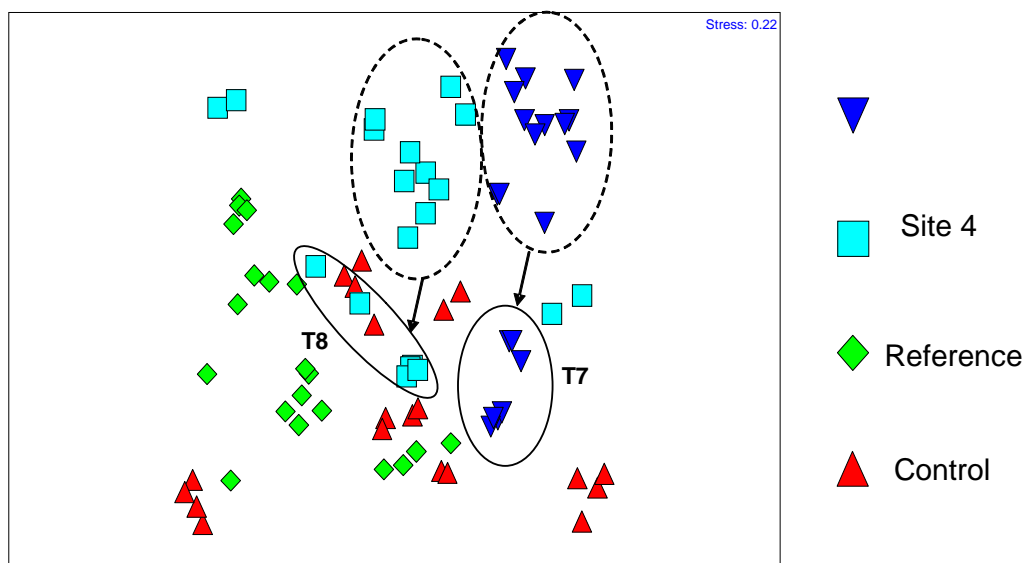


**Figure 19:** Relative percent abundance (as biovolume) of algal divisions from sites 1-4 (Mitta Mitta River) and reference and control sites (n=4). The Cyclic Release Pattern, released on the 4/01/2005 is represented by the black line.



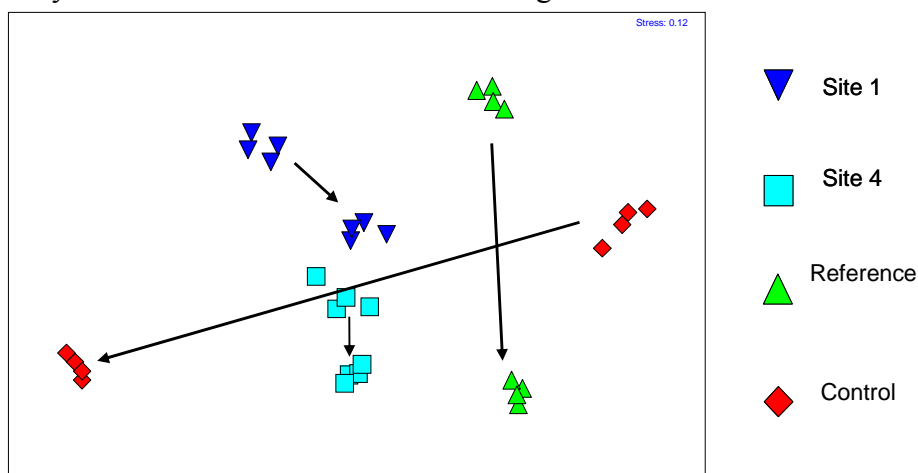
An multidimensional scaling (MDS) ordination of the relative abundance of all algal taxa with an occurrence over 5 percent was calculated for sites 1 and 4 on the Mitta Mitta and Buffalo Rivers and Snowy Creek for sample dates immediately before and during the CRP (T5, 6, 7, 8 & 9). Site 1 forms a separate group to the reference site, and only overlaps site 4 and the control site during peak flows (Figure 20). Similarly, site 4 forms a cohesive group except for during the recession of the CRP in sampling event 8. In figure 20, sample dates from site 1 moved from the dashed ellipsoid to the solid ellipsoid during the CRP peak on T7. Similar to the delay in the loss of biovolume of Green algae, sample dates from site 4 move from the dashed ellipsoid to the solid ellipsoid after the CRP peak on T8. Snowy Creek forms a separate group from the Mitta Mitta sites and overlaps with the control site on the Buffalo River. The samples from Buffalo River group with sampled from the Mitta Mitta River collected during the flood peak and recession, when there was low relative abundance of green algae.

These results suggest that the species composition of algal biofilms in the Mitta sites 1 and 4 became more similar to the reference sites during the peak flows of the CRP. This supports the hypothesis that peak flows will change the community composition of algal biofilm and promote early successional algal taxa on cobble substrate due to scouring from increased velocity.



**Figure 20:** MDS ordination plot of relative abundance of algal taxa from the Mitta River sites 1 and 4, and the control and reference sites between the last sampling date of the constant flow prior to the CRP (T5) and the first constant flow after the CRP (T9) (n = 4). Sample dates from site 1 move from the dashed ellipsoid to the solid ellipsoid during the flood peak on the second sample during the CRP (T7). Sample dates from site 4 move from the dashed ellipsoid to the solid ellipsoid after the CRP peak on the last sample date of the CRP (T8).

A flow peak in the control, reference and Mitta site 4 occurred in early February 2005 due to a natural rainfall event (i.e. not a dam release). The absence of these flows at site 1 on the Mitta Mitta River provided an opportunity to examine the potential changes associated with a second flow peak. The MDS shows two cohesive groups for each site, each representing the algal community on the last two sampling dates of the second constant flow period (T11 and T12 respectively). The control site forms 2 cohesive groups separated along Axis 1 before and after peak flows. Both site 1 and the reference site show cohesive groupings along Axis 2, before and after peak flows, site 4 shows reduced separation and did not experience a change in flow regime at this time (Arrows show direction of change from T11 to T12) (Figure 21). This suggests there are two processes at work; there was a shift in species at site 1 towards the reference as a result of recolonisation processes, and there was a shift toward the reference by site 4 as a result of a second scouring event.



