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Murrumbidgee Ecological Monitoring Program

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Cover Photograph: Facing North West, the Murrumbidgee Pump Station - March 2009

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Table of Contents

Table of Figures

List of Tables

Appendices

List of abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
AFDM – Ash Free Dry Mass (periphyton)
ANOVA – Analysis of Variance (statistics)
ANZECC – Australian and New Zealand Conservation Council
AUSRIVAS – Australian River Assessment System
ECD – Enlarged Cotter Dam
EPA – Environmental Protection Authority
EPT taxa- Ephemeroptera; Plecoptera and Trichoptera
GL/a – gigalitres per annum
GPS – global positioning system
M2C – Murrumbidgee to Cotter
ML/d – Megalitres per day
MPS – Murrumbidgee Pump Station
NATA – National Association of Testing Authorities
NMDS – Non-metric Multidimensional Scaling (statistics)
OCD taxa – Oligochaeta; Chironomidae and other Diptera
QA – Quality Assurance
QC – Quality Control
TN – Total Nitrogen
TP – Total Phosphorus
TSS – Total Suspended Solids

Executive Summary

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. It is adjacent to the Cotter Pump Station which currently abstracts up to 50ML/d, contributing to the water supply for the ACT. Construction is underway to increase the abstraction amount from the Murrumbidgee River (via the MPS) to 150ML/d through an upgraded pumping network.

The upgraded infrastructure will also provide a recirculating flow from the Murrumbidgee to the base of the proposed Enlarged Cotter Dam; this project is referred to as the Murrumbidgee to Cotter transfer (M2C). This program does not monitor the effects of M2C, as this is being undertaken by others. MPS is currently expected to be commissioned in spring 2010. Pumping will only occur when there is sufficient demand for the water (for M2C and/or potable water supply), and sufficient flow in the Murrumbidgee River.

The framework for this program responds primarily to requirements of ACTEW's Dec 2008 – Dec 2009 water abstraction licence (WU67 section D6). Water abstraction at the Murrumbidgee Pump Station (MPS), combined with a change of environmental flow releases from the Cotter Reservoir, require an assessment of the response of the river through monitoring methods that can quantify subtle impacts.

This program aims to establish the baseline river condition prior to the increased abstraction, then continue monitoring afterwards to determine what physicochemical and ecological changes occur.

The key aims of this sampling run were to:

1. *Collect macroinvertebrate community data, upstream and downstream of the MPS*
2. *Provide ACTEW with river health assessments based on AUSRIVAS protocols at the key sites that could potentially be impacted by construction works and operation of the MPS upgrade*
3. *Collect baseline periphyton data in order to assist in the characterisation od seasonal and inter-annual temporal variability, and*
4. *Report on water quality upstream and downstream of the MPS*

This report presents the results from biological sampling of the Murrumbidgee River for the monitoring of the MPS in spring 2009. Sampling was completed in May 2009. Sampling was based on the AUSRIVAS sampling protocols, but was extended to include multiple replicates from each site where specimens were identified to genus level, instead of family level.

The purpose of this protocol was to:

a) *establish biological signatures at each site prior to the commencement of pumping, and*
b) *enable subtle changes to be detected if there are impacts associated with reduced flows.*

The key results from the spring 2009 sampling of the MPS indicate that:

- *All sites were categorised as Band-B ("significantly impaired") by the AUSRIVAS assessment;*

- *Water quality was generally good, with most water quality parameters at levels within ANZECC (Australian and New Zealand Conservation Council) guidelines. Electrical Conductivity (EC) was below the recommended limits at the time of sampling. Turbidity and nutrient concentrations exceeded guideline targets at all sites and were up to 60% higher than levels recorded in autumn. The changes in these parameters are likely due to increased surface runoff and high flows during spring.*

- *There were no statistical differences in periphyton AFDM or Chlorophyll-a measurements between the upstream and downstream sites; nor was there any clear difference between upstream and downstream sites in macroinvertebrate community assemblages based on ANOSIM results. The sudden increased flow in early November is thought to have resulted in a) the BAND –B AUSRIVAS assessment and b) caused many of the free-living, sensitive taxa to be dislodged from the ampling sites. Recovery of the macroinvertebrate community and improved river health ratings are predicted as re-colonisation progresses.*

- *It is recommended that the current sampling protocols remain as they are with the inclusion of total suspended solids added to the list of water quality analytes to be tested. At this stage, turbidity is being used as a proxy for estimating suspended solids, based on corelational data acquired by Ecowise. However, estimates of TSS from turbidity data can vary considerably depending on the size and duration of the event and where on the hydrograph the samples are collected, and as such it is advisable to include TSS in the next sampling run.*

1 Introduction

The Murrumbidgee Ecological Monitoring Program was set up by ACTEW Corporation to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It is being undertaken as part of the ACT Water Supply security infrastructure upgrade. The proposed timeline is to undertake sampling in spring and spring over a three year period commencing in Spring 2008.

There are four component areas being considered:

Part 1: Angle Crossing
Part 2: Burra Creek (discharge point for Angle Crossing abstraction)
Part 3: Murrumbidgee Pump Station
Part 4: Tantangara to Burrinjuck

This report focuses on Part 3: Murrumbidgee Pump Station.

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. It is adjacent to the Cotter Pump Station which currently abstracts up to 50ML/d, contributing to the water supply for the ACT. Construction is underway to increase the abstraction amount from the Murrumbidgee River to 150ML/d via the MPS. The upgraded infrastructure will also provide a recirculating flow from the Murrumbidgee to the base of the proposed Enlarged Cotter Dam (ECD); this project is referred to as Murrumbidgee to Cotter (M2C) transfer.

This program does not aim to monitor the effects of the M2C transfer, but rather provide a characterisation of the baseline condition prior to that project coming on line.

The upgraded pump station is currently expected to be commissioned in spring 2010. Pumping will only occur when there is sufficient demand for the water (for M2C and/or potable water supply), and when there is sufficient water flow in the Murrumbidgee River. The framework for this program responds primarily to requirements of ACTEW's Dec 2008 – Dec 2009 water abstraction licence (WU67 section D6).

The increase in abstraction at the Murrumbidgee Pump Station (MPS) may place additional stress on the downstream river ecosystem. This monitoring program has been established to monitor the condition of the Murrumbidgee River in terms of water quality and ecological condition at key sites both upstream and downstream of the extraction point (MPS). Monitoring will eventually extend to the period after the proposed abstractions are implemented and data collected in that phase will be compared with those collected as part of this study.

The information derived from this program will support ACTEW's and the ACT Environmental Protection Authority's (EPA) adaptive management approach to water abstraction and environmental flow provision in the ACT.

1.1 Project objectives

The objectives of the MPS monitoring program is to provide ACTEW with seasonal assessments of river health effected by the operation and works during the upgrade of the Murrumbidgee Pump Station under the license requirements of ACTEW's licence to abstract water # WU67, section D6.

Specifically, the aims of the project are to:

1. Meet ACTEW's monitoring obligations under the requirements of its licence to abstract water (Licence # WU67, section D6);

2. Provide seasonal "river health" reports in accordance with the licence requirements;

3. Obtain baseline macroinvertebrate, water quality and periphyton data for eventual use in the assessment of whether or not the proposed abstractions from the MPS are impacting the ecology and ecological "health" of the Murrumbidgee System downstream of the MPS. This study will also provide ACTEW with river health assessments based on AUSRIVAS protocols at the key sites concerning the operation and the works concerned with the upgrade of the MPS

1.2 Project scope

The current ecological health of the sites monitored as part of the Murrumbidgee Pump Station (MPS) monitoring program is estimated using AURIVAS protocols for macroinvertebrate community data; combined with a suite of commonly used biological metrics and descriptors of community composition. The scope of this report is to convey the results from the spring 2009 sampling runs. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (Ecowise, 2009), this work includes:

- Sampling from autumn 2009;
- Macroinvertebrate sampling from riffle and edge habitats;
- Riffle and edge samples collected as per the ACT AUSRIVAS protocols;
- Macroinvertebrates counted and identified to the taxonomic level of genus;
- Riffle and edge samples assessed through the appropriate AUSRIVAS model;
- Some water quality measurements to be measured *in*-situ, and nutrient samples to be collected and analysed in Ecowise's NATA accredited laboratory.

1.3 Rationale for using biological indicators

Macroinvertebrates and periphyton are two of the most commonly used biological indicators used in river bio-assessment. Macroinvertebrates are commonly used to characterise ecosystem health because they represent a continuous record of preceding environmental, chemical and physical conditions at a given site. Macroinvertebrates are also very useful indicators in determining specific stressors on freshwater ecosystems because many taxa have known tolerances to heavy metal contamination, sedimentation, and other physical or chemical changes (Chessman, 2003). Macroinvertebrate community assemblage, and two indices of community condition; the AUSRIVAS index and the proportions of three common taxa (the Ephemeroptera, Plecoptera, and Trichoptera, or EPT index), are used during this survey to assess river health.

Periphyton is the matted community that resides on the river bed. The composition of these communities is dominated by algae but the term “periphyton” also includes fungal and bacterial matter (Biggs & Kilroy, 2000). Periphyton is important to maintaining healthy freshwater ecosystems as it absorbs nutrients from the water, adds oxygen to the ecosystem via photosynthesis, and provides a food for higher order animals. Periphyton communities respond rapidly to changes in water quality, light penetration of the water column and other disturbances, such as floods or low flows. This feature of rapid response makes them a valuable indicator of river health. Changes in total periphyton biomass and/or the live component of the periphyton (as determined by chlorophyll-a) can vary with changes in flow volume, so these variables are often used as indicators of river condition (Biggs, 1989; Whitton & Kelly, 1995; Biggs *et al.*, 1999). As changes in flow volume are expected with the proposed changes in the flow regime in the Murrumbidgee River, periphyton biomass and chlorophyll-a are included as biological indices.

2 Materials and method

The potential for impacts to arise during the implementation of M2G are dependant upon the pumping regime and the environmental flow rules adopted. Potential effects may include modification to the stream substrate through altered sedimentation processes, loss or reduced quality of riffle zones, changes in water chemistry and periphyton biomass accumulation. These processes in turn may influence the composition of macroinvertebrate and periphyton communities downstream of the abstraction point.

To monitor for potential impacts, macroinvertebrates were sampled in two meso-habitats (riffle and pool edges) at each site and organisms identified to family or genus level. Periphyton was sampled in the riffle zones at each site and analysed for chlorophyll-a and Ash Free Dry Mass (AFDM), which will provide estimates of the algal (autotrophic) biomass and total organic mass respectively (Biggs & Kilroy, 2000).

Sampling of riffle and edge habitats was carried out in order to provide a comprehensive assessment of each site. The monitoring of both habitats potentially allows the program to isolate flow related impacts from other disturbances. The reasoning behind this is that each habitat is likely to be effected in different ways. Riffle zones, for example, are likely to be one of the first habitats affected by low flows and water abstractions (Smakhtin, 2001; Boulton, 2003; Dewson *et al.*, 2007), as water abstraction will result in an immediate reduction in flow velocities and inundation level over riffle zones downstream of the abstraction point. Impacts on edge habitat macroinvertebrate assemblages might be less immediate as it may take some time for the reduced flow conditions to cause loss of macrophyte beds and access to trailing bank vegetation habitat. Therefore, monitoring both habitats will allow the assessment of the short-term and longer-term impacts associated with water abstraction.

2.1 Sampling details

Sampling occurred in November 2009 with flows indicated in Figure 2 (section 3.1). All sampling was carried out by AUSRIVAS accredited staff. Sampling in spring was conducted in late October/early November to correspond to the same sampling period in 2008 for parts 1-4 of the MEMP. A week into the sampling program the event of November 2nd came through, meaning that conditions made it unsafe to sample. Sampling was conducted on the 11th and 12th at the downstream and upstream sites respectively when the river had subsided to safe, wadable levels.
The conditions during the days of sampling were generally fine apart from some scattered shower periods.

2.2 Hydrology and rainfall

Murrumbidgee River flows and rainfall for the sampling period were recorded at ECOWISE gauging stations at Lobb's Hole (410761, downstream of Angle Crossing) and Mt. MacDonald (410738, downstream of the Cotter River confluence). Site locations and codes are given in Table 1.