**Figure 21:** MDS ordination plot of relative abundance of algal taxa from the Mitta River sites 1 and 4, and the control and reference sites between the last two sample dates of the second constant flow period (T11 and T12), 2005. (n = 4). Arrows show direction of change from T11 to T12.

#### **Summary of biofilm algal species taxonomic composition results**

- Diatoms were the most commonly occurring taxa;
- Filamentous green algae were the most abundant by volume and were scoured from cobble during the CRP;
- Species richness was significantly different between sites, with more species at the reference, control and site 1; and
- There was significantly lower species richness on the peak and recession of the CRP. The CRP shifted the biofilms from filamentous green dominated to ones dominated by early successional diatoms.
- Species composition of algal biofilms in the Mitta Mitta River sites 1 and 4 became more similar to the reference site during the peak flows of the CRP.

### **3.4 Benthic macroinvertebrates**

#### **Benthic macroinvertebrate hypothesis**

The CRP will alter the biofilm biomass and biofilm community composition on cobble substrata and this will result in a higher diversity of benthic macroinvertebrates and an increase in the proportion of sensitive taxa (as measured by the SIGNAL-2 Index) in cobble habitats following the CRP.

Over 25,000 individuals representing thirty-seven macroinvertebrate taxa were identified from Snowy Creek, Buffalo River and sites 1 and 4 in the Mitta Mitta River over 6 sample dates (T4 and T5 prior to the CRP, T7 during the CRP, and T9, T11 and T12 after the CRP). This included ten trichopteran (caddis fly) families, four ephemeropteran (mayfly) families, and eight dipteran (fly) families. The dominant taxa were Chironomidae fly larvae (6584 individuals), Oligochaete worms (4762 individuals), Simuliidae fly larvae (4292 individuals), Hydropsychidae caddisfly larvae (2616 individuals), Baetidae mayfly larvae (1873 individuals) and Leptophlebiidae mayfly nymphs (1202 individuals).

#### **3.4.1 Benthic macroinvertebrate community composition**

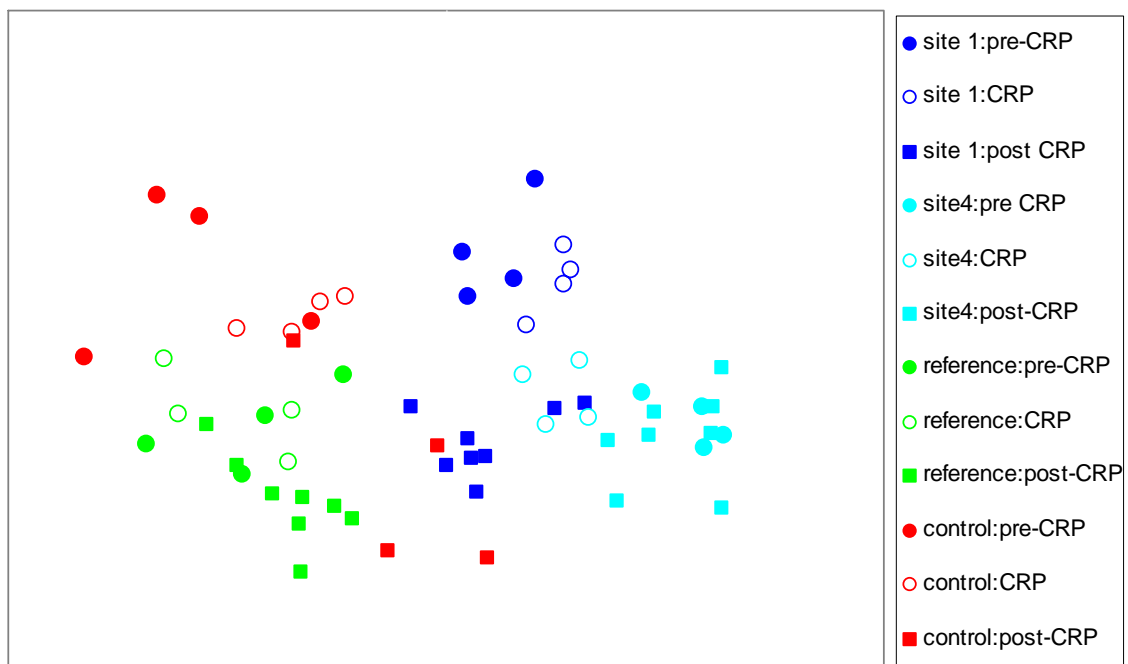
The four sites that were examined for benthic macroinvertebrates (sites 1, 4, reference and control) had a significantly different community composition in the constant flow period prior to the CRP release (T5) (Global R 0.870,  $P < 0.001$ ), during the CRP (T7) (Global R 0.879,  $P < 0.001$ ) and in the constant flow period after the CRP (T9, T11) (R 0.902,  $p < 0.001$ ) (Figure 22). Site 1 was dominated by oligochaete worms, hydropsychid caddisfly larvae, simuliid fly larvae and chironomid fly larvae. Site 4 was dominated by chironomids, oligochaetes and hydropsychids. In contrast, the Snowy Creek reference site was characterised by simuliids, baetid mayfly nymphs, leptophlebiid mayfly nymphs and glossosomatid caddisfly larvae. The Buffalo River control site was characterised by simuliids, baetids, chironomids and hydropsychids (Appendix 3).

The similarities and differences between the macroinvertebrate communities at the four sites prior to the CRP (T5), during the CRP (T7) and post-CRP (T9, T11) are represented in Figure 22. Samples that plot closer together in the ordination have a more similar community composition.