Table 1. Location and details of continuous rainfall, water quality and flow stations

Site Code	Location/Notes	Parameters*	Latitude	Longitude
570825	Pierces Creek weather station	Rainfall	S -35.3322	E 148.9189
410738	M'bidgee River @ Mt. McDonald	WL, Q	S -35.2917	E 148.9565
410761	M'bidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO , Temp, Turb, Rainfall	S -35.5398	E 149.1015

* WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity; Rainfall = Rainfall (0.2 mm).

2.3 Water quality

Baseline *in-situ* physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded at each sampling site using a multiprobe YSI 556 surveyor. The surveyor was calibrated in accordance to QA procedures and the manufactures requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with the AUSRIVAS protocols (Coysh *et al.*, 2000b) for YSI verification and nutrient analysis. All samples were placed on ice and returned to the ECOWISE laboratory and analysed for nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in A.P.H.A (2005). Collectively, this information on the water quality parameters was used to assist in the interpretation of biological data and provide a basis to gauge changes that can potentially be linked to flow reductions at these key sites following water abstractions.

2.4 Macroinvertebrate sampling

Riffle and edge habitats were sampled for macroinvertebrates and analysed in strict accordance with the ACT spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al.*, 2000b) during spring (May 6-8th) 2009. At each site, two samples were taken from the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10cm; (Coysh *et al.*, 2000b) using a framed net (350mm wide) with 250 µm mesh size. Sampling began at the downstream end of each riffle. The net was held perpendicular to the substrate with the opening facing upstream. The stream bed directly upstream of the net opening was agitated by vigorously kicking, allowing dislodged invertebrates to be carried into the net by the current. The process continued, working upstream over 10 metres of riffle habitat. Samples were then preserved in 70% ethanol, clearly labelled with site codes and date, then stored on ice and placed in a refrigeration unit until laboratory sorting commenced.

The edge habitat was also sampled in strict accordance with the ACT AUSRIVAS protocols. Two samples were taken from the edge habitat using a framed net (350mm wide) with 250 µm mesh size. The nets and all other associated equipment were washed thoroughly between sampling events to remove any macroinvertebrates retained on them. Samples were collected by sweeping the collection net along the edge habitat at the sampling site; the operator worked systematically over a ten metre section covering overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation. Samples were preserved on-site as described for the riffle samples.

Site selection was based upon the recommendations outlined in ACTEW's Licence to take water WU67 section D6 (Figure 1; Table 2). Prior to sampling, comprehensive site assessments were carried out, including assessments of safety, suitability and granted access from landowners. As outlined in this document, there are no suitable reference sites in the proximity for this assessment, so a before – after / control – impact (BACI) design (Downes *et al.*, 2002) was adopted based on sites upstream of the abstraction point serving as Control sites and sites downstream of the abstraction / construction point serving as 'Impacted' sites. Baseline monitoring carried out as part of this study will serve as the 'Before' period for this assessment.

Table 2. Sampling site locations and details

Site Code	Location	Landuse	Purpose
Mur 931	"Fairvale" approximately 4km upstream of the Cotter River confluence	Cattle grazing	Upstream control site
Mur 28	~100m upstream of the Cotter River confluence	Currently in the MPS construction zone. Grazing.	Upstream control site
Mur 935	Casuarina Sands	Recreation, construction upstream	Downstream impact site
Mur 937	"Huntly" ~3km downstream of the Cotter River confluence. Near Mt. MacDonald gauging station	Sheep and cattle grazing	Downstream impact site
Mur 29	U/S Uriarra Crossing	Recreation, sheep and cattle grazing, some pine forest	Downstream impact / recovery site

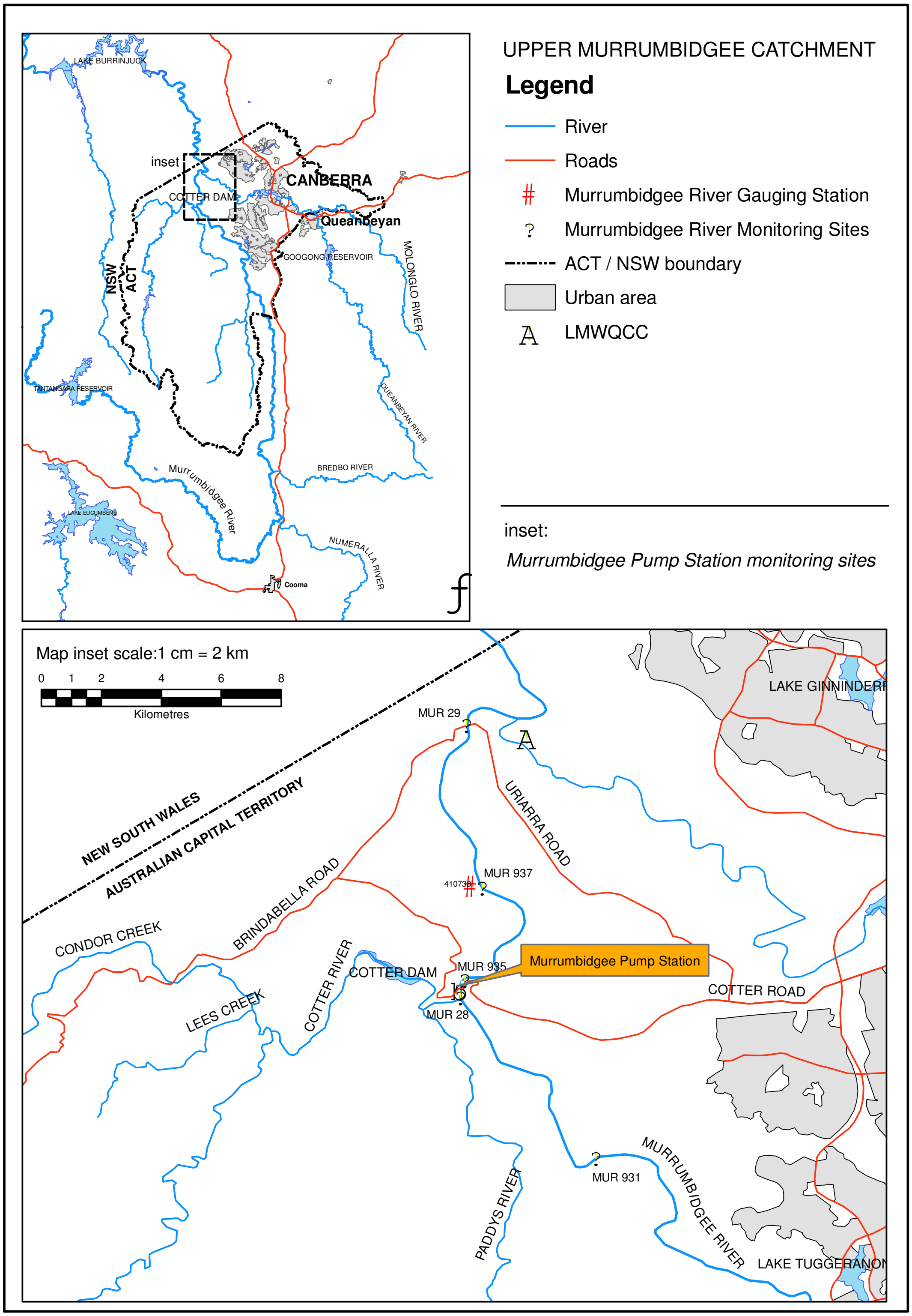


Figure 1. Murrumbidgee Pump Station sampling locations

2.5 Periphyton

Estimates of algal biomass were made using complimentary data from both chlorophyll-*a* (which measures autotrophic biomass) and ash free dry mass (AFDM; which estimates the total organic matter in periphyton samples and includes the biomass of bacteria, fungi, small fauna and detritus in samples) of the periphyton samples (Biggs, 2000).

The five sites selected (Figure 1; Table 2) were sampled for periphyton in spring in conjunction with the macroinvertebrate sampling. All periphyton - adnate and loose forms of periphyton, as well as organic/inorganic detritus in the periphyton matrix, were collected using the *in-situ* syringe method similar to Loeb (1981), as described in Biggs and Kilroy (2000). A 1 m wide transect was established across riffles at each site. Along each transect, twelve samples were collected at regular intervals, using a sampling device of two 60 ml syringes and a scrubbing surface of stiff nylon bristles covering an area of ~637 mm^2. The samples were divided randomly into two groups of six samples to be analysed for Ash Free Dry Mass (AFDM mg/m^{-2}), and chlorophyll-a. Samples for Ash Free Dry Mass (mg/m^{-2}) and chlorophyll-a analysis were filtered onto glass filters and frozen. Sample processing follows the methods outlined in APHA (2005).

2.6 Data analysis

2.6.1 Water quality

Water quality parameters were examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC, 2000). Trend analyses of water quality parameters were conducted at the end of the baseline collection period.

2.6.2 Macroinvertebrate communities

The macroinvertebrate data were examined separately for riffle and edge habitats. Replicates were examined individually (i.e. not averaged) at all sites because the aim is to examine within site variation as much as it is to describe patterns among sites. All multivariate analyses were performed using PRIMER version 6 (Clarke & Gorley, 2006). Univariate statistics were performed using R version 2.9.2 (R Development Core Team, 2009).

Processing of the macroinvertebrate samples followed the ACT AUSRIVAS protocols. Briefly, in the laboratory, the preserved macroinvertebrate samples were placed in a sub-sampler, comprising of 100 (10 X 10) cells (Marchant, 1989). The sub-sampler was then agitated to evenly distribute the sample and the contents of randomly selected cells removed. Macroinvertebrates from each selected cell were identified to genus level. Specimens that could not be identified to the specified taxonomic level (i.e. immature or damaged taxa) were removed from the data set prior to analysis.

For the AUSRIVAS model, all taxa were analysed at the family level except Chironomidae (identified to sub-family), Oligochaeta (class) and Acarina (order). The first 200 animals were identified (identification followed taxonomic keys published by Hawking (2000)) and if 200 were identified before a cell had been completely analysed, identification continued until the animals within the entire cell were identified. Data was entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer.

Non-metric multidimensional scaling (NMDS) was also performed on the macroinvertebrate community data following the initial cluster analysis. NMDS is a multivariate procedure that reduces the dimensionality of multivariate data and aids interpretation. It reduces the dimensionality of the data by describing trends in the joint occurrence of taxa. The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Clarke & Warwick, 2001). For the macroinvertebrate data collected during this survey, the final number of dimensions was reduced to two. Stress values for each plot were examined before results were interpreted. The stress level is a measure of the distortion produced by compressing multidimensional data into a reduced set of dimensions and will increase as the number of dimensions is reduced and can be considered a measure of "goodness of fit" to the original data matrix (Kruskal, 1964). Stress near zeros suggests that NMDS patterns are very representative of the multidimensional data, while stresses greater than 0.2 indicate a poor representation (Clarke and Warwick 2001).

An analysis of similarities (ANOSIM) was performed on the data to test whether macroinvertebrate communities were statistically different upstream and downstream of the MPS. Sites were nested within location (i.e. upstream or downstream of the abstraction point) for the purposes of the analysis.

The Similarity percentages (SIMPER) routine was carried out on the datasets only if the initial ANOSIM test was significant (i.e. P<0.05), to examine which taxa were responsible for, and explained the most variation among statistically significant groupings. This procedure was also used to describe groups (i.e. which taxa characterised each group of sites) (Clarke & Warwick, 2001).

Several additional metrics to the AUSRIVAS and SIGNAL-2 were used. The number of taxa (taxa richness) was counted for each site and other descriptive metrics such as the relative abundances of sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera- EPT) and, tolerant taxa, (Oligochaeta and chironomids) were examined at family and genus levels.

Taxa richness was monitored as a means of assessing macroinvertebrate diversity. In assessing the taxonomic richness of a site, it is important to keep in mind that high taxa richness scores can, but does not always indicate better ecological condition at a given location. In certain instances high taxa richness might indicate a response to the provision of new habitat or food resources that might not naturally occur as a result of anthropogenic activities.

2.6.3 AUSRIVAS assessment

AUSRIVAS is a prediction system that uses macroinvertebrates to assess the biological health of rivers and streams. Specifically, the model uses site-specific information to predict the macroinvertebrate fauna Expected (E) to be present in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics influenced by non-human characters, e.g. altitude) are then compared to the Observed fauna (O) and the ratio derived is used to indicate the extent of any impact (O/E). The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 3) which are used to gauge the overall health of particular site (Coysh *et al.* 2000). Data is presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating bands (Tables 4 and 5).

Site assessments are based on the results from both the riffle and edge samples. The overall site assessment was based on the furthest band from reference in a particular habitat at a particular site. For example, a site that had a Band A assessment in the edge and a Band B in the riffle would be given an overall site assessment of Band B (Coysh *et al.*, 2000b). In cases where the bands deviate significantly between habitat (e.g. D – A) an overall assessment is avoided due to the unreliability of the results.

The use of the O/E 50 scores is standard in AUSRIVAS. However it should be noted that this restricts the inclusion of rare taxa and influences the sensitivity of the model. Taxa that are not predicted to occur more than 50% of the time are not included in the O/E scores produced by the model. This could potentially limit the inclusion of rare and sensitive taxa and might also reduce the ability of the model to detect any changes in macroinvertebrate community composition over time (Cao *et. al.*, 2001). However, it should also be noted that the presence or absence of rare taxa does vary over time and in some circumstances the inclusion of these taxa in the model might indicate false changes in the site classification because the presence or absence of these taxa might be a function of sampling effort rather than truly reflecting ecological change.

Table 3. AUSRIVAS band-widths and interpretations for the ACT SPRING riffle and edge models

	RIFFLE	EDGE	
BAND	O/E Band width	O/E band width	Explanation
X	>1.14	>1.13	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.86-1.14	0.87-1.13	Similar to reference. Water quality and / or habitat in good condition.
B	0.57-0.85	0.61-0.86	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.28-0.56	0.35-0.60	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	0-0.27	0-0.34	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

2.6.4 SIGNAL-2 (Stream Invertebrate Grade Number – Average Level)

Stream Invertebrate Grade Number – Average Level (SIGNAL) is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families that have been derived from published and unpublished information on their tolerance to pollutants, such as sewage and nitrification (Chessman, 2003). Each family in a sample is assigned a grade between 1 (most tolerant) and 10 (most sensitive). Sensitivity grades are also given in the AUSRIVAS output which can then be used as complimentary information to these assigned bandwidths to aid the interpretation of each site assessment.

2.6.5 Periphyton

To test whether estimated biomass (as AFDM) and live content (Chlorophyll-a) were different between sites upstream and downstream of the MPS, a mixed effects nested analysis of variance (ANOVA) was fitted to the log transformed data. Sites were nested within location. Site was treated as a random effect, while location was treated as a fixed effect. Log transformations were necessary to meet the assumptions of normality. For the purposes of graphical visualisation however, raw data are presented.

2.7 Macroinvertebrate quality control procedures

A number of Quality Control procedures were undertaken during the identification phase of this program including:

- Organisms that were heavily damaged were not selected during sorting. To overcome losses associated with damage to intact organisms during vial transfer, attempts were made to obtain significantly more than 200 organisms.
- Identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience.
- When required, taxonomic experts performed confirmations of identification. Reference collections were also used when possible.
- ACT AUSRIVAS QA/QC protocols were followed.
- An additional 10% of samples were re-identified by another senior taxonomist.
- Very small, immature, or damaged animals or pupae that could not be positively identified were not included in the dataset.

All procedures were performed by AUSRIVAS accredited staff.

2.8 Licences and permits

All sampling was carried out with current NSW scientific research permits under section 37 of the Fisheries Management Act 1994 (permit number P01/0081(C)).

Ecowise field staff maintain current ACT AUSRIVAS accreditation.

3 Results

3.1 Hydrology and rainfall

Rainfall was highest in October, with 90.6 mm and lowest in November with 11mm (recorded at Lobb's Hole: 410761). There were 38 wet days in spring (compared to 19 in autumn), with 16 days recorded in October, 13 in September and 9 in November. Total daily rainfall ranged from the detectable minimum of 0.2mm to 28 mm. There were four days in which the daily total exceeded 15mm two days in late October and two days in September. The two events in October (28mm and 17.8mm) occurred within three days of each other and triggered a spate* affecting all sites downstream of Bredbo.

As a result of the increase in rainfall, the average flow during spring was 277 ML/d (approximately 15 times higher than the autumn average flow) (Figure 2; Table 4) at Lobb's Hole (410761), while average flows recorded at Mt. MacDonald (410738) for spring were 418 ML/d (Table 4).

A high flow event registered on the 2nd of November at Lobb's Hole which peaked at 1605 ML/d. Flows decreased to pre-event levels within 24 hours and steadily declined to below 60 ML/d by the end of November. The spate passed Mt. MacDonald on the 3rd of November where it peaked at 1690 ML/d. The recession curve followed a similar pattern to Lobb's Hole with flows receding rapidly to pre-spate conditions. Following this event, rainfall essentially ceased with only a further 8mm falling in November.

** Ecowise recognise that there is a stand down period of four weeks following floods (Coysh et al., 2000b), however in this case the timing of the sampling program meant that, if the obligatory 4 week waiting period was adhered to sampling would have overlapped into summer, for which AUSRIVAS predictive models do not apply. Further, the majority of sampling was completed before the high flow event occurred. It was felt that by sampling over one continuous sampling period, rather than two disrupted periods, the potential biasing influence of other sources of variation (e.g. seasonal changes in water temperatures, light incidence, recruitment, etc) might be avoided.*

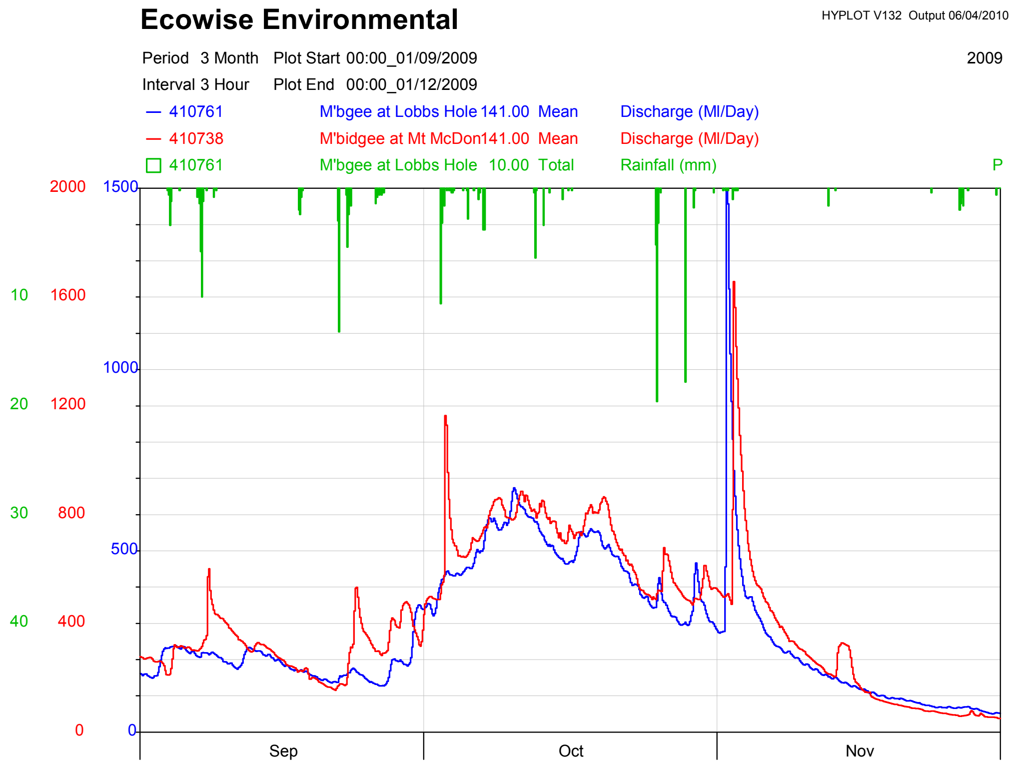


Figure 2. Spring hydrograph of the Murrumbidgee River at Lobb's Hole (red) and Mount McDonald (blue). Total rainfall (mm) is shown in green**.**

Table 4. Spring rainfall and flow summary for Lobb's Hole and Mt. MacDonald.

Flow values are daily means. Rainfall is total (mm).

Site	Lobb's Hole (410761)		Mt. MacDonald (410738)
	Rainfall Total (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)
September	63.4	189.8	307.9
October	90.6	459.5	682.1
November	11.0	184.3	265.9
Spring mean	164.4	277.8	418.6

The continuous water quality data obtained from Lobb's Hole for the period 1/09/09-30/11/0

The four week gap in the pH data series is due to a lightening strike in late September dama
conductivity and turbidity were the most variable parameters throughout spring resulting fro

Turbidity exceeded the ANZECC and ARMCANZ (2000) guidelines (based on daily means)
September was only marginally over the 25 NTU upper limits for healthy ecosystems, with d
later in the month NTU recordings ranged form 1.8-3.3 NTU. These low values continued fo
heavier rainfalls in the catchment turbidity spiked to a daily mean of 1463 NTU and remaine
26 -1660 NTU until mid-December, when the weather stabilised.

Temperature, and electrical conductivity fluctuated with river flow (Figure 3). Water tempera
temperate and increased steadily over the coarse of spring from September (mean = 13.5) t
during periods of high flow (Figure 3) but increased following the high flow event in early No
monthly average of 91 µs/cm in November with daily means peaking at 104 µs/cm. There w
from Lobb's Hole. Monthly means ranged from 7.7-7.9 though there was a loss of data thro

3.2 Water quality

The nutrient levels recorded in spring exceeded ANZECC and ARMCANZ (2000) recommendations, as they did in autumn. The highest levels were recorded at MUR 931, upstream of the MPS (Table 6), with total nitrogen being ~40% higher and total phosphorus 60% higher than the concentrations recorded in autumn. Electrical conductivity readings were below the recommended minimum values, ranging from 19-22 µs/cm. Turbidity exceeded the upper guideline limit of 25 NTU at each site. The highest values were recorded upstream of the MPS, but this reflects the fact that the downstream sites were sampled a day later as the hydrograph was still receding, so does not reflect a location related impact (Table 5).

3.3 Periphyton

Average ash free dry mass (AFDM) was considerably lower than the estimates from autumn. The average upstream of the MPS was 148.7 mg/m$^{-2,}$, while the downstream mean was 119.78 mg/m^{-2}. These results were not statistically different ($F_{1,29}$ = 3.72, P= 0.14; Figure 4). Estimated AFDM was approximatelty ten times lower than the estimates from autumn. Increased current velocity explained ~75% of the variation in the AFDM data set (based on site means) (R^2 =0.76; $P<0.05$) but caution should be taken in extrapolating this finding to predict periphyton biomass responses o variation in flow because of the small sample size.

The average chlorophyll-a concentration was higher upstream of the MPS (mean = 18236 µg/m^{-2}) compared to downstream (mean = 5079 µg/m^{-2}). Despite these differences, the results were not statistically significant ($F_{1,29}$= 2.81, P=0.19) based on log transformed data (Figure 4). There were also no between site differences in AFDM ($F_{3,29}$= 1.07, P=0.95) or chlorophyll-a ($F_{3,29}$= 1.65, P=0.2) despite some apparently higher concentrations at MUR 28 and MUR 935.

There were no strong relationships in either AFDM or chlorophyll-a in any of the habitat parameters, as there were in autumn 2009. The moderate negative relationship between flow and AFDM was not evident for Chlorophyll-a (R^2=0.11) indicating that the unexplained variation might be associated with some unmeasured factor.