The community composition of the benthic invertebrates at site 1 changed over time in response to the CRP. The community composition at site 1 prior to the CRP (T5) differed significantly from the samples collected during the CRP release (T7) (global R 0.688,  $P < 0.05$ ) becoming more similar to the community composition at site 4

(Figure 22). However, the biggest shift in community composition at site 1 occurred after the CRP, suggesting that there is a delay in the response of the macroinvertebrate community to a CRP flow event. The community composition at site 1 became more similar to the reference condition following the CRP release (T9, T11), however the composition of site 1 and the reference site were still significantly different at this time (Global R 0.964,  $P < 0.001$ ). This shift was due to an increase in the abundance of taxa such as conoesucid, hydropsychid and glossosomatid caddisfly larvae, leptophlebiid, baetid and coloburiscid mayfly nymphs and simuliid fly larvae at site 1.

The response of the macroinvertebrate community composition to the CRP was not as evident at site 4 further downstream in the Mitta Mitta River. The community composition at site 4 became more similar to the reference condition during the CRP release (T7) (Figure 22). However, this shift in community composition at site 4 was not sustained. After the CRP event the community composition at site 4 reverted back and was similar to the community composition at that site prior to the CRP (T5). The community composition at site 4 during the CRP release (T7) differed significantly from the samples collected at this site prior to the CRP (T5) (global R 0.875,  $P < 0.05$ ) and those collected in the period after the CRP (T9, T11) (global R 0.722,  $P < 0.001$ ).



**Figure 22:** MDS ordination plot of macroinvertebrate community composition from the Mitta River sites 1 and 4, and the control and reference sites for prior to the CRP (T5), during the CRP (T7) and post-CRP (T9, T11).

### 3.4.2 Benthic macroinvertebrate indices

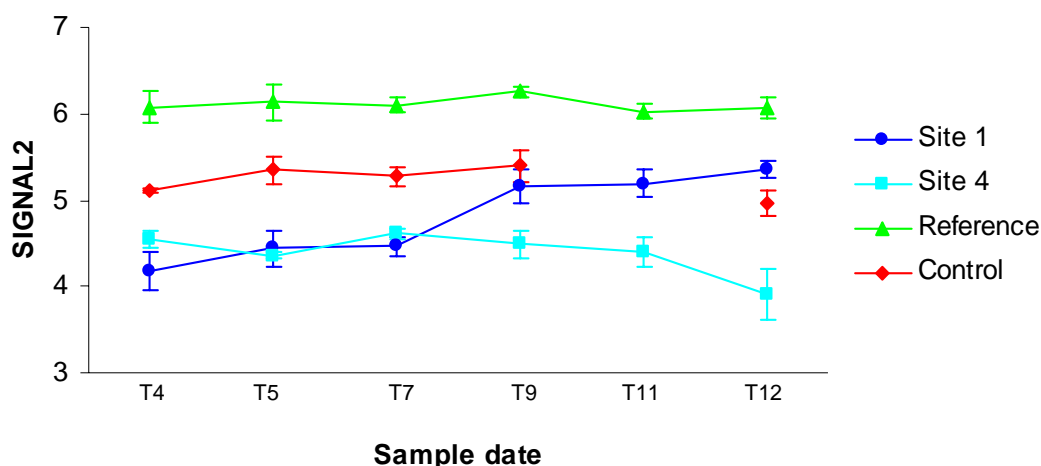
Temporal changes in four macroinvertebrate indices (SIGNAL-2 index, number of taxa, number of oligochaetes and number of chironomids) were examined for sites 1, 4, the reference and control (Table 5, Figures 23-26) for sample dates T4 and T5 (prior to CRP), T7 (during CRP) and T9, T11 and T12 (post CRP). The reference site did not change over the six sample dates for any of the four variables (Table 5). Thus, any difference observed between pre- and post-CRP samples at sites 1 and 4 in the Mitta Mitta River can be attributed to the CRP event.

**Table 5:** P values and significance of GLM's comparing the SIGNAL-2 index, number of families, number of oligochaetes and number of chironomids across 6 sample dates (T4,T5, T7, T9, T11, T12) for two sites in the Mitta Mitta River (site 1 and site 4), Snowy Creek (reference) and Buffalo River (control). (\* p<0.05, \*\* p<0.01, \*\*\*p<0.001, ns is not significant).

|                    | Site1     | Site 4   | Reference | Control  |
|--------------------|-----------|----------|-----------|----------|
| SIGNAL-2 Index     | 0.000 *** | 0.080 ns | 0.893 ns  | 0.188 ns |
| Number of taxa     | 0.000 *** | 0.012*   | 0.194 ns  | 0.002 ** |
| Number Oligochaeta | 0.001 **  | 0.000*** | 0.323 ns  | 0.129 ns |
| Number Chironomids | 0.108 ns  | 0.018*   | 0.240 ns  | 0.122 ns |

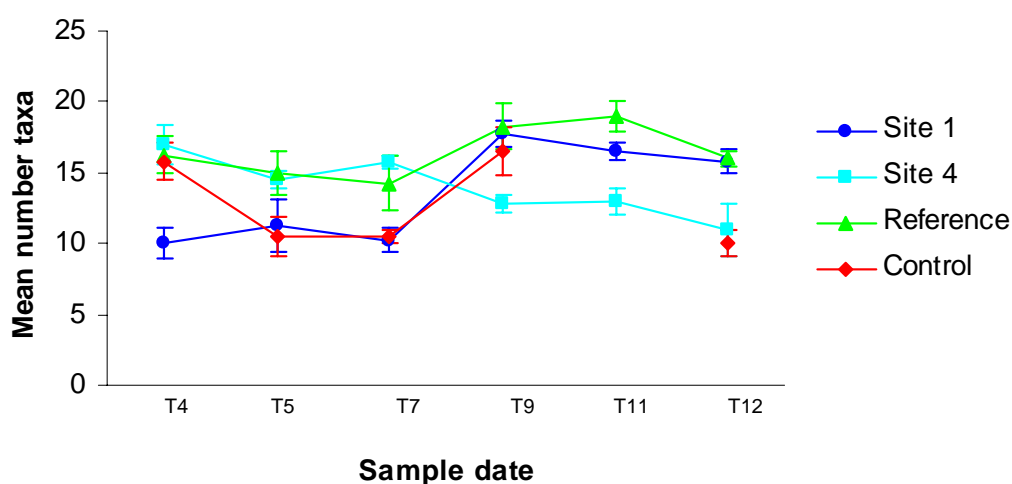
The SIGNAL-2 index (Chessman 2003) gives an indication of the water quality of the river from which the sample of macroinvertebrates was collected. It can provide an indication of the types of pollution and other physical and chemical factors that are affecting the macroinvertebrate community. Sites with a higher SIGNAL-2 score are generally considered to be in better condition than those with a lower score.

Sites 1 and 4 in the Mitta Mitta River had a lower SIGNAL-2 index than the reference or the control prior to the CRP (T4, T5)(Figure 23), indicating that at that time the reference and control contained more sensitive macroinvertebrate families than the Mitta Mitta River sites. After the CRP release (T9, T11, T12) there was a significant increase in the SIGNAL-2 index at site 1, indicating an improvement in ecosystem health at this site. This finding is consistent with the hypothesis that there will be an increase in the proportion of sensitive taxa in cobble habitats following the CRP. These results are also consistent with the findings of Sutherland *et al.* (2002) who observed increased SIGNAL scores at site 1 following a CRP in 2001. The SIGNAL2 index for site 1 at T9, T10 and T11 was still significantly lower than that in Snowy Creek. This suggests that some sensitive taxa that occur in the reference river had not colonised site 4 by the end of the study period. In contrast, all of the other sites showed no difference in SIGNAL-2 between sample dates. The absence of a response at site 4 suggests that effect of the CRP was attenuated between site 1 and site 4.



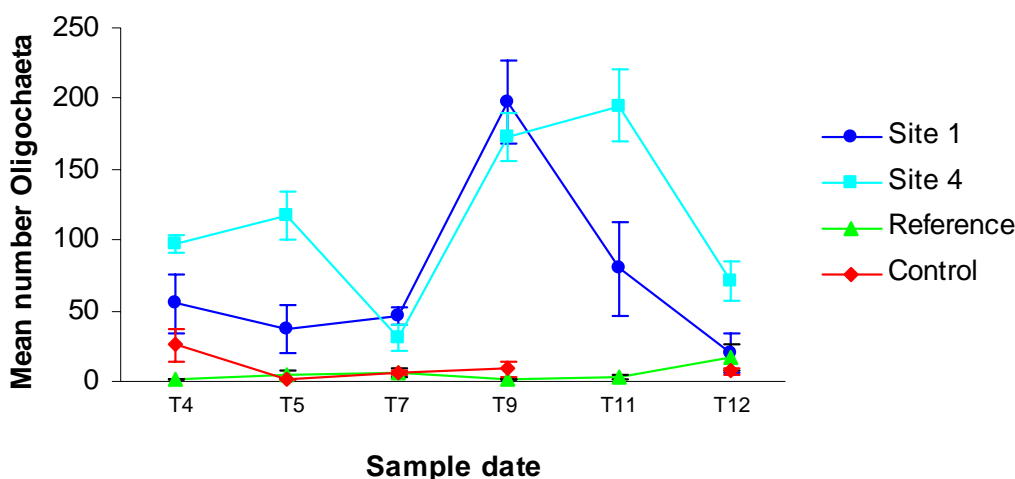
**Figure 23:** SIGNAL-2 index for samples from the Mitta Mitta River sites 1, and 4, and the reference and control site prior to the CRP (T4, T5), during the CRP (T7) and post-CRP (T9, T11, T12).

The number of benthic macroinvertebrate taxa at the reference site did not change significantly over the six sample dates (Table 5). In contrast, the number of taxa at site 1 in the Mitta Mitta River was significantly higher on all of the dates after the CRP (T9, T11, T12) compared to dates prior to and during the CRP (T4, T5, T7) (Table 5, Figure 24). Taxa including glossosomatid and hydroptilid caddisfly larvae, megaloptera (toebiters) and elmid beetle larvae that were previously absent from site 1 prior to the CRP (T4, T5) were present in low numbers at this site after the CRP (T9, T11, T12). This finding is consistent with the hypothesis that there will be a higher diversity of benthic macroinvertebrates in cobble habitats following the CRP. The increase in number of taxa observed at site 1 was not evident at site 4 further downstream (Figure 24).



**Figure 24:** Number of taxa (mean  $\pm$  SE, n=4) from the Mitta Mitta River sites 1 and 4, and the reference and control site prior to the CRP (T4, T5), during the CRP (T7) and post-CRP (T9, T11, T12).