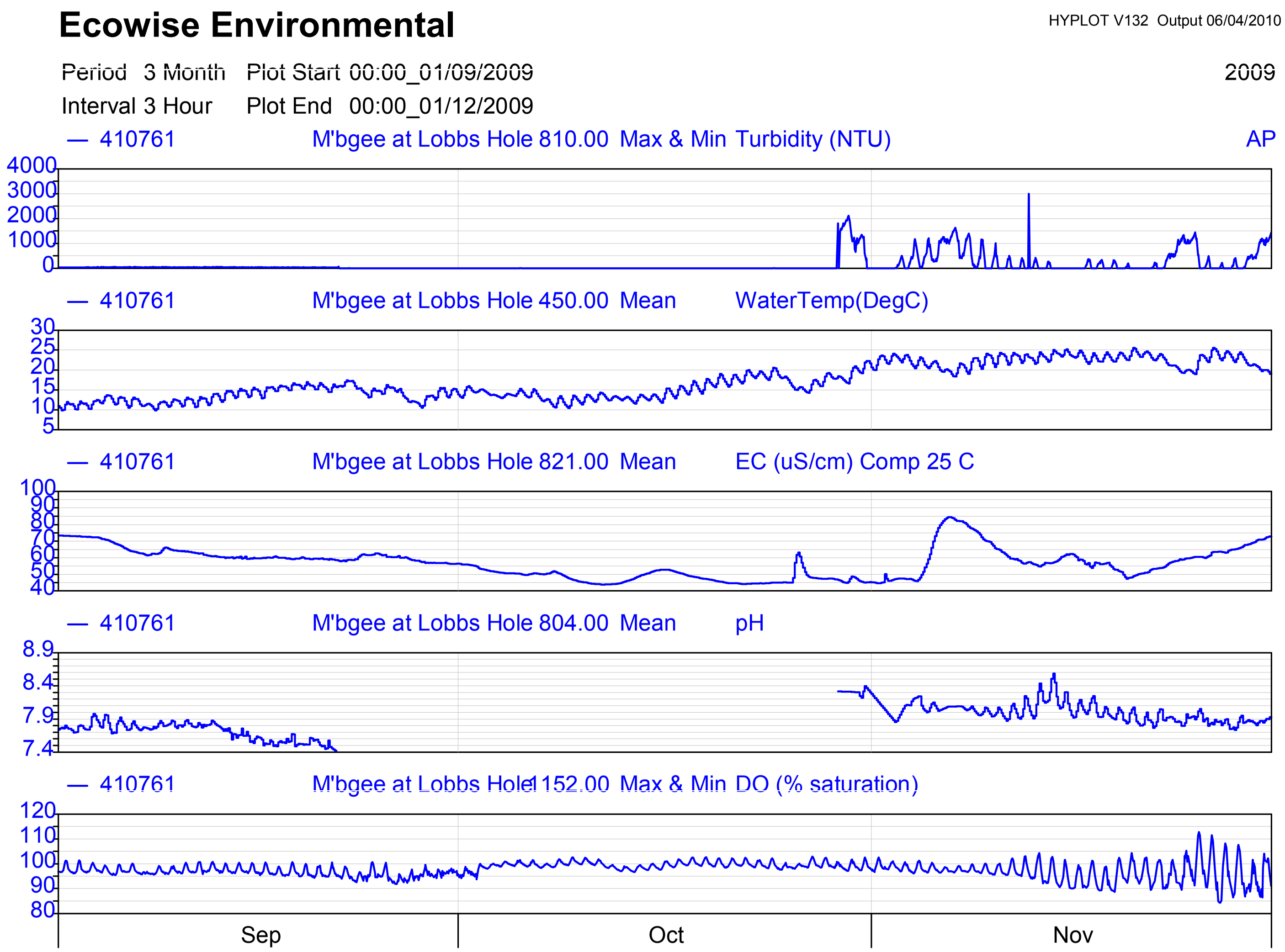


Figure 3. Water quality records from Lobb's Hole during spring 2008

Table 5. In-situ water quality and nutrient results from spring 2009 (ANZECC guideline values are in red). Yellow cells indicate values outside of ANZECC guidelines.

Location	Site	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	pH (6.5-8)	D.O. (% Sat.) (90-110)	D.O. (mg/L)	Alkalinity	NOX (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Total Phosphorus (mg/L) (0.02)	Total Nitrogen (mg/L) (0.25)
Upstream	Mur 0931	0700	21.3	22	54	7.4	92.4	7.6	28.2	<0.01	<0.01	<0.01	<0.01	0.08	0.62
	Mur 28	1400	24.7	19.1	60	7.7	107.4	8.3	26	<0.01	<0.01	<0.01	<0.01	0.07	0.57
Downstream	Mur 0935	100	22.5	22.5	36	7.4	105.5	8.5	26	<0.01	<0.01	<0.01	<0.01	0.07	0.57
	Mur 0937	0600	22.8	22.3	41	7.2	90	7.3	33.2	<0.01	<0.01	<0.01	<0.01	0.06	0.54
	Mur 29	1430	26.4	20.9	37	7.8	113.2	8.5	27.8	<0.01	<0.01	<0.01	<0.01	0.07	0.53

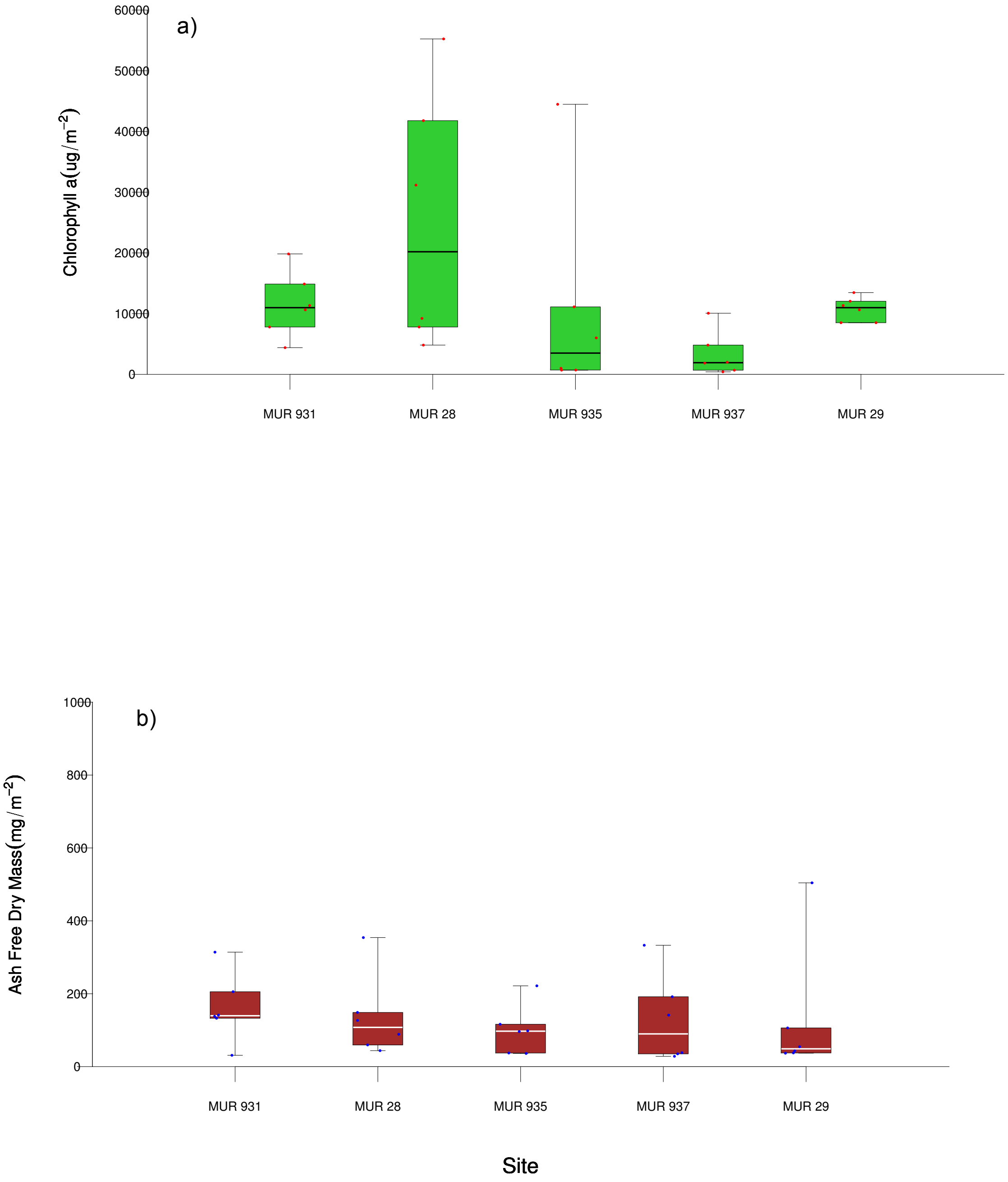


Figure 4. The distribution of a) Chlorophyll-a and b) Ash Free Dry Mass (AFDM) up - and downstream of the MPS.

Strip chart values (in red) represent the raw data values for each site. See APPENDIX A for an explanation of how to interpret the box and whisker plots

3.4 Macroinvertebrate communities

Statistically, there were no differences in the riffle macroinvertebrate assemblages between locations (i.e. upstream and downstream of the MPS) (R=-0.163; P=0.4), nor were there upstream – downstream differences detected in community composition based on edge habitat sample data (R=-0.167; P=0.8). However, for both habitats, individual sites tended to vary significantly from each other, albiet with low similarity coefficients [edge: R=0.405; P=0.1; riffle: R=0.369; P=0.1] (APPENDIX B).

The negative r-values indicate that samples within a given group are more similar to samples of a different group than they are to samples drawn from within their own group (Clarke & Warwick, 2001). For example, the samples from MUR 931 in upstream riffle habitat can be seen to overlap with riffle habitat samples taken downstream of the MPS (Figure 7). For the edge samples, this was evident in the grouping of MUR 28 and MUR 937 in Figure 8.

The moderate stress levels indicated in the NMDS plots (Figure 7 and 8) suggest that the graphical representation of the relationships between samples presented in these plots should be interpreted with caution and that they should be viewed in conjunction with the outputs of the cluster analysis to see if the same patterns hold. Results for the cluster analysis for riffle habitat and edge habitat are presented in Figure 5 and 6. Results of the cluster analysis are generally in agreement with those for the NMDS plots based on the superimposed clusters.

3.4.1 Riffles

The number of invertebrate taxa recorded in the riffle zones varied from 13 families at MUR 937 to MUR 931 where 20 families were collected (Figure 9). Genus richness was also highest at MUR 931 also with 29 genera collected at this site and lowest at again at MUR 935 and MUR 28, both with 20 genera.

All sites were dominated by three major groups of pollution tolerant taxa: Oligochaetes (SIGNAL =2), Chironomids (SIGNAL =3) and Simulids (SIGNAL =5) (Figure 10). Collectively, these taxa contributed between 63% (MUR 931) and 96% (MUR 935) of the total macroinvertebrate community abundances. *Austrosimulium sp*. was the main genus represented in the Simulids, while Orthocladiinae and Chironominae were the two dominant Chironomid sub-families.

A distinct pattern of change that occurred between the three major taxonomic groups represented. Upstream at MUR 931, Chironomids were the dominant group, with Simulids and Oligochaetes making up on average 11 and 43 % of the total abundance. Downstream of the MPS, Simulids were dominant accounting for more than 65% of the total abundance. There were fewer Simulids again downstream at MUR 29 (Uriarra Crossing), with this group only accounting for 6% of the total abundance at this site. Chironomids made up 45% of the total abundance at MUR 29. The number and diversity of Mayflies (Ephemeroptera) at this site was notably higher than that recorded at sites upstream.

Sensitive taxa were generally poorly represented both numerically (Figure 8) and in terms of diversity at all sites. Relative abundances of EPT and other sensitive taxa (SIGNAL ≥7) had declined by as much as 55% since autumn 2009, although there was an 11% increase at MUR 937 (Mt. MacDonald). Plecoptera (stoneflies) were almost entirely absent from all of the sites, the exceptions being the collection of a few individual collected at MUR 931, 28 and 935. These taxa were entirely absent in autumn.

The most abundant taxa from the EPT suite were *Tasmanocoenis sp.* (Caenidae: SIGNAL=4), *Ecnomus sp.* (Ecnomidae: SIGNAL =4); *Cheumatopsyche sp*. (Hydropsychidae: SIGNAL = 6). Leptophlebiidae (SIGNAL =8) were absent from many of the samples between MUR 931 and 935 in low numbers, but became more common and abundant at MUR 937 and MUR 29, particularly *Jappa sp.*.