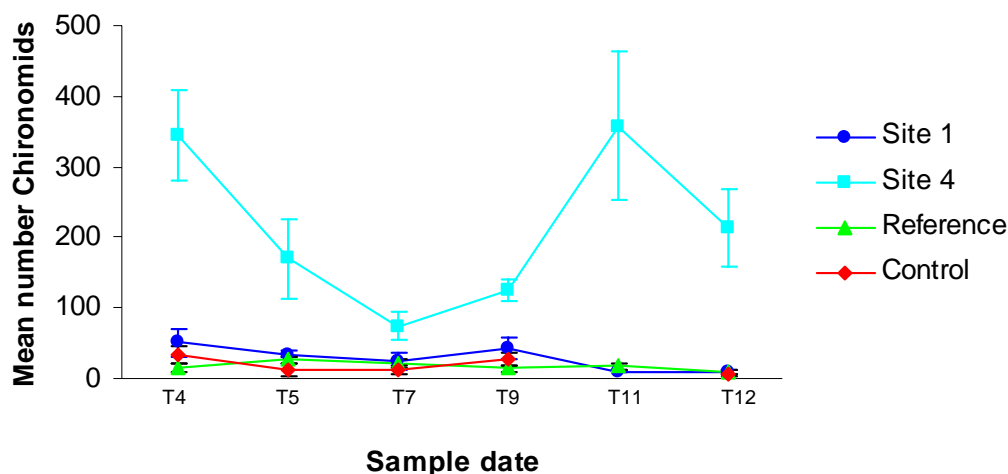
Oligochaete worms are very tolerant of poor environmental conditions and often serve as an indicator of poor health in aquatic habitats (Gooderham and Tsyrlin 2002). The reference and control sites had very low numbers of oligochaete worms throughout the study period (Figure 25) and there was no difference in the abundance of oligochaetes over time at these sites (Table 5). In contrast, both sites in the Mitta Mitta River supported large numbers of oligochaetes at some of the sampling times. The numbers of oligochaetes reduced significantly at site 4 during the CRP (T7) but significantly increased immediately after the CRP (T9, T11) (Figure 25). There was another significant reduction in oligochaetes at site 4 at T12 after the natural fresh from Snowy Creek (Figure 25). This suggests that discharge events like the CRP and natural freshes can reduce the abundance of abundant tolerant taxa such as oligochaetes. Site 1 generally had a lower number of oligochaetes than site 4 (Figure 25). There were significantly more oligochaetes at site 1 immediately after the CRP (T9) ( $p < 0.01$ ) and this may have been in response to the increased levels of particulate organic matter in the river during the CRP. However, there was a reduction in the number of oligochaetes at site 1 by sampling time 11 and 12 (Figure 25).



**Figure 25:** Number of oligochaetes (mean  $\pm$  SE,  $n=4$ ) from the Mitta Mitta River sites 1 and 4, and the reference and control site prior to the CRP (T4, T5), during the CRP (T7) and post-CRP (T9, T11, T12).

Some chironomid fly larvae are tolerant of poor environmental conditions and the abundance of chironomids can be used as an indicator of the health of aquatic habitats. The reference, control and site 1 had very low numbers of chironomid larvae throughout the study period (Figure 26) and there was no difference in the abundance of chironomids at these sites over time (Table 5). In contrast, site 4 supported large numbers of chironomids at some of the sampling times. The numbers of chironomids reduced significantly at site 4 during the CRP (T7), but increased significantly after the CRP and were at high levels at sampling time 11 (Figure 26). The natural fresh

from Snowy Creek reduced the numbers of chironomids at site 4 between T11 and T12 (Figure 26). This suggests that discharge events like the CRP and natural freshes can reduce the abundance of abundant taxa such as chironomids.



**Figure 26:** Number of chironomid fly larvae (mean  $\pm$  SE, n=4) from the Mitta Mitta River sites 1 and 4, and the reference and control site prior to the CRP (T4, T5), during the CRP (T7) and post-CRP (T9, T11, T12).

#### **Summary of benthic macroinvertebrate results**

- The community composition of benthic macroinvertebrates was significantly different between sites 1, 4, the reference and control at all sampling times. The community composition at site 1 changed over time, moving towards the reference condition following the CRP release (T9, T11). The community composition at site 4 became more similar to the reference during the CRP release (T7), however after the CRP event the community composition at site 4 reverted back and had a similar composition to that observed prior to the CRP.
- There was a higher SIGNAL-2 index at the reference and control sites than at both Mitta Mitta sites prior to CRP. There was a significant increase in the SIGNAL-2 index at site 1 after the CRP. There was no change in the SIGNAL-2 index at site 4 further downstream in the Mitta Mitta River.
- There was an increase in the number of benthic macroinvertebrate taxa in cobble habitats at site 1 following the CRP (T9, T11, T12), but this pattern was not evident further downstream at site 4 in the Mitta Mitta River.
- The numbers of oligochaete worms and chironomid fly larvae reduced significantly at site 4 during the CRP, but increased significantly immediately after the CRP (T9, T11). There was another significant reduction in oligochaetes and chironomids at site 4 at T12 after the natural fresh from Snowy Creek. The reference and control sites had low numbers of oligochaetes and chironomids throughout the study.



## 4 Summary

The water quality in the Mitta Mitta River changed in response to the CRP. Water temperature and conductivity decreased on the peak of the CRP and increased during the recession after the CRP. Turbidity, particulate organic matter, total suspended solids and water column chlorophyll-*a* in the Mitta Mitta River increased during the peak of the CRP and decreased during the recession of flow at the end of the CRP.

Table 6 summarises the effects of the CRP on biofilm parameters in the Mitta Mitta River and Snowy Creek. There was a decrease in algal biofilm biomass at site 1 in the Mitta Mitta River during the peak of the CRP but this increased again after the CRP. At site 4 there was a decrease in the total, organic and algal biofilm biomass during the peak of the CRP and all parameters increased again after the CRP. This suggests that the CRP scoured algal biofilms from cobble substrata along the Mitta Mitta River but biomass increased again after the CRP. The response was more pronounced at site 4 because there were higher initial levels of biofilm biomass at this site prior to the CRP event. The community composition of the biofilm in the Mitta Mitta River became more similar to the reference site following the CRP. The scouring of biofilms removed filamentous green algae and increased the relative biovolume of early successional diatoms.

The effects of the CRP on benthic macroinvertebrates in the Mitta Mitta River and Snowy Creek are summarised in Table 7. There was an increase in the number of taxa and the SIGNAL-2 index at site 1 after the CRP. The macroinvertebrate community composition at site 1 also became more similar to the reference site following the CRP. This was due to the colonisation of site 1 by several sensitive taxa that had been absent from this site prior to the CRP. In contrast, there was only a minor ecological response at site 4 further downstream in the Mitta Mitta River. The community composition at site 4 became more similar to the reference condition during the CRP, but shifted back towards the original composition at the end of the CRP. There was a reduction in the number of oligochaetes and chironomids at site 4 during the CRP, however this change was short lived as the numbers of these taxa increased by the end of the CRP. These results are consistent with the findings of Sutherland *et al.* (2002) who observed a more pronounced effect of the CRP at site 1 than at site 4 following a CRP event in the Mitta Mitta River in 2001/2002.