3.4.2 Edges

The edge habitat communities were more diverse the riffles (Figure 8). Genus richness ranged from 20 (at MUR 29) to 31 (MUR 28). Family richness ranged from 17 to 22 at the same sites respectively.

The edge samples were dominanted by pollution tolerant taxa with low to intermediate SIGNAL -2 scores, such as Oligochaeta (SIGNAL = 2), Simulids, two dominant sub-families of Chironomids: Orthocladiinae and Chironominae,), *Micronecta sp*. (Corixidae) and Hellyethira sp. & Oxyethira sp. (Hydroptilidae: SIGNAL =4). These taxa all featured as the seven most dominant across these sites, but in different orders of relative abundance. Generally however, the Oligochaeta Orthocladiinae and Chironominae *Micronecta sp*. were the most abundant taxa in these samples.

The introduced snail, Physa acuta (Gastropoda) was also common particularly at MUR 29 and MUR 931 and the mayfly, Tasmanocoenis sp. (Caenidae: SIGNAL =4) were also commonly found in most samples although only in relatively low abundances (20-100 individuals). Notably, Baetidae, a usually ubiquitous and highly abundant family of mayfly were poorly represented in the samples with only a few individuals found at MUR 931 and downstream at Mt. MacDonald (MUR 937).

3.5 AUSRIVAS assessment

There was no reliable assessment available for MUR 931 or the edge at MUR 29 due to large deviations in the subsamples at the sites. MUR 931 ranged from BAND A to BAND C in both the riffle and edge samples while at MUR 29 the discrepancy only applied to the edge habitat. Based on site averages however MUR 931 and 29 are considered to be "significantly impaired" or BAND-B which is in accordance with the remaining sites in this program (Table 6). When both habitats are under assessment, the AUSRIVAS assessment protocols require that the overall assessment should be based on the lowest value of the two. However, in cases where the bands deviate significantly between habitat (e.g. D – A) an overall assessment is avoided due to the unreliability of the results (Coysh *et al.*, 2000a).

On average the upstream riffles had a higher ratio of observed to expected macroinvertebrate families (O/E upstream = 0.71) compared to the downstream sites (O/E downstream = 0.68) but these differences were not statistically significant ($F_{1,28}$=0.35; P=0.61). The edges on the other hand were identical with upstream and downstream locations both having average O/E scores of 0.82.

The SIGNAL scores suggested that while there were slight differences in the ratios of the riffle habitats, they both contained a moderately-tolerant suite taxa with average SIGNAL scores of 4.79 and 4.81 at the upstream and downstream sites respectively. The average SIGNAL score results from the edge samples were almost identical with 4 and 4.1 scored respectively from the combined upstream and downstream sites.

Compared to autumn of this year, there has been an improvement in the edge habitat at MUR 937 from BAND C to BAND B, resulting in an improved site assessment. The sites with no reliable assessment contained two BAND C assessments, which were not found in autumn. The remaining sites were unchanged since autumn. Only MUR 28 and 29 were sampled in spring 2008, so annual spring comparisons are restricted to these two sites. MUR 28 received the same assessment as spring 2008 while similar results were also found at MUR 29 (no reliable assessment in the riffle zone), suggesting that this site is naturally variable in the distribution of its fauna..

The taxa predicted to occur with ≥50% probability, but absent from each habitat and site are presented in APPENDIX C.

Sites MUR 931 and MUR 935 had the most taxa missing in the riffle zone (10) while at MUR 29 there were 7 missing taxa from one of the edge subsamples. In the edge the range of missing taxa was broadest at MUR 931 and MUR 29 which is the cause of the unreliable assessment. Most of the missing taxa in the habitat were moderately tolerant macroinvertebrates (e.g. Baetidae: SIGNAL =5; Tanypodinae: SIGNAL =4 and Ceratpogoninae: SIGNAL =4). Sensitive taxa were present at most sites but in lower numbers. Gripopterygidae (SIGNAL =8) was completely absent from MUR 935 and MUR 29, but the equally sensitive Leptophlebiidae were present at all of the sites in at least one sample.

The riffle samples were indicative of communities following high flow disturbances. Many of the common taxa were absent, including Elmidae (SIGNAL=7), Tipulidae (SIGNAL =5) and Psephenidae (SIGNAL=6), whereas many of the more tolerant and early colonists and such as Chironominae (SIGNAL = 3), Ceratpogoninae (SIGNAL =4) and Simuliidae were present in all of the samples. Several sensitive taxa were missing at each site including the highly sensitive Caddisfly, Glossosomatidae (SIGNAL=9), which was only collected in one subsample from MUR 29 (Uriarra Crossing). Gripopterygidae (SIGNAL =8) was collected at MUR 931, 28 and 935 but was missing from the remaining two sites. The caddisfly, Conoesucidae (SIGNAL =7) was rare in this sampling run, only being present in one sample at MUR 931.

Table 6. AUSRIVAs and SIGNAL scores for spring 2009

SITE	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
Mur 931	1	5.5	4.11	1.03	1	A	A	**NRA**	**NRA**	**NRA**
Mur 931	2	4.57	3.5	0.52	0.66	C	B			
Mur 931	3	4.29	3.4	0.52	0.55	C	C			
Mur 931	4	5.1	4.17	0.74	0.66	B	B			
Mur 931	5	4.8	4.14	0.74	0.78	B	B			
Mur 931	6	-	-	-	-	-	-			
Mur 28	1	4.7	3.78	0.75	1	B	A	**B**	**B**	**B**
Mur 28	2	4.4	4.67	0.75	1	B	A			
Mur 28	3	4.67	4.56	0.67	1	B	A			
Mur 28	4	4.75	3.88	0.6	0.89	B	A			
Mur 28	5	4.38	4.13	0.6	0.89	B	A			
Mur 28	6	5.1	3.86	0.75	0.78	B	B			
Mur 935	1	5.25	3.83	0.89	0.66	A	B	**B**	**B**	**B**
Mur 935	2	4.78	4.11	0.67	1	B	A			
Mur 935	3	5	4	0.74	0.89	B	A			
Mur 935	4	4.78	4.67	0.67	1	B	A			
Mur 935	5	4.38	4.14	0.67	0.78	B	B			
Mur 935	6	4.33	4.25	0.67	0.89	B	A			
Mur 937	1	4.78	4.67	0.67	1	B	A	**B**	**B**	**B**
Mur 937	2	4.75	4.14	0.67	0.78	B	B			
Mur 937	3	5	4.25	0.67	0.89	B	A			
Mur 937	4	5.1	-	0.74	-	B	-			
Mur 937	5	4.7	-	0.74	-	B	-			
Mur 937	6	5	-	0.82	-	B	-			
Mur 29	1	5.18	4.14	0.82	0.78	B	B	**B**	**NRA**	**B**
Mur 29	2	4.78	3.78	0.67	1	B	A			
Mur 29	3	4.78	3.5	0.67	0.66	B	B			
Mur 29	4	4.78	4.14	0.67	0.78	B	B			
Mur 29	5	4.91	4.13	0.82	0.89	B	A			
Mur 29	6	4.91	3.75	0.74	0.44	B	C			

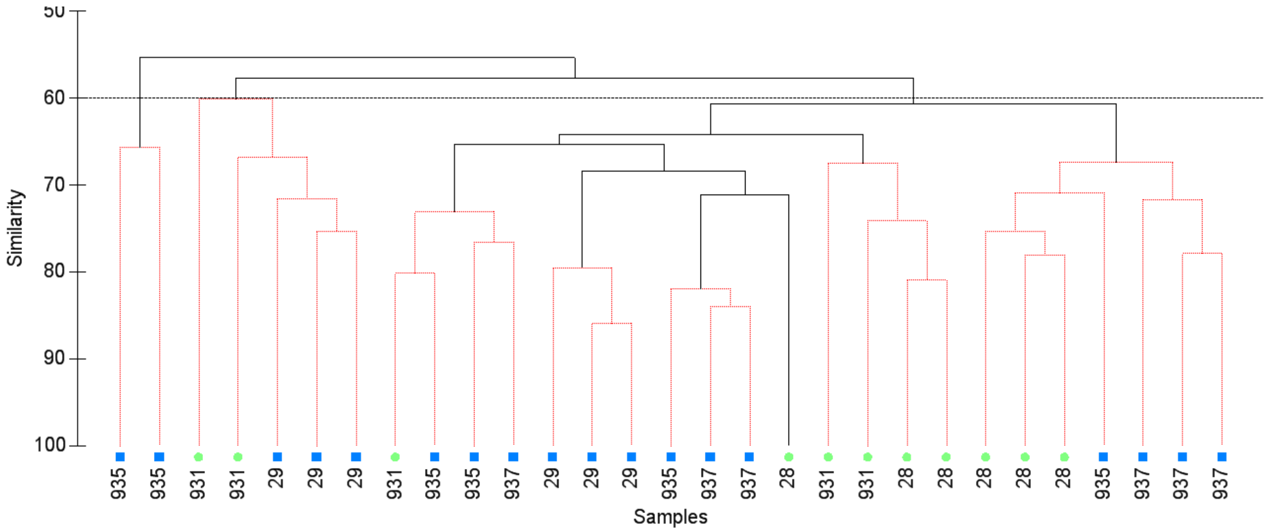


Figure 5. Cluster analysis of riffle samples in spring 2009

Green circles are upstream of the MPS, blue squares are downstream.