This study demonstrates that the CRP in the Mitta Mitta River had a positive effect on river health, shifting the ecosystem towards that in the reference site in Snowy Creek. Several of the improvements in condition were only short lived. Within a week of the CRP peak, several indices had shifted away from the reference condition, back towards values observed prior to the CRP.

**Table 6:** Summary of effects of the CRP release on biofilm parameters in the Mitta Mitta River and Snowy Creek. Peak of CRP = comparison of the conditions prior to the CRP (T5) to conditions at the peak of the CRP release (T6). End of CRP = comparison of the conditions at the peak of the CRP (T6) to conditions at the end of the CRP release (T9). Post-CRP = comparison of conditions at the end of the CRP (T9) to conditions at the end of the constant flow period after the CRP (T11). ↑ = increase, ↓ = decrease, - = no change in parameter

| Parameter                             | Site 1                        |                                 |                                 | Site 4                        |                                 |                             | Reference (Snowy Creek)        |                       |                      |
|---------------------------------------|-------------------------------|---------------------------------|---------------------------------|-------------------------------|---------------------------------|-----------------------------|--------------------------------|-----------------------|----------------------|
|                                       | Peak of CRP (T5 to T6)        | End of CRP (T6 to T9)           | Post-CRP (T9 to T11)            | Peak of CRP (T5 to T6)        | End of CRP (T6 to T9)           | Post-CRP (T9 to T11)        | Peak of CRP (T5 to T6)         | End of CRP (T6 to T9) | Post-CRP (T9 to T11) |
| Total biomass (dry weight)            | -                             | -                               | ↑ Moved away from ref condition | ↓ Moved towards ref condition | ↑ Moved away from ref condition | -                           | ↑ small increase in dry weight |                       | -                    |
| Organic biomass (AFDW)                | -                             | -                               | -                               | ↓ Moved towards ref condition | ↑ Moved away from ref condition | -                           | -                              | -                     | -                    |
| Algal biomass (chlorophyll <i>a</i> ) | ↓ Moved towards ref condition | ↑ Moved away from ref condition | -                               | ↓ Moved towards ref condition | ↑ Moved away from ref condition | -                           | -                              | -                     | -                    |
| Biofilm taxonomy                      | Moved towards ref condition   | Moved towards ref condition     | Moved away from ref condition   | -                             | Moved towards ref condition     | Moved towards ref condition | -                              | ↓ red algae           | ↓ green algae        |

**Table 7:** Summary of effects of the CRP release on benthic macroinvertebrate parameters in the Mitta Mitta River and Snowy Creek. CRP = comparison of the conditions prior to the CRP (T5) to conditions during the CRP release (T7). Post CRP = comparison of conditions during the CRP (T7) to conditions at the end of the constant flow period after the CRP (T11). ↑ = increase, ↓ = decrease, - = no change in parameter.

| Parameter              | Site 1               |                                     | Site 4                              |                                       | Reference (Snowy Creek) |                      |
|------------------------|----------------------|-------------------------------------|-------------------------------------|---------------------------------------|-------------------------|----------------------|
|                        | CRP (T5 to T7)       | Post-CRP (T7 to T11)                | CRP (T5 to T7)                      | Post-CRP (T7 to T11)                  | CRP (T5 to T7)          | Post-CRP (T7 to T11) |
| Community composition  | Moved towards site 4 | Moved towards reference condition   | Moved towards reference condition   | Moved away from reference condition   | -                       | -                    |
| SIGNAL-2 scores        | -                    | ↑ Moved towards reference condition | -                                   | -                                     | -                       | -                    |
| Number of taxa         | -                    | ↑ Moved towards reference condition | -                                   | -                                     | -                       | -                    |
| Number of Oligochaetes | -                    | -                                   | ↓ Moved towards reference condition | ↑ Moved away from reference condition | -                       | -                    |
| Number of Chironomids  | -                    | -                                   | -                                   | ↑ Moved away from reference condition | -                       | -                    |

## 5 Recommendations

### 5.1 Sampling recommendations

- As recommended by Sutherland *et al.* (2002), it is important to examine baseline conditions during a constant flow period prior to a CRP release. In the current study it was necessary for RMW to adjust Dartmouth releases in response to changes in demand associated with changes in condition in the River Murray system downstream. This reduced the possible duration of the constant flow period prior to the CRP, and consequently only two samples could be collected at site 4 during the constant flow period.

**Recommendation 1:** Future assessments of CRP's to include sampling in the period prior to the CRP. A minimum of three weeks of near constant flow (see section 2.4) at Coleman's gauge prior to the CRP is required to strengthen the ability to assign ecological changes to the implementation of the CRP.

- There is currently no knowledge of the extent of biofilm scouring and organic matter transport that occurs during the period prior to the CRP when transfers from Dartmouth Reservoir to Hume Reservoir is initiated. In 2004, the discharge from Dartmouth Reservoir prior to the study period was high, reaching 7063 ML/day at Colemans gauge. A comparison of the effect of this release relative to the effect of the CRP on the river ecosystem could not be made given the sampling regime of the current study.

**Recommendation 2:** Future assessments of CRP's to include sampling during the period of low constant flows during the period when Dartmouth Reservoir is filling prior to the commencement of transfer of water from Dartmouth Reservoir to Hume Reservoir.

- The current study showed that the response of some of the parameters (eg. biofilm biomass) were short-lived. However, for other parameters (eg. SIGNAL-2 index, number of macroinvertebrate taxa) the response was sustained for up to 5 weeks after the CRP commenced (and possibly beyond this time). Consequently, the duration of the current study was not sufficient to determine how long the ecological benefits are maintained after the CRP event.