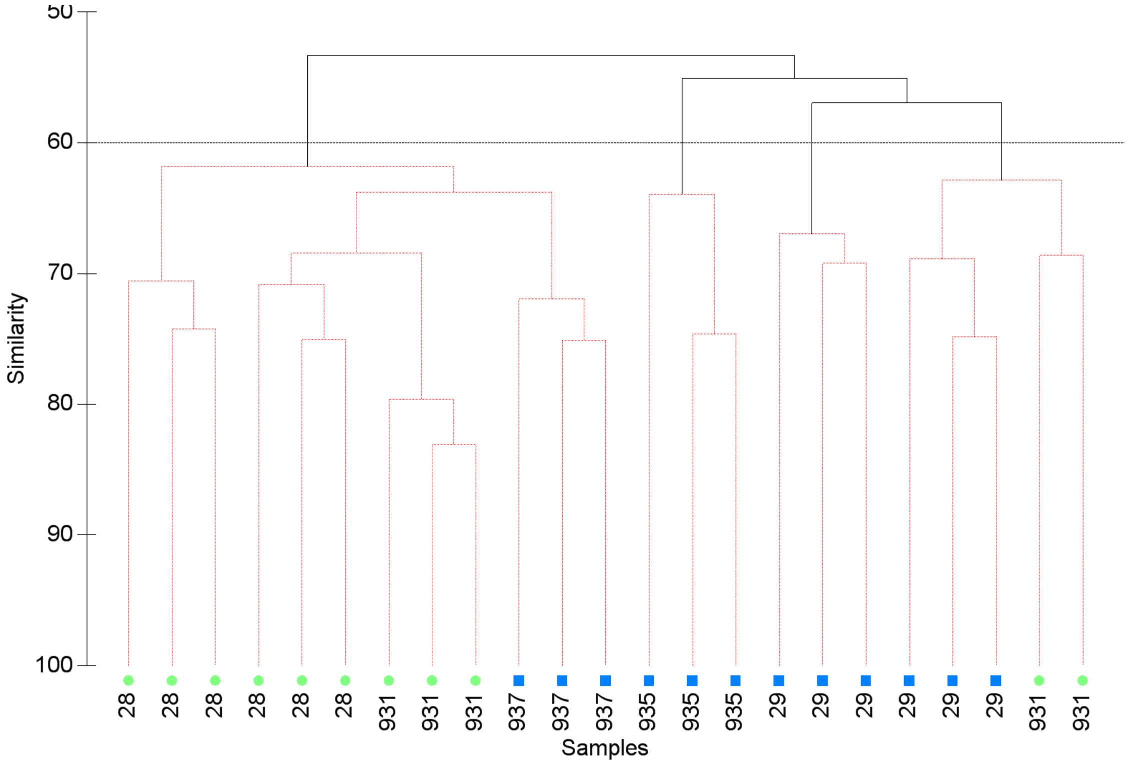


Figure 6. Cluster analysis of edge samples in spring 2009

Green circles are upstream of the MPS, blue squares are downstream

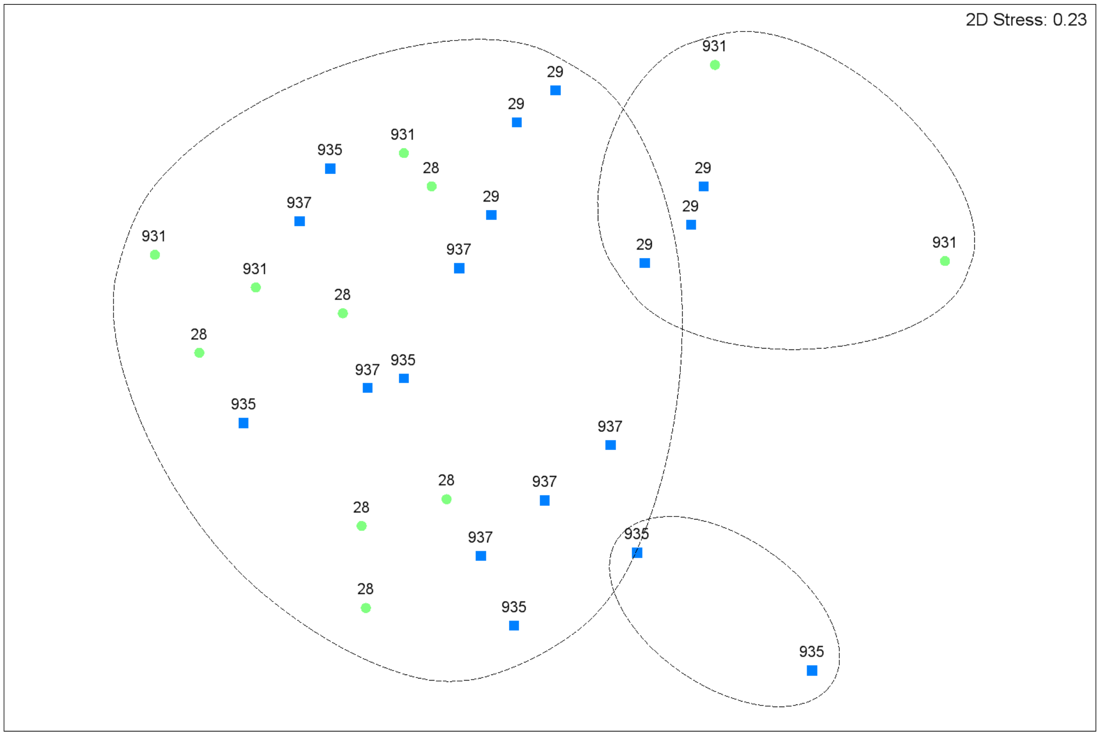


Figure 7. NMDS plot of riffle samples taken in spring 2009

Green circles are upstream of the MPS, blue squares are downstream. Ellipses represent the 60% similarity groups superimposed from the cluster analysis

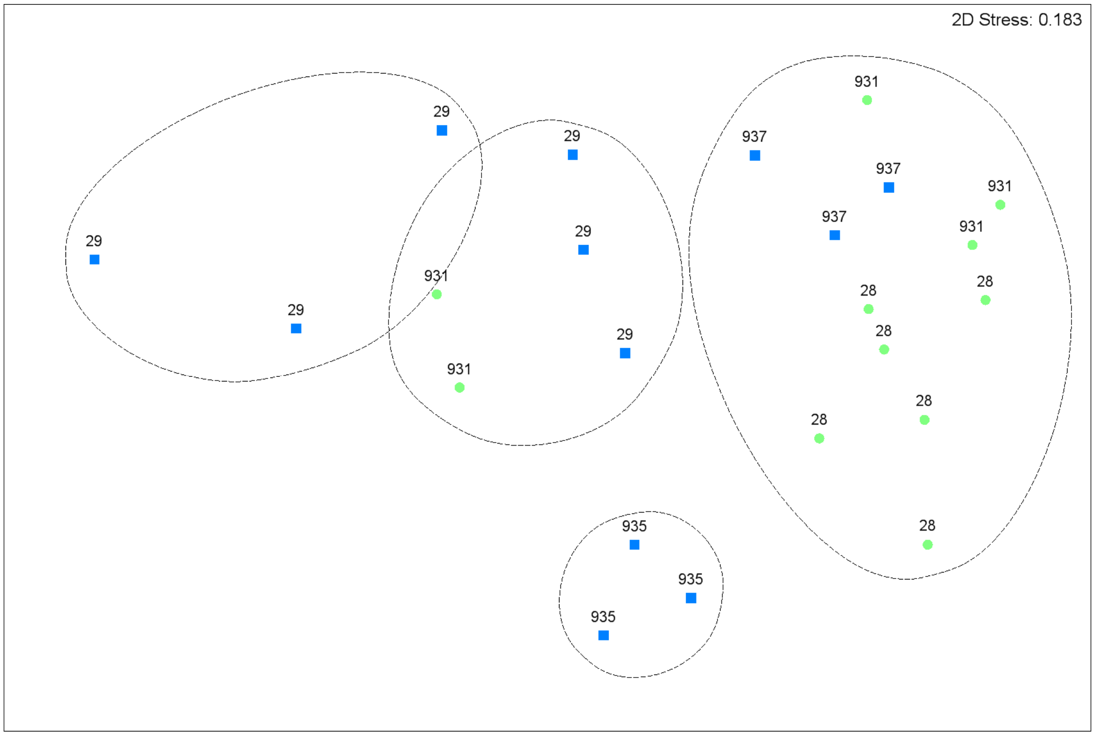


Figure 8. NMDS plot of edge samples taken in spring 2009

Green circles are upstream of the MPS, blue squares are downstream Ellipses represent the 60% similarity groups superimposed from the cluster analysis

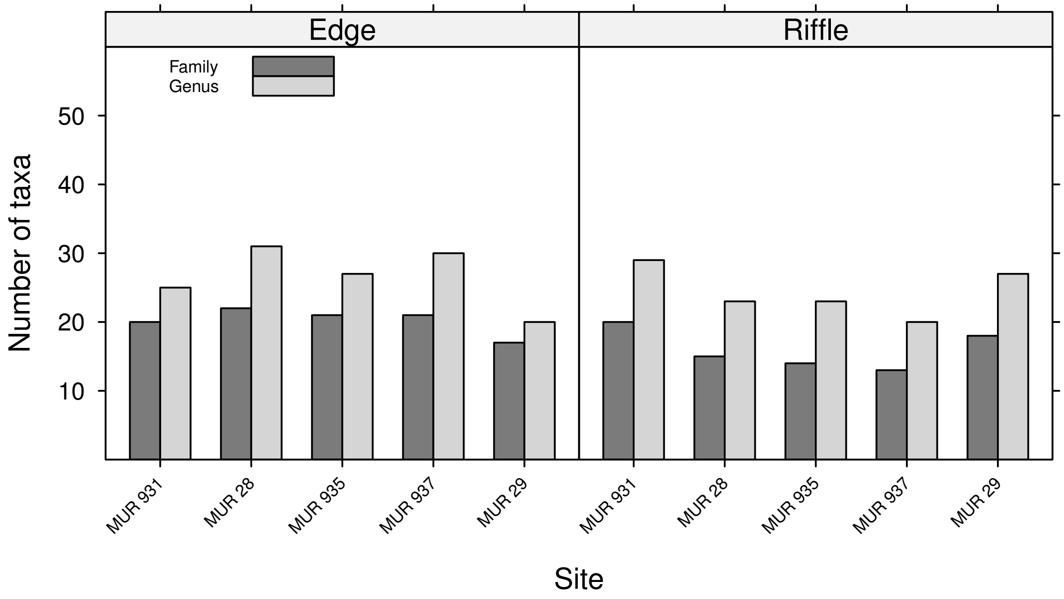


Figure 9. Family and genus richness

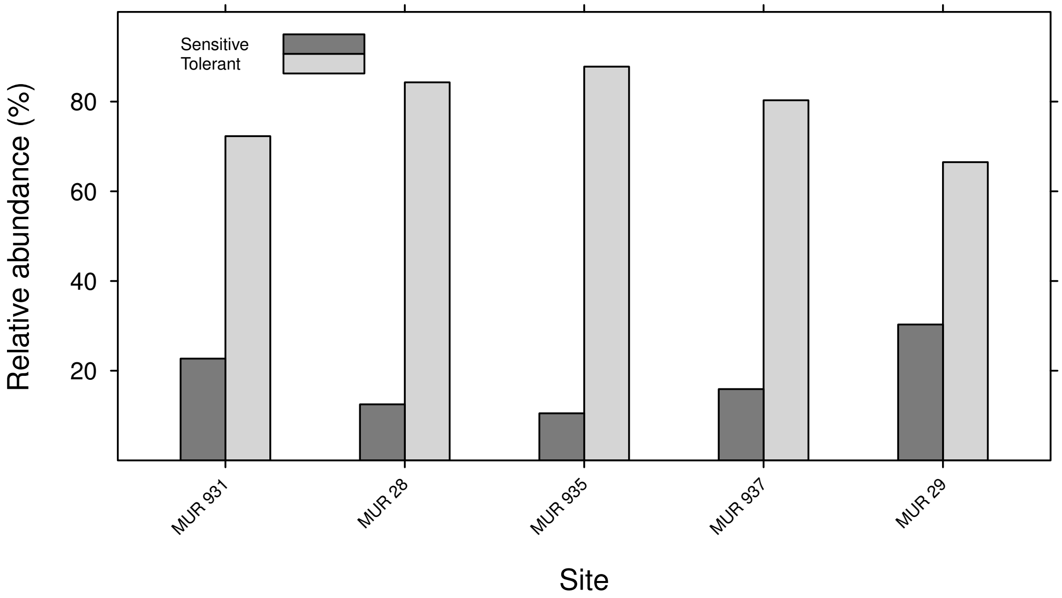


Figure 10. Relative abundance of sensitive (EPT) and tolerant taxa.

EPT is a commonly used metric comprising the relative abundance of Ephemeroptera (mayflies); Plecoptera (stoneflies) and Trichoptera (Caddisflies). Tolerant taxa are comprised mainly of Oligochaeta (worms); Chironomids (non-biting midges) and other Diptera (true flies).

Figure 11. Top: looking upstream to the Cotter confluence; Bottom: looking downstream towards Casuarina sands

*At the time these photographs were taken (10/11/2009), the mean daily flow recorded at Mt. MacDonald (410738) was **287 ML/d**

4 Discussion

4.1 Water quality and periphyton

The water quality parameters all responded to changes in flow throughout spring. Electrical conductivity for example decreased through much of September and October as high flows had a dilution effect. The spike in early November reflected a higher input of solutes from surface run off, which declined as flows receded and gradually increased as the onset of summer brought lower flows, which, in turn, concentrated existing salts in the system.

The results from the grab samples show that almost all the analytes were within the ANZECC & ARMCANZ (2000) water quality guidelines, except TN and TP concentrations, which were over the guideline limit,electrical conductivity which were under the recommended lower limit and dissolved oxygen which exceeded the guidelines by a marginal 3.2%. The slightly high D.O. reading was most likely related to the time of day the sample was taken (mid-afternoon), which is when photosynthesis is at its peak. The continuous records indicate that the during the diurnal cycle, there was approximately 20% variation around the daily mean value.

Nutrient values are more than double the guideline values in some cases (TP) which could be problematic if they remain high, during periods of stable flow; as this will encourage algal growth. The elevated nutrient levels were higher than those recorded in autumn (Ecowise, 2009) and is probably due to surface runoff from the high rainfall during spring, these levels can create problems to the health of river systems by increasing periphyton biomass (where nutrients are limiting) and causing proliferations of filamentous algae growth. This in turn can result in alterations in water quality (specifically declines in pH and can alter the diurnal patterns in dissolved oxygen), degrade the aesthetics of rivers and streams, cause operational difficulties (e.g. clogging intake valves) and have been related to reduced numbers of sensitive taxa in the macroinvertebrate communities (Suren *et al.*, 2003). However, as noted by Biggs and Close (1989) periphyton biomass can only respond to increased nutrient availability during periods of stable low flows. The proposed increase in water abstraction will not affect the magnitude and timing of high flows, but the lower flow velocities associated with abstraction may increase nutrient availability through increased residence time (particularly in seasonal low flow periods).

During spring, flows fluctuated extensively (Figure 2) so despite the higher nutrient loads during this period in early November, it is unlikely that the AFDM and Chlorophyll-a data presented in this report (Figure 4 a & b) represent responses to increased nutrient levels, but instead are an indication of natural responses to these high flows. Chlorophyll-a levels were higher than autumn at MUR 28 and MUR 935, while AFDM showed significant declines since autumn.

The decline in AFDM is likely to be a response to the high flows that persisted through October and reached a spring maximum following the high flow event in early November (Figure 2). However, the correspondingly low fluctuations in chlorophyll-a concentrations (relative to the changes in AFDM) could have been be because, prior to the high flows, the standing stock was very high such that chlorophyll-a concentrations remained relatively high despite some scour removal of periphyton. Biggs and Close (1989), for example found that pre-flood levels of chlorophyll-a were more important than the event itself in determining post flood levels. Alternatively, there could have been rapid recruitment of autotrophic organisms in the periphyton samples. Diatoms for example have been shown to recover within 2 days of high flow disturbances (Grimm & Fisher, 1989). Another explanation is the runoff from adjacent access roads for the MPS upgrade just upstream of MUR 28 (Figure 10 top) could have stimulated growth during this period.

4.2 River health

The AUSRIVAS river health assessment indicates that the section of the Murrumbidgee River within the limits of this program was under considerable stress in November 2009. All sites sampled were "*significantly impaired*" (BAND –B) based on the AUSRIVAS spring model, indicating that several of the taxa predicted to occur were missing from the samples. Most of the missing taxa are sensitive, free-swimming taxa forming the group of taxa: EPT, but also contained Elmidae, which were missing from >80% of the samples and when present, were in very low abundances (<15 individuals). There was a marked increase in Oligochaetes (worms) since autumn, making up to 40% of total the abundances in some samples. There were also, notably large increases in Chironomids and Simulids, which made up between 45% and 80% of total abundances recorded at various sites, respectively. Taxonomic richness had also decreased since autumn, which is a reflection of the uneven structure of the communities (i.e. dominated by three or four highly abundance taxa).

While these results are consistent with other studies looking at the effects of construction related impacts (Cline *et al.*, 1982; Chessman *et al.*, 1987; Hedrick *et al.*, 2010), they are also consistent with studies showing how communities respond to high flow disturbances, such as floods and high flow events (Molles JR., 1985; Collier & Quinn, 2003; Suren & Jowett, 2006; Miller *et al.*, 2007). There are several lines of evidence from this study to suggest that it is the later, which has produced the results found in this study.

First, the fact that all of the metrics used in this assessment showed no statistical difference between the upstream and downstream sites, such as SIGNAL and O/E scores (Table 6), EPT (Figure 10) and relative abundances of both sensitive and tolerant taxa showed no differences between locations (i.e. the absence of sensitive taxa was not limited to sites downstream of the MPS) (Figure 10) suggests, that a broad scale impact such as the spate occurring in early November, affected these sites rather than a point source impact, such as MPS related works. Furthermore, there were also non-significant results from the ANOSIM analysis, and no separation between upstream and downstream sites in the NMDS ordination plots (Figures 7 and 8).

One of the key impacts of high flow disturbances is scouring and dislodgement caused by high shear stress across the substrate (Collier & Quinn, 2003) resulting in low taxa diversity, reduced abundances of sensitive and usually common taxa and the removal of snags, detritus and other key invertebrate habitat (Hynes, 1970a; Resh *et al.*, 1988) compared to pre-sevent conditions. The resulting communities (as seen in this study) are often dominated by Chironomids, Simulids and Oligochaetes (Molles JR., 1985; Miller & Gollady, 1996).

Oligochaetes will survive flood impacts because, being sediment dwellers (Hynes, 1970b) they are not exposed to the pressure exerted by the high flows. Chironomids also reside in silty substrates and may not be exposed to the same stressors as the more sensitive, free swimming taxa. Their high abundance might be attributed partially to their ability to burrow and therefore withstand high flow stress, but also because they are also regarded as rapid colonisers and are some of the first taxa to begin the successive recolonisation process (Niemi *et al.*, 1990). Simuliidae will also rapidly colonise disturbed surfaces (Downes & Lake, 1991) and the very high numbers observed in this study suggests that the community overview presented here represents the early stage of the colonisation process given their preference for clean, relatively silt free surfaces (Harrod, 1964; Downes & Lake, 1991).

Despite the dominance of these tolerant taxa, there was evidence to suggest that prior to the high flow event, communities were showing signs of improvement from the drought stress that affected these communities in autumn. For example, in the riffle, Gripopterygidae (SIGNAL=8) were collected for the first time at three sites (two upstream and one at Casuarina sands, immediately downstream of the MPS). This could be an indication of improving water quality conditions (e.g. higher dissolved oxygen and cooler temperatures) with increasing surface flow prior to the spate. Other taxa were present that were not collected in autumn, but because they were not predicted by the model, this indicates that their appearance in this sampling run is probably due to seasonality rather than responses to improved conditions.

Sedimentation is a leading cause of degraded water quality and habitat conditions during construction works (Chessman *et al.*, 1987; Doeg *et al.*, 1987; Hedrick *et al.*, 2010). If there were increased sediment loads from the MPS, the edge habitat might also show signs of sediment related impacts because they act as sediment sinks (Cline *et al.*, 1982; Norris & Norris, 1995). During this sampling period it was difficult to determine because this reach of the Murrumbidgee remained turbid for several weeks following the November high flow event (Figures 3 and 11). As with the riffle samples however, there was no evidence from these results to suggest any impact from the MPS related works due to non-significant differences in any of the macroinvertebrate community related metrics derived from these data (Figures 7 -10). The only indication of any sediment-related effect comes from the absence of the sediment sensitive *Baetis sp.* (Baetidae) and *Jappa sp.* (Leptophlebiidae) at three sites (APPENDIX C) which have until this sampling run been common in many of the samples. However, the absence of these taxa was both upstream and downstream of the MPS and is more likely related to the high flow event in early November.

Estimating sediment deposits will be possible when the cross-sectional survey data become available. Seasonal reporting will benefit from adding total suspended solids (TSS) to the suite of water quality because this will allow the quantification of fine sediment transport over the study period. Estimates of TSS from turbidity data can vary considerably depending on the size and duration of the event and where on the hydrograph the samples are collected, and as such it is advisable to include TSS in the next sampling run.

5 Conclusions

There has been no evidence to date to indicate any impacts on water quality from the construction works, as both upstream and downstream sites have recorded almost identical reading from the majority of the parameters tested in spring (and autumn) 2009. Similarly, the macroinvertebrate data has indicated that the BAND –B, "significantly impaired" assessment at the majority of the sites in this program to date is likely due to non-point source impacts. In autumn for example, the likely cause for the BAND –B assessment was indicated to be the drought conditions impacting the area during the sampling period. While high flows during spring have scoured out and dislodged many of the common taxa expected to occur.

There were slightly larger decreases of sensitive taxa downstream of the MPS since autumn, but these differences were not statistically significant.

There is little indication from the results to suggest that there are any significant downstream effects due to the works associated with the MPS upgrade. Water quality parameters (EC, turbidity and nutrients) were outside the guidelines at each site, suggesting the impacts of high flows are greater than, or were masking the effects of, the works associated with the MPS upgrade (if any there were any).

We consider the current river health assessment to be a result of a spring high flow event which appears to have impacted all sites under the MEMP, downstream of Bredbo. There is little evidence at this stage to suggest that the works associated with the preliminary infrastructure upgrade of the MPS has any direct link to the current river health assessment.

The condition of these sites is likely to improve rapidly following recolonisation assuming further disturbances do not occur in the effected reaches.

6 Recommendations

A condition stated in the Murrumbidgee Pump Station monitoring proposal (section 4.1.5) is that the program is to be adaptive and that the methods, sites, and analysis in previous runs be reviewed so the objectives of ACTEW are being met satisfactorily.

Based on the data presented in this report and the following recommendations are made for future sampling runs and reporting:

1) The level of taxonomic resolution will be addressed more thoroughly when additional data are collected. Preliminary investigations of both the ordinations of family and genus data sets do suggest some overlap (redundancy) of information for the edge habitat data, but there were no such correlations apparent for the riffle data. In fact, the low genus / family ratio indicated in the riffle zone might suggest some loss of information (Lenat & Resh, 2001) if family level identification is perused. In light of this, it is advisable to continue monitoring to genus level with the view that that this be reassessed once two comparable seasons of data become available.
2) One of the causes often cited to cause declines in sensitive taxa, and subsequent changes in macroinvertebrate communities is increased sedimentation downstream of the impact (e.g. Chessman *et al.*, 1987; Hedrick *et al.*, 2010). At this stage, turbidity is being used as a proxy for estimating suspended solids, based on correlational data acquired by Ecowise. However, estimates of TSS from turbidity data can vary considerably depending on the size and duration of the event and where on the hydrograph the samples are collected, and as such it is advisable to include TSS in the next sampling run.

7 Literature Cited

A.P.H.A. (2005) *Standard methods for the examination of water and waste water.21st Edition. American Public Health Association.*

Biggs, B.J.F. (1989) Biomonitoring of organic pollution using periphyton, South Branch, Canterbury, New Zealand. *New Zealand Journal of Marine and Freshwater Research,* **23,** 263-274.

Biggs, B.J.F. (2000) *New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams.* Ministry for the Environment, Wellington.

Biggs, B.J.F. & Close, M.E. (1989) Periphyton biomass dynamics in gravel bed rivers: the relative effects of flow and nutrients. *Freshwater Biology,* **22,** 209-231.

Biggs, B.J.F. & Kilroy, C. (2000) *Stream Periphyton Monitoring Manual. NIWA, Christchurch.* NIWA.

Biggs, B.J.F., Smith, R.A. & Duncan, M.J. (1999) Velocity and sediment disturbance of periphyton in headwater streams: biomass and metabolism. *Journal of the North American Benthological Society,* **18,** 222-241.

Boulton, A.J. (2003) Parallels and contrasts in the effects of drought on stream macroinvertebrate assemblages. *Freshwater Biology,* **48,** 1173-1185.

Chessman, B.C. (2003) New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research,* **54,** 95-103.

Chessman, B.C., Robinson, D.P. & Hortle, K.G. (1987) Changes in the riffle macroinvertebrate fauna of the Tanjil River, southeastern Australia, during construction of the blue rock dam. *Regulated Rivers Research and Management,* **1,** 317-329.

Clarke, K.R. & Gorley, R.N. (2006) *PRIMER v6: User Manual/Tutorial.*

Clarke, K.R. & Warwick, R.M. (2001) *Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition.*

Cline, L.D., Short, R.A. & Ward, J.V. (1982) The influence of highway construction on the macroinvertebrate and epilithic algae of a high mountain stream. *Hydrobiologia,* **96,** 149-159.

Collier, K.J. & Quinn, J.M. (2003) Land-use influences macroinvertebrate community response following a pulse disturbance. *Freshwater Biology,* **48,** 1462-1481.

Coysh, J., Nichols, S., Ransom, G., Simpson, J., Norris, H.R., Barmuta, L.A. & Chessman, B.C. (2000a) AUSRIVAS Macroinvertebrate bioassessment: predictive modelling manual. CRC for Freshwater Ecology.

Coysh, J.L., Nichols, S.J., Simpson, J.C., Norris, R.H., Barmuta, L.A., Chessman, B.C. & Blackman, P. (2000b) *Australian River Assessment System (AUSRIVAS) National River Health Program Predictive Model Manual.* Co-operative Research Centre for Freshwater Ecology, Canberra.

Dewson, Z.S., James, A.B.W. & Death, R.G. (2007) A review of the consequences of decreased flow for instream habitat and macroinvertebrates. *Journal of the North American Benthological Society,* **26,** 401-415.

Doeg, T.G., Davey, G.W. & Blyth, J.D. (1987) Response of the aquatic macroinvertebrate communities to dam construction on the Thompson River, southeastern Australia. *Regulated Rivers: Research and Management,* **1,** 195-209.