**Recommendation 3:** Future assessments of CRP's to include additional sample events after the CRP and continue into the period when there are minimum releases from Dartmouth Reservoir to the Mitta Mitta River. This will determine the longer-term impacts of the CRP on the ecosystem and the resilience of the ecosystem to change.

- Sutherland *et al.* (2002) recommended that increased replication of biofilm attributes should be undertaken in future studies. In the current study additional replication (n=8) of biofilm attributes improved the ability to determine the within-site variability.

**Recommendation 4:** Future assessments of CRP's to sample biofilm with minimum of eight replicates.

- Sutherland *et al.* (2002) recommended that a minimum of four replicates of benthic surber samples of cobble habitat be taken for each site at each sampling event to allow ANOSIM analyses to be performed to detect significant differences in community composition between sample dates. In response to this recommendation four surber samples were collected for benthic macroinvertebrates at each habitat for each site and sampling event.

**Recommendation 5:** Future assessments of CRP's to continue to sample a minimum of four surber samples of cobble habitat be taken for each site at each sampling event.

## 5.2 Flow management recommendations

- There was change in several indicators of river ecosystem health in response to the CRP that suggested an improvement in the ecological condition of the Mitta Mitta River.

**Recommendation 6:** CRP's to be incorporated into future water transfers from Dartmouth Reservoir to the Hume Reservoir.

- Several of the indicators responded to the peak of the CRP, suggesting that high discharge levels are a driver of ecological change. However, at present we do not have the knowledge to interpret the relative importance of the duration, magnitude, and shape of the lag of the CRP on the response of the ecosystem.

**Recommendation 7:** Studies exploring the effects of the CRP magnitude, duration and shape to be undertaken during periods of future water transfer from Dartmouth Reservoir to the Hume Reservoir.

- The flow peak of the CRP is attenuated as it moves down the river. Consequently, the average velocity of the water is likely to be considerably reduced at downstream sites. This may explain why algal communities were not scoured to the same extent at site 4 as they were at site 1, and changes in macroinvertebrate communities observed at site 4 were not sustained.

If the ecological benefits of the CRP's are to be extended to sites further downstream in the Mitta Mitta River then several different options for flow management could be explored. Options to consider include the possibility of increasing the discharge of CRP events from Dartmouth Reservoir; to piggy-back the CRP from Dartmouth Reservoir onto inflows from tributaries such as Snowy Creek; or to introduce multiple CRP's to the release pattern.

**Recommendation 8:** Studies of the effects of different management options such as increased discharge, multiple CRP's, and piggy-backing flows to be undertaken to determine if ecological benefits of the CRP's can be extended to sites further downstream in the Mitta Mitta River.

**N.B.** water releases do not follow a set pattern. There is a range of possible patterns that are used in response to a range of conditions.

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## **APPENDIX 1 – CRP MEDIA RELEASE**



## **MEDIA RELEASE**

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**Friday, 31 December 2004**

### **Variation in Release from Dartmouth Reservoir for Environmental Purposes**



River Murray Water (RMW) announced today that the rate of transfer of water from Dartmouth Reservoir to Hume Reservoir is to be temporarily increased with the aim of providing environmental benefits.

RMW General Manager, Mr David Dreverman said that the program to vary the release from Dartmouth in a cyclic pattern is aimed to mimic, to some extent, the variability of river levels seen under natural conditions.

“This mode of operation is expected to benefit the ecology of the river by providing some wetting and drying of in-channel and streamside habitat to improve biological productivity of macro-invertebrates, vegetation and bio-films along the river,” Mr Dreverman said.

“The variation in flow will be based on a cycle over a period of a fortnight, with a significant rise in release from Dartmouth over 2 days, followed by a recession of flow over 12 days.”

“River pumpers should note that this cycle in flow represents a significant change in river level of about 0.7 m over a two day period, which is more than the fluctuation made in previous operations of this type in recent years,” Mr Dreverman said.

This cyclic release pattern has been incorporated in the overall program of transfer of water from Dartmouth to Hume over the 2004/05 irrigation season. However, due to improvements in inflows in the River Murray system in recent months, the volume required to be transferred to Hume Reservoir had reduced. As a result, it may only be possible to introduce one such cycle of variable release in the 2004/05 season.

“The release from Dartmouth has been steady at about 2 000 ML/day or about 1.7 m on the Colemans gauge in the Mitta Mitta River since mid December. Environmental monitoring of the river and its banks has been undertaken since early December whilst flow has been in the range 2 000 to 4 000 ML/day,” Mr Dreverman said.

Beginning on the morning of Tuesday 4 January 2005, release is to be increased to about 6 000 ML/day (2.3 m gauge height) over a period of 2 days. Flow at Colemans will then be gradually reduced until it reaches 2 000 ML/day by 17 January. Further downstream at Tallandoon, it is expected that the river level (currently 2 700 ML/day, and about 2.0 m gauge height) will initially rise to about 2.7 m gauge height, and then gradually recede to about 2.0 m if there is no significant rain.

However, greater variation in river level at Tallandoon might occur in response to significant rain and increased flows in tributaries of the Mitta Mitta River. If this occurs, release from Dartmouth may need to be reduced with the aim to avoid flow exceeding channel capacity.

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Further environmental monitoring of the river and the riverbank will be undertaken in coming weeks to investigate the ecological response to the two week cyclic flow pattern compared with the previous steady flow pattern.

After completion of this cycle of release, the requirements for transfer of water from Dartmouth to Hume will again be assessed. However, after mid January, it is likely that release from Dartmouth will be further reduced.

River Murray Water will provide further updates throughout the season on the program of release from Dartmouth Reservoir, particularly when significant changes are required.