Downes, B.J., Barmuta, L.A., Fairweather, P.G., Faith, D.P., Keough, M.J., Lake, P.S., Mapstone, B.D. & Quinn, G.P. (2002) *Monitoring Environmental Impacts - Concepts and Practice in Flowing Waters.*, Cambridge, U.K.

Downes, B.J. & Lake, P.S. (1991) Different colonization patterns of two closely related stream insects (*Austrosimulium* spp.) following disturbance. *Freshwater Biology,* **26,** 295-306.

Ecowise Environmental. (2009). *Murrumbidgee Ecological Monitoring Program. Autumn 2009. Part 3: Murrumbidgee Pump Station. Report to ACTEW Corporation.*

Grimm, N.B. & Fisher, S.G. (1989) Stability of periphyton and macroinvertebrates to disturbance by flash floods in a desert stream. *Journal of the North American Benthological Society,* **8,** 293-307.

Harrod, J.J. (1964) Effect of Current Speed on the Cephalic Fans of the Larva of Simulium ornatum var. nitidifrons Edwards (Diptera: Simuliidae) *Hydrobiologia,* **26,** 8-12.

Hedrick, L.B., Welsh, S.A., Anderson, J.T., Lin, L., Chen, Y. & Wei, X. (2010) Response of benthic macroinvertebrate communities to highway construction in an Appalachian watershed. *Hydrobiologia,* **641,** 115-131.

Hynes, H.B.N. (1970a) *The Ecology of Running Waters.* Liverpool University Press, Liverpool.

Hynes, H.B.N. (1970b) The ecology of stream insects. *Annual Review of Entomology,* **15,** 25-42.

Kruskal, J.B. (1964) Multidimensional scaling by optimizing goodness of fit to a non-parametric hypothesis. *Psychometrika,* **20,** 1-27.

Lenat, D. & Resh, V.H. (2001) Taxonomy and stream ecology - The benefits of genus- and species-level identification. *Journal of the North American Benthological Society,* **20,** 287-298.

Loeb, S. (1981) An in-situ method for measuring the primary productivity and standing crop of the epilithic periphyton community in lentic systems. *Limnology and Oceanography*, 394-399.

Marchant, R. (1989) A subsampler for samples of benthic invertebrates. *Bulletin of the Australian Society of Limnology,* **12,** 49-52.

Miller, A.M. & Gollady, S.W. (1996) Effects of spates and drying on macroinvertebrate assemblages of an intermittent and perennial prairie stream. *Journal of the North American Benthological Society,* **15,** 670-689.

Miller, S.W., Wooster, D. & Li, J. (2007) Resistance and resilience of macroinvertebrates to irrigation water withdrawals. *Freshwater Biology,* **52,** 2494-2510.

Molles Jr., M.C. (1985) Recovery of a stream invertebrate community from a flash flood in Tesuque Creek, New Mexico. *The Southwestern Naturalist,* **30,** 279-287.

Niemi, G.J., Devore, P., Detenbeck, N., Taylor, D., Lima, A., Pastor, J., Yount, D.J. & Naiman, R.J. (1990) Overview of case studies on recovery of aquatic systems from disturbance. *Environmental Management,* **14,** 571-587.

Norris, R.H. & Norris, K.R. (1995) The Need for Biological Assessment of Water-Quality - Australian Perspective. *Australian Journal of Ecology,* **20,** 1-6.

R Development Core Team (2009). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Resh, V.H., Brown, A.V., Covich, A.P., Gurtz, M.E., Li, H.W., Minshall, G.W., Reice, S.R., Sheldon, A.L., Wallace, J.B. & Wissmar, R.C. (1988) The Role of Disturbance in Stream Ecology. *Journal of the North American Benthological Society,* **7,** 433-455.

Smakhtin, V.U. (2001) Low flow hydrology: a review. *Journal of Hydrology,* **240,** 147-186.

Suren, A.M., Biggs, B.J.F., Duncan, M.J., Bergey, L. & Lambert, P. (2003) Benthic community dynamics during summer low-flows in two rivers of contrasting enrichment 2. Invertebrates. *New Zealand Journal of Marine and Freshwater Research,* **37,** 71-83.

Suren, A.M. & Jowett, I.G. (2006) Effects of floods versus low flows on invertebrates in a New Zealand gravel-bed river. *Freshwater Biology,* **51,** 2207-2227.

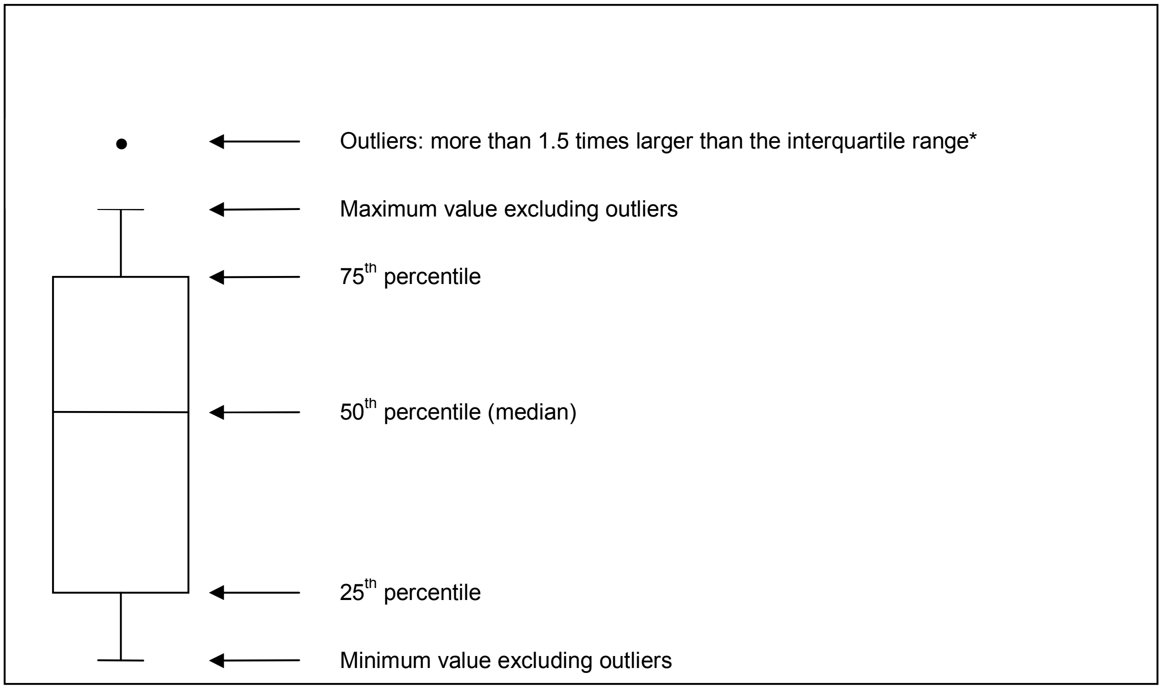
Whitton, B.A. & Kelly, M.G. (1995) Use of algae and other plants for monitoring rivers. *Australian Journal of Ecology,* **20,** 45-56.

Appendix A –

Interpreting box and whisker plots

Appendix A. Interpreting box and whisker plots.

Box and whisker plots are intended as an exploratory tool to help describe the distribution of the data. The red points on the inside of the plot area indicate the raw data values that make up the distribution portrayed in the boxplot. The plot below explains how the box and whisker plots should be read.



* The interquartile (IQR) range is the difference between the 25th and 75th percentile. This value is important when two sets of data are being compared. The closer the values are to the median, the smaller the IQR. Conversely, the more spread out the values are, the larger the IQR..

Appendix B–
ANOSIM output for riffle and edge samples

Appendix B. Analysis of Similarity results for both riffle and edge habitats

ANOSIM

Analysis of Similarities

Two-Way Nested Analysis

Edge

```
TESTS FOR DIFFERENCES BETWEEN # site GROUPS
(across all # location groups)
Global Test
Sample statistic (Global R): 0.405
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 4268880)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN # location GROUPS
(using # site groups as samples)
Global Test
Sample statistic (Global R): -0.167
Significance level of sample statistic: 80%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 8
```

Riffle

```
TESTS FOR DIFFERENCES BETWEEN # site GROUPS
(across all # location groups)
Global Test
Sample statistic (Global R): 0.369
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN # location GROUPS
(using # site groups as samples)
Global Test
Sample statistic (Global R): 0.167
Significance level of sample statistic: 40%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 4
```

Appendix C–
Taxa predicted to occur but not collected in the AUSRIVAS assessment

Appendix C. Taxa predicted to occur with >50% probability by the AUSRIVAS model, but were not collected in the edge habitat.

Site	Taxa	Oligochaeta	Ceratopogonidae	Tanypodinae	Baetidae	Leptophlebiidae	Caenidae	Corixidae	Gripopterygidae	Leptoceridae	Total number of missing taxa
	SIGNAL	2	4	4	5	8	4	2	8	6	
MUR 931	Edge				×				×		2
MUR 931	Edge		×	×	×	×			×		5
MUR 931	Edge		×	×	×	×	×		×		6
MUR 931	Edge		×	×	×	×	×				5
MUR 931	Edge			×	×	×	×				4
MUR 28	Edge								×		1
MUR 28	Edge		×	×							2
MUR 28	Edge			×	×						2
MUR 28	Edge				×				×	×	3
MUR 28	Edge			×	×				×		3
MUR 28	Edge		×		×					×	3
MUR 935	Edge	×	×		×				×		4
MUR 935	Edge				×				×		2
MUR 935	Edge	×							×		2
MUR 937	Edge		×	×							2
MUR 937	Edge		×	×					×		3
MUR 937	Edge		×	×					×		3
MUR 29	Edge			×	×		×		×		4
MUR 29	Edge					×			×		2
MUR 29	Edge		×	×	×	×			×		5
MUR 29	Edge		×	×	×				×		4
MUR 29	Edge		×		×				×		3
MUR 29	Edge	×	×	×	×	×	×		×		7

Appendix C (cntd). Taxa predicted to occur with ≥50% probability by the AUSRIVAS model, but were not collected in the riffle habitat.

Site	Taxa	Acarina	Elmidae	Psephenidae	Tipulidae	Tanypodinae	Baetidae	Leptophlebidae	Gripopterygidae	Hydrobiosidae	Glossosomatidae	Hydropsychidae	Conoesucidae	Total number of missing taxa
	SIGNAL	6	7	6	5	4	5	8	8	8	9	6	7	
MUR 931	Riffle			×	×						×			3
MUR 931			×	×	×	×	×	×		×	×	×	×	10
MUR 931			×	×	×	×	×	×	×	×	×		×	10
MUR 931	Riffle		×	×	×	×			×		×		×	7
MUR 931			×	×	×	×			×	×	×		×	8
MUR 931		-	-	-	-	-	-	-	-	-	-	-	-	-
MUR 28	Riffle			×		×		×	×	×	×		×	7
MUR 28			×	×				×	×	×	×		×	7
MUR 28		×	×	×		×			×	×	×		×	8
MUR 28	Riffle		×	×	×	×	×		×	×	×		×	9
MUR 28			×	×	×	×		×	×	×	×		×	9
MUR 28			×	×	×	×				×	×		×	7
MUR 935	Riffle		×	×	×						×		×	5
MUR 935			×	×	×	×			×	×	×		×	8
MUR 935				×	×	×			×	×	×		×	7
MUR 935	Riffle		×	×	×	×		×		×	×		×	8
MUR 935			×	×	×	×		×	×	×	×		×	9
MUR 935			×	×	×	×	×	×	×		×	×	×	10
MUR 937	Riffle		×	×		×	×		×	×	×		×	8
MUR 937			×	×	×	×	×		×	×	×		×	9
MUR 937			×	×	×		×		×	×	×		×	8
MUR 937	Riffle		×	×	×				×		×		×	6
MUR 937			×	×	×	×			×	×	×		×	8
MUR 937			×	×	×				×		×		×	6
MUR 29	Riffle		×	×		×			×	×			×	6
MUR 29			×	×		×	×		×	×	×		×	8
MUR 29			×	×	×	×			×	×	×		×	8
MUR 29	Riffle		×	×	×	×			×	×	×		×	8
MUR 29				×	×				×	×	×		×	6
MUR 29				×	×		×		×	×	×		×	7