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Manager Communication

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*(Lawrie Kirk is not to be quoted as a spokesperson)*

*TRIM Ref: 04/13065DO*

## **APPENDIX 2 – ALGAL SPECIES LIST**

Species list of algal taxa found in the Mitta Mitta and Buffalo Rivers, and Snowy Creek

| <b>Taxa</b>                            | <b>Site 1</b> | <b>Site 2</b> | <b>Site 3</b> | <b>Site 4</b> | <b>Reference</b> | <b>Control</b> |
|--|---------------|---------------|---------------|---------------|------------------|----------------|
| <b>Rhodophyta</b>                      |               |               |               |               |                  |                |
| <i>Audouenella</i>                     | x             | x             | x             | x             | x                | x              |
| <b>Chlorophyta</b>                     |               |               |               |               |                  |                |
| <i>Akinstrodesmus</i>                  |               |               |               | x             | x                | x              |
| <i>Bulbochaete</i>                     | x             |               |               |               |                  |                |
| <i>Closterium</i>                      |               | x             |               | x             |                  |                |
| <i>Cosmarium</i>                       |               |               | x             | x             | x                | x              |
| <i>Drapnaldia</i> sp. 1                | x             |               |               |               |                  |                |
| <i>Mougoutia</i>                       | x             | x             | x             |               |                  | x              |
| <i>Oedogonium</i> sp. 1                | x             | x             | x             | x             | x                | x              |
| <i>Oedogonium</i> sp. 2                | x             | x             | x             | x             |                  |                |
| <i>Rhizoclonium</i>                    |               | x             |               | x             |                  |                |
| <i>Scenedesmus</i>                     |               |               |               | x             |                  | x              |
| <i>Spirogyra</i>                       |               | x             | x             | x             | x                | x              |
| <i>Spondylosium</i>                    |               |               | x             |               |                  |                |
| <i>Stigeoclonium</i>                   | x             | x             | x             | x             | x                | x              |
| <i>Ulothrix zonata</i>                 | x             | x             | x             | x             | x                | x              |
| <b>Cyanobacteria</b>                   |               |               |               |               |                  |                |
| <i>Gleotrichia</i>                     | x             | x             | x             | x             |                  |                |
| <i>Lyngbya</i>                         | x             | x             |               | x             | x                | x              |
| <i>Oscillatoria</i>                    | x             | x             | x             | x             | x                | x              |
| <i>Phormidium</i>                      |               | x             |               |               | x                |                |
| <i>Planktolyngbya</i>                  | x             | x             | x             | x             | x                | x              |
| <i>Planktothrix</i> sp 1               | x             | x             | x             | x             | x                | x              |
| <i>Planktothrix</i> sp 2               | x             | x             | x             | x             | x                | x              |
| <i>Pseudoanabaena</i>                  | x             | x             |               | x             | x                | x              |
| <i>Trichodesmium</i>                   | x             | x             |               | x             | x                | x              |
| <b>Bacillariophyta</b>                 |               |               |               |               |                  |                |
| <i>Achnanthes</i> cf. <i>subexigua</i> | x             | x             | x             | x             | x                |                |
| <i>Achnanthes exigua</i>               | x             | x             | x             | x             | x                | x              |
| <i>Achnanthes</i> sp. 1                | x             | x             | x             | x             | x                | x              |
| <i>Achnanthidium minutissima</i>       | x             | x             | x             | x             | x                | x              |
| <i>Amphora</i> sp. 1                   | x             | x             | x             | x             |                  | x              |
| <i>Amphora veneta</i>                  |               |               |               | x             |                  | x              |
| <i>Aulocoseira granulata</i>           | x             | x             | x             | x             |                  |                |
| <i>Cymbella</i>                        | x             | x             | x             | x             | x                | x              |
| <i>Diatoma</i>                         | x             | x             | x             | x             |                  | x              |
| <i>Encynema minutum</i>                | x             | x             | x             | x             | x                | x              |
| <i>Encynema silesiacum</i>             | x             | x             | x             | x             | x                | x              |

|                               |   |   |   |   |   |   |
|-------------------------------|---|---|---|---|---|---|
| <i>Eunotia</i>                |   | X |   |   | X |   |
| <i>Fragilaria constuens</i>   | X |   |   | X |   |   |
| <i>Fragillaria capucina</i>   | X | X | X | X | X | X |
| <i>Fragillaria</i> sp 1       | X | X | X | X | X | X |
| <i>Gomphonema acuminatum</i>  | X | X | X | X |   |   |
| <i>Gomphonema lagenula</i>    | X | X | X | X | X | X |
| <i>Gomphonema parvulum</i>    | X | X | X | X | X | X |
| <i>Gomphonema pseudoaugar</i> |   |   |   | X | X | X |
| <i>Gomphonema truncatum</i>   | X | X | X | X | X | X |
| <i>Melosira varians</i>       | X | X | X | X | X | X |
| <i>Navicula erifuga</i>       | X | X |   | X | X | X |
| <i>Navicula gregaria</i>      | X | X | X | X | X |   |
| <i>Navicula radiosa</i>       | X | X | X | X |   | X |
| <i>Navicula rhyncocephala</i> | X | X | X | X | X | X |
| <i>Navicula</i> sp .1         | X | X | X | X | X | X |
| <i>Nitzschia aciculans</i>    | X | X | X |   | X | X |
| <i>Nitzschia gracilis</i>     | X | X |   | X | X |   |
| <i>Nitzschia</i> sp. 1        | X | X | X | X | X | X |
| <i>Nitzschia</i> sp. 2        | X |   |   | X |   |   |
| <i>Pinnularia</i>             | X | X | X | X |   | X |
| <i>Planothidium</i>           | X | X | X | X | X | X |
| <i>Synedra ulna</i>           | X | X | X | X | X | X |
| <i>Tabellaria flocculosa</i>  | X | X | X | X | X | X |

## **APPENDIX 3 – MACROINVERTEBRATE SPECIES LIST**